

Manual of Transmission Methods

Reference Document



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© 2014 Rohde & Schwarz GmbH & Co. KG

Mühlhofstr. 15, 81671 München, Germany

Phone: +49 89 41 29 - 0

Fax: +49 89 41 29 12 164

E-mail: info@rohde-schwarz.com

Internet: www.rohde-schwarz.com

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1 General

1.1 Audience

Who should read this book?

You should read this book if you are not familiar with radiocommunications methods but work with *Rohde & Schwarz* radioanalysis products.

1.2 Purpose

This publication gives a review of the radiotransmission (modulation and coding) methods that can be

- detected (classified) and/or
- processed with a view to extracting content information (i.e. monitored)

with *Rohde & Schwarz* radiomonitoring systems.

With the book on hand it has been intended to give the reader a basic understanding of each single transmission method – but not to achieve a completeness in description of whatever kind. Though, by reason that mostly (where available) the underlying rules, recommendations or standards are being told, in case of need, if more detailed informations should be required, these can be consulted.



Peculiarities of Transmission Methods

Always be aware that mentioning of special peculiarities of individual transmission methods in the book may have been done for reasons of a more comprehensive overview of these methods, but need not indicate in any single case that this peculiarity is being covered by the *Rohde & Schwarz* radiomonitoring systems. Relevant for the specification of the individual product always is exclusively its own data sheet/manual.



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2 Universal Modulation Methods



Nomenclature

- With universal modulation methods, in relevant publications and also in the basic standards several ways of labeling exist, i.e. of combining the name of the method with its valency (number of possible amplitude/phase states). Valency can precede or follow the name, be attached directly or separated by a hyphen, in some rare cases actually a space (examples: "4PSK", "4-PSK", "PSK4", "PSK-4", "4 PSK") or even entirely different designations be in use ("QPSK"). (Also, in this context, mind common aliases told with individual methods or with the appropriate glossary in the appendix.)

In this book consequently the style *valency follows name without hyphen* will be used: "PSK4"; if a method should exist in several variants, indication of the variant follows next, also without a hyphen: "PSK4B".

- Additionally mind that any combination of PSK and ASK is called "QAM" here, no matter whether it be "rectangular" or "non-rectangular" (see [chapter 2.4, "QAMn"](#), on page 21).

In some special cases, deviant designations used in the basic standard, relevant manual or other publication will be pointed out in parantheses (as, for example, the term "PSK/ASK" meaning QAM).

2.1 ASKn

2.1.1 General

Modulation method	ASKn
Explanation of name	Amplitude Shift Keying, n amplitude states ($n \geq 2$)
Other designations (see also "Nomenclature")	ASK-n n-ASK OOK (On-Off Keying, if $n = 2$)
Variants existing	Keying with 2 or more amplitude states, e.g. 4 or 8
Derived from method	
Typical users	Example: German DCF77 signal (longwave [LF: 77.5 kHz] date and time signal)
Kind of data	
Reference to standard	
Frequency band	HF, VHF/UHF
Modulation method	ASKn

Modulation method	ASKn
Shift/tone spacing	
Baud rate	(Universal method)
Modulating subcarrier	
Bandwidth	
Operating method	
Data protection	
Code table	

2.1.2 Description

With the ASKn method a carrier is keyed in amplitude, this means: amplitude-modulated with a digital signal, with a fixed rate (baud rate). Keying may take place in a "hard" manner (rectangular edges of the modulating signal, i.e. without keying filter) or, in order to achieve a more economic bandwidth consumption, in a "soft" manner (with a pulse-forming keying filter creating less steep edges). The number of amplitude states may be 2 (so-called On-Off Keying, [OOK](#)) or more; common practice are powers of 2, thus 2, 4 or 8. Plain amplitude-keying is seldomly found, because amplitude-modulation methods are delicate to interference, more usual are methods with combined [ASK](#) and [PSK](#) (Phase Shift Keying), e.g. [QAM](#) (Quadrature Amplitude Modulation) (see [chapter 2.3, "PSKn"](#), on page 14). Furthermore, a distinction is made between keying the carrier frequency directly and keying first a lower frequency, which is then modulated to a high-frequency carrier in a common way ([AM](#), [PM](#), [FM](#), so-called indirect modulation).

ASK is rather delicate to interference (pitching signal levels especially in the [HF](#) band) and thus used not very often in higher-sophisticated transmission methods; on the other hand, due to the little bandwidth consumed by "plain" ASK, for a very basic mode of communicating, ASK methods such as Morse transmission (cf [chapter 3.68, "MORSE"](#), on page 208) might be selected however.

2.2 FSKn

2.2.1 General

Modulation method	FSKn
Explanation of name	Frequency Shift Keying, n frequency states
Other designations (see also "Nomenclature" on page 11)	FSK-n n-FSK

Modulation method	FSKn
Variants existing	Keying with 2 or more frequency states, e.g. 8, see chapter 2.7, "MTONE" , on page 28 MSK (M inimum S hift K eying) or FFSK (F ast F requency S hift K eying): frequency shift is half the baud rate GMSK (G aussian M inimum S hift K eying)
Derived from method	
Typical users	
Kind of data	
Reference to standard	
Frequency band	HF, VHF/UHF
Modulation method	FSKn
Shift/tone spacing	
Baud rate	(Universal method)
Modulating subcarrier	
Bandwidth	
Operating method	
Data protection	
Code table	

2.2.2 Description

With the FSKn method a carrier is no longer keyed in amplitude, but in frequency, this means: frequency-modulated with a digital signal. As to **ASK** (see [chapter 2.1, "ASKn"](#), on page 11), keying may take place in a "hard" manner (rectangular edges of the modulating signal, i.e. without keying filter creating less steep edges) or, in order to achieve a more economic bandwidth consumption, in a "soft" manner (with a pulse-forming keying filter). Usual **FSK** methods avoid just "switching" the carrier frequency, but pursue a continuous progress of its time signal to obtain a better robustness to nonlinear distortion; similar considerations gave rise to higher-sophisticated varieties like **MSK** (**M**inimum **S**hift **K**eying, same as **FFSK** [**F**ast **F**requency **S**hift **K**eying]) or **GMSK** (**G**aussian **M**SK). Also, the number of frequency states may be 2 or more; common practice are powers of 2, thus 2, 4 or 8 (see [chapter 2.7, "MTONE"](#), on page 28). The distinction between keying the carrier frequency directly and keying first a lower frequency, then modulating it to a high-frequency carrier in a common way (**AM**, **PM**, **FM**, so-called indirect modulation), is also made.

2.3 PSK_n

2.3.1 General

Modulation method	PSK _n
Explanation of name	Phase Shift Keying, n phase states ($n \geq 2$); dependent on phase state count and type of mapping of coded symbol to carrier phase state (see 2.3.3, "Phase States and Symbol Mapping"), several types are distinguished: a) PSK2A bx) PSK2C¹⁾ d) PSK4B f) PSK8B b) PSK2B c) PSK4A e) PSK8A
Other designations (see also "Nomenclature" on page 11)	a) PSK-2, 2-PSK, BPSK (Binary PSK) b) $\pi/2$-(D)BPSK (Differential BPSK) c) PSK-4, 4-PSK, QPSK (Quaternary PSK) d) $\pi/4$-(D)QPSK (Differential QPSK) e) PSK-8, 8-PSK, MPSK (Multiple PSK) f) $\pi/8$-(D)MPSK (Differential MPSK)
Variants existing	OQPSK (O ffset Q PSK)
Derived from method	
Typical users	
Kind of data	
Reference to standard	ITU-T Recommendation V.26: "2400 Bits per Second Modem Standardized for Use on 4-Wire Leased Telephone-Type Circuits" ITU-T Recommendation V.26 bis: "2400/1200 Bits per Second Modem Standardized for Use in the General Switched Telephone Network"
Frequency band	HF , VHF/UHF
Modulation method	PSK_n
Shift/tone spacing	
Baud rate	(Universal method)
Modulating subcarrier	
Bandwidth	
Operating method	
Data protection	
Code table	

¹⁾ Not considered a universal modulation method, only observed sometimes in a PACTOR II (see [chapter 3.76, "PACTOR II"](#), on page 232) and PACTOR III (see [chapter 3.77, "PACTOR III"](#), on page 238) context

2.3.2 Description

With the **PSK** method a carrier is no longer keyed in amplitude, but in phase, this means: phase-modulated with a digital signal. As to **ASK** (see [chapter 2.1, "ASK_n"](#), on page 11), keying may take place in a "hard" manner (rectangular edges of the modulating signal, i.e. without keying filter) or, in order to achieve a more economic bandwidth consumption, in a "soft" manner (with a pulse-forming keying filter creating less steep edges). "Directly" keying the absolute symbol values to the phase of the carrier would result in the necessity to have the original carrier signal available in the receiver to perform correct decoding, which is generally not the case; deriving the carrier from the received signal itself, on the other hand, has the consequence of phase ambiguities that are not easy to eliminate. Therefore, all practically deployed PSK methods apply differential coding, that is, not the user symbol itself, but its difference to the preceding one is used.

The number of phase states again (as with ASK and **FSK** [see [chapter 2.2, "FSK_n"](#), on page 12]) is commonly a power of 2, thus 2, 4, 8 or even 16, resulting in the denominations given in [table 2-1](#).

Table 2-1: PSK modulation schemes.

Name	Phase step		Phase states for variant							
	nominal	additional for "B"	"A"				"B"			
PSK2	180°	90°	0°		180°		90°		270°	
PSK4	90°	45°	0°	90°	180°	270°	45°	135°	225°	315°
PSK8	45°	22.5°	0°	45°	90°	135°	22.5°	67.5°	112.5°	157.5°
			180°	225°	270°	315°	202.5°	247.5°	292.5°	337.5°
PSK16 ¹⁾	22.5°	12.25°	0°	22.5°	45°	67.5°	12.25°	34.75°	57.25°	79.75°
			90°	112.5°	135°	157.5°	102.25°	124.75°	147.25°	169.75°
			180°	202.5°	225°	247.5°	192.25°	214.75°	237.25°	259.75°
			270°	292.5°	315°	337.5°	282.25°	304.75°	327.25°	349.75°

¹⁾ not very common

A second basic problem in PSK are changes of 180 degrees in phase (zero crossing in the phase plane) resulting in large amplitude collapses after filtering, which is not desired from the aspect of level control in receiving equipment. So the so-called "B"-variants have been derived from the above-mentioned methods (called "A"-variants), they avoid these 180° changes by introducing an additional phase increment of half the nominal phase step, thus allowing only changes of (in the case of PSK2A/B) 90 degrees (see [table 2-1](#)). Also, a phase change is performed with every transmitted symbol '0' **and** '1' and not, as with the "A"-variant coding, only with either '0' **or** '1' (depending on kind of coding), facilitating reconstruction of sampling clock from the modulated signal.

Because of the increasing error rate with more than 8 phases, PSK is often combined with ASK to more complex modulation forms such as **QAM** (**Q**uadrature **A**mplitude **M**odulation). The distinction between keying the carrier frequency directly and keying

first a lower frequency, then modulating it to a high-frequency carrier in a common way (AM, PM, FM, so-called indirect modulation), is also made.

In addition to the fact that not (as with ASK) the amplitude (level), which is subject to variations especially in the HF band, carries the information, low-level PSK does not consume much bandwidth and therefore is rather resistant to interference.

2.3.3 Phase States and Symbol Mapping



Side Bands

The usage of phrases "Upper" and "Lower" side band indicates that, in SSB transmitting equipment, the usage of the USB (the side band in "regular" position) is much more frequent than LSB (the side band in "inverted" position). The issue to describe, however, is the question whether the side band used to demodulate is the same (the "correct" one) as the one originally modulated or the opposite (the "wrong" one), regardless of, in detail, USB or LSB.

The latter case is also denoted here as "interchanged" or "swapped" side bands.

2.3.3.1 PSK2

Table 2-2: Symbol mapping for modulation type PSK2.

		PSK2A		PSK2B	
Phase difference		0°	180°	90°	270°
Symbol	USB	0	1	0	1
	LSB	0	1	1	0

PSK2A

Flow of the phase of modulated (keyed) carrier with PSK2A is illustrated in figure 2-1. Only phase changes of 0° (i.e. no phase change) and 180° (change of polarity) exist, thus, just one bit is codable per symbol. Be aware that here as in all following examples the phase changes are shown to happen in the zero transition of the carrier signal, which is not necessarily the case at all – what only interests is the phase deviation after demodulation at the instance of sampling (symbol decision point).

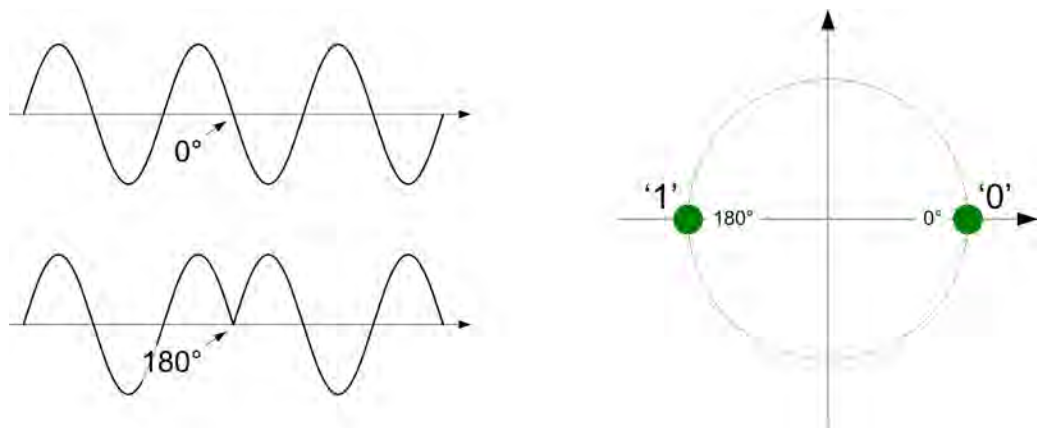


Fig. 2-1: Phase flow and phase diagram with PSK2A.

Assignment (mapping) of symbols '0' and '1' to phase changes 0° and 180° is arbitrary in principle; the assignment chosen in *Rohde & Schwarz* decoders is shown in the figure and in [table 2-2](#); this means: if emissions of unknown mapping are on hand, a different (reversed) mapping may have been used and decoding has to be modified.

Due to the fact that a 180° phase change is also a -180° phase change (no y-component included in the modulated signal), the mapping remains unchanged if the side-band used with the receiver (demodulator) is the "wrong" one, i.e. not the one used in the transmitter (modulator).

PSK2B

As explained in [2.3.2, "Description"](#), in PSK2B (in contrast to [PSK2A](#)) every transmitted symbol causes a phase change to the carrier, either a $+90^\circ$ change or a -90° ($+270^\circ$) change (again one codable bit per symbol); this is the same as adding an additional phase increment of 90° to the transitions of PSK2A. Phase flow and diagram are given in [figure 2-2](#). Mapping is chosen according to [ITU-T Recommendation V.26 bis](#) (section 2.5.1) and shown additionally in [table 2-2](#). Because modulating frequency is "negative" in the lower side band, now an interchange of side bands in modulator and demodulator leads to a mirroring at the abscissa in the phase chart and thus to a reversion of mapping (given in the table and in red color in the figure).

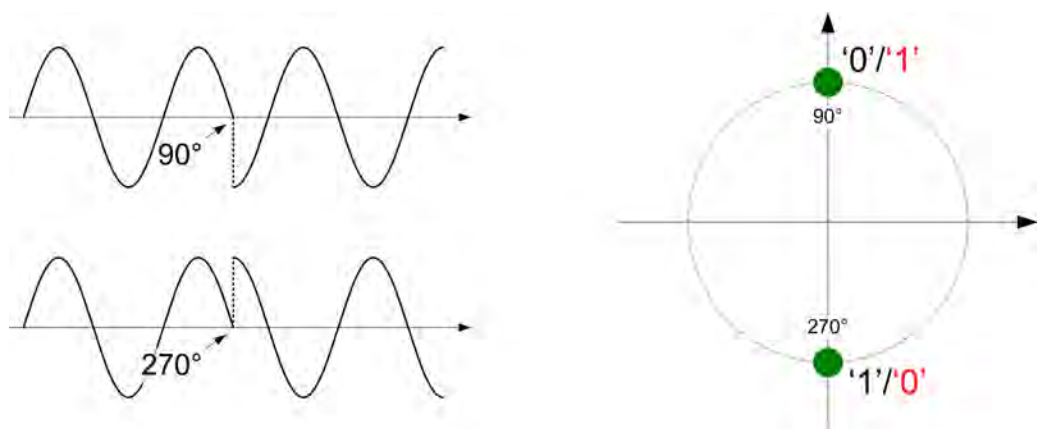


Fig. 2-2: Phase flow and phase diagram with PSK2B.

black = mapping with correct side band
red = mapping with swapped side band

PSK2C

A special mapping only with the two phase states 45° and 225° (i.e. an additional phase increment of 45° to PSK2A, figure 2-3) is sometimes observed in context of PACTOR II (see chapter 3.76, "PACTOR II", on page 232) and PACTOR III (see chapter 3.77, "PACTOR III", on page 238) and called PSK2C now and then. It is not considered a universal modulation method and mentioned here just for completeness.

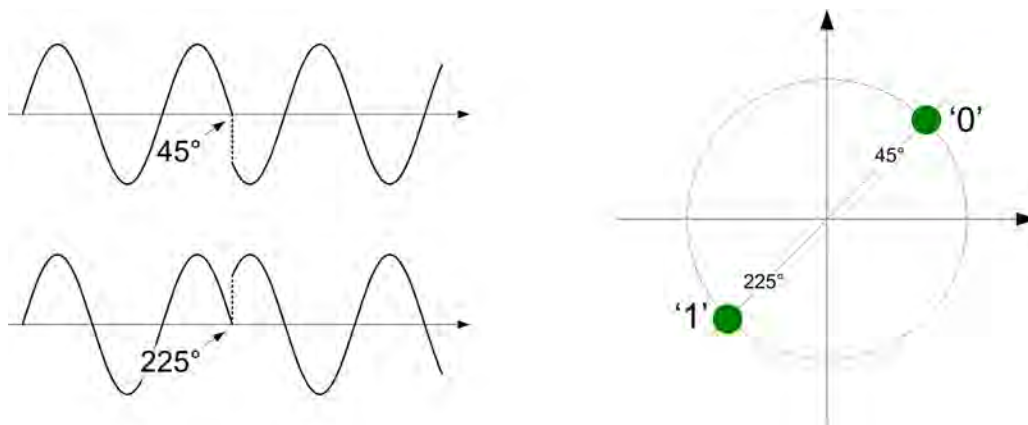


Fig. 2-3: Phase flow and phase diagram with PSK2C.

2.3.3.2 PSK4

Table 2-3: Symbol mapping for the modulation type PSK4.

		PSK4A				PSK4B			
Phase difference		0°	90°	180°	270°	45°	135°	225°	315°
Symbol	USB	0	1	3	2	0	1	3	2
	LSB	0	2	3	1	2	3	1	0
Bits	USB	00	01	11	10	00	01	11	10
	LSB	00	10	11	01	10	11	01	00

PSK4A

Similarly to PSK2, also in PSK4 two variants "A" and "B" exist; the now four possible phase changes (two bits codable per symbol) are multiples of 90° , and in PSK4A the "disadvantageous" phase transitions of 0° and 180° take place. Mapping chosen (table 2-3) accords to ITU-T Recommendation V.26 (section 2.3), but, of course, again might have to be modified in particular cases.

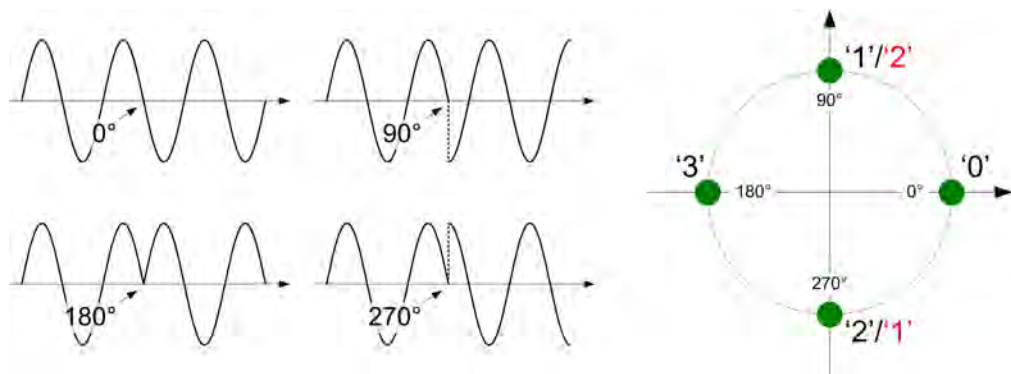


Fig. 2-4: Phase flow and phase diagram with PSK4A.

black = mapping with correct side band
red = mapping with swapped side band

Also shown in the table are the bit representations of the decoded numbers; according to ITU-T Recommendation V.26 (section 2.3), the bit sequence is read from left to right; the first appearing bit within the transmitted data stream is the bit to the left.

Side band interchange now leads to a reversion of meanings of 90° and 270° phase transitions (shown in red in the figure).

PSK4B

PSK4B introduces an additional 45° phase change to each 90° phase transition, as shown in figure 2-5 and table 2-3. Mapping chosen follows ITU-T Recommendation V.26 (section 2.3) and also ITU-T Recommendation V.26 bis (section 2.4.1).

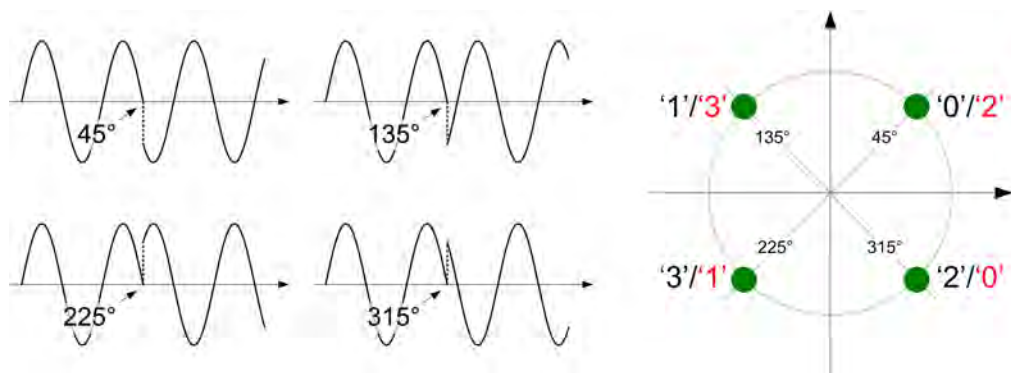


Fig. 2-5: Phase flow and phase diagram with PSK4B.

black = mapping with correct side band
red = mapping with swapped side band

Again, according to ITU-T Recommendation V.26 (section 2.3), the bit sequence (cf table 2-3) is read from left to right; the first appearing bit within the transmitted data stream is the bit to the left. Side band swapping and therewith abscissa mirroring results in a completely different symbol mapping (written in red in the figure).

2.3.3.3 PSK8

Table 2-4: Symbol mapping for the modulation type PSK8.

		PSK8A							
Phase difference		0°	45°	90°	135°	180°	225°	270°	315°
Symbol	USB	0	1	3	2	7	6	4	5
	LSB	0	5	4	6	7	2	3	1
Bits	USB	000	001	011	010	111	110	100	101
	LSB	000	101	100	110	111	010	011	001
		PSK8B							
Phase difference		22.5°	67.5°	112.5°	157.5°	202.5°	247.5°	292.5°	337.5°
Symbol	USB	0	1	3	2	7	6	4	5
	LSB	5	4	6	7	2	3	1	0
Bits	USB	000	001	011	010	111	110	100	101
	LSB	101	100	110	111	010	011	001	000

PSK8A

Last, PSK8 is depicted with its "A" and "B" variants (PSK16 is rarely found). See [figure 2-6](#) for PSK8A variant; two of the overall existing eight phase changes (three codable bits per symbol) again are 0° and 180°.

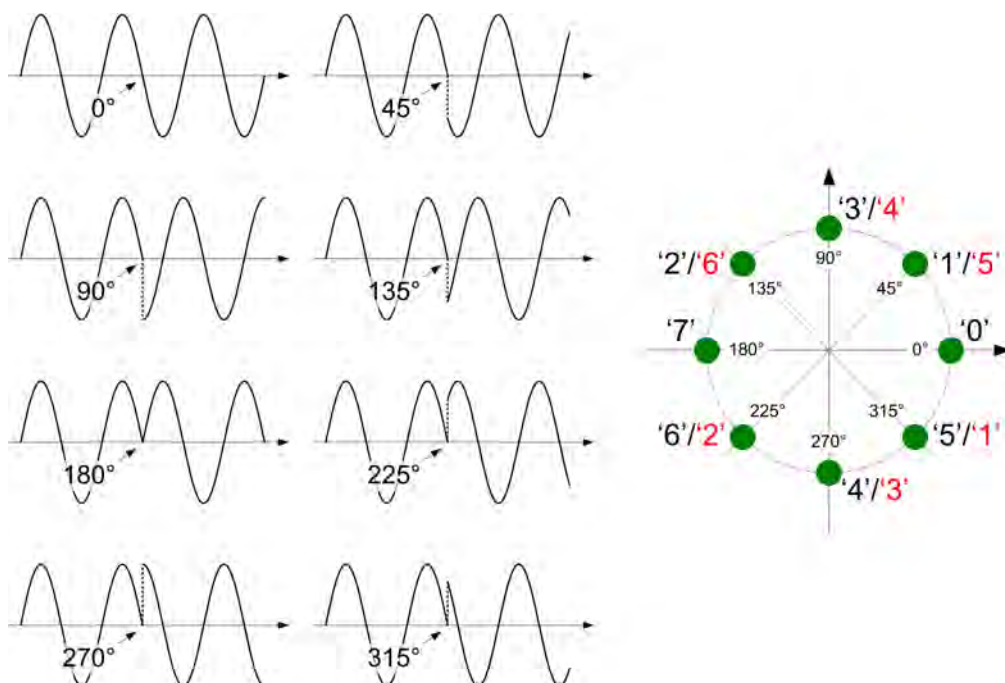


Fig. 2-6: Phase flow and phase diagram with PSK8A.

black = mapping with correct side band
red = mapping with swapped side band

Standard mapping is done as shown in the figure and in [table 2-4](#); symbol permutation obtained if not the correct side band assignment is taken (abscissa mirroring) is also shown (in red in the figure).

PSK8B

PSK8B avoids the 0° and 180° transitions by the additional phase increment of 22.5° to each transition of PSK8A; see the situation (phase flow, phase diagram, symbol mapping in case of correct and swapped side band usage) in [figure 2-7](#) and [table 2-4](#).

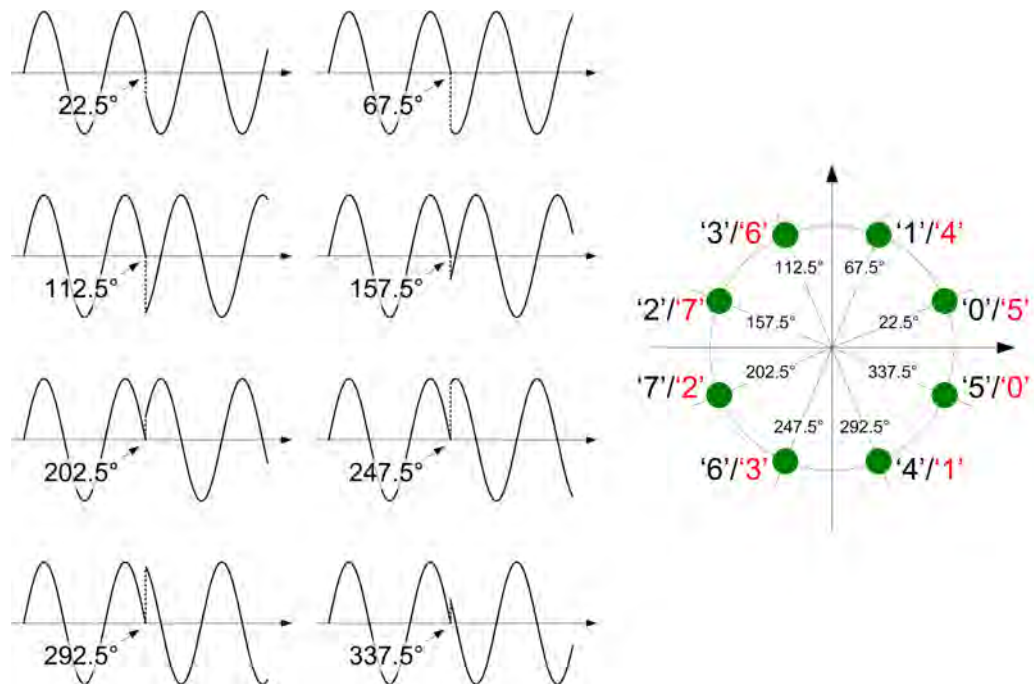


Fig. 2-7: Phase flow and phase diagram with PSK8B.

black = mapping with correct side band
red = mapping with swapped side band

2.4 QAMn

2.4.1 General

Modulation method	QAMn
Explanation of name	Quadrature Amplitude Modulation, n amplitude/phase states ($n \geq 4$, commonly power of 2); distinction in naming only done according to amplitude/phase state count but without regard to arrangement of states in the complex plane (various arrangements in use): a) QAM4 c) QAM16 e) QAM64 g) QAM256 b) QAM8 d) QAM32 f) QAM128 ...

Modulation method	QAMn
Other designations (see also "Nomenclature" on page 11)	PSK/ASK (various styles)
Variants existing	Rectangular QAM: arrangement of amplitude/phase states in constellation diagram forms a square (rectangle) Non-rectangular QAM: another arrangement of amplitude/phase states in constellation diagram
Derived from method	
Typical users	
Kind of data	
Reference to standard	ITU-T Recommendation V.29: "9600 Bits per Second Modem Standardized for Use on Point-to-Point 4-Wire Leased Telephone-Type Circuits" ITU-T Recommendation V.32: "A Family of 2-Wire, Duplex Modems Operating at Data Signalling Rates of up to 9600 bit/s for use on the General Switched Telephone Network and on Leased Telephone-Type Circuits" ITU-T Recommendation V.32 bis: "A Duplex Modem Operating at Data Signalling Rates of up to 14400 bit/s for Use on the General Switched Telephone Network and on Leased Point-to-Point 2-Wire Telephone-Type Circuits" ITU-T Recommendation V.33: "14400 Bits per Second Modem Standardized for Use on Point-to-Point 4-Wire Leased Telephone-Type Circuits"
Frequency band	HF, VHF/UHF
Modulation method	PSKn, ASKn
Shift/tone spacing	
Baud rate	(Universal method)
Modulating subcarrier	
Bandwidth	
Operating method	
Data protection	
Code table	

2.4.2 Description

2.4.2.1 Definitions

QAM (quadrature amplitude modulation) combines modulating a carrier both in amplitude (like with **ASK**) and in phase (like with **PSK**). In principle, QAM can be an analog as well as a digital modulation method, the book on hand confines description to the digital, i.e. keying variant. Several definitions are in common use:

- In the narrower sense, only modulation methods resulting in a constellation diagram forming a square (rectangular QAM) are called "QAM" (the term "quadrature"

might lead to this, even though in reality it means the two carriers being in quadrature [phase difference 90°] to each other), whereas other modulation forms combining ASK and PSK (non-rectangular QAM) are named "PSK n /ASK m " (n number of phase states and m of amplitude states).

- The broader way of looking sums up any combination of ASK and PSK to "QAM"; this is the definition used in this book.

2.4.2.2 Even Case

The by far most common forms of QAM n are the ones with n being a power of 2; $n = 2^x$ allows to accommodate x bits in one constellation (amplitude/phase) state. The forms the most basic and easiest to understand with that are the ones with x being an even number and thus delivering a square diagram running parallel to the **I** (in-phase) and **Q** (quadrature) axes. In concrete terms, variants of QAM of practical interest are QAM4 ($x = 2$), see [figure 2-8](#) (left), QAM16 ($x = 4$) (right), QAM64 ($x = 6$), [figure 2-9](#) (left), and QAM256 ($x = 8$) (right). Still "higher" forms of QAM (offering even more states to house more bits at a time) have no practical importance due to the large SNR that would be necessary for an error-free decoding facility. Mind in this context that QAM4 is the same as PSK4A, rotated by 45° , cf "PSK4A" ([chapter 2.3](#), "PSK") – but not PSK4B ("PSK4B") performing an additional phase change of 45° .

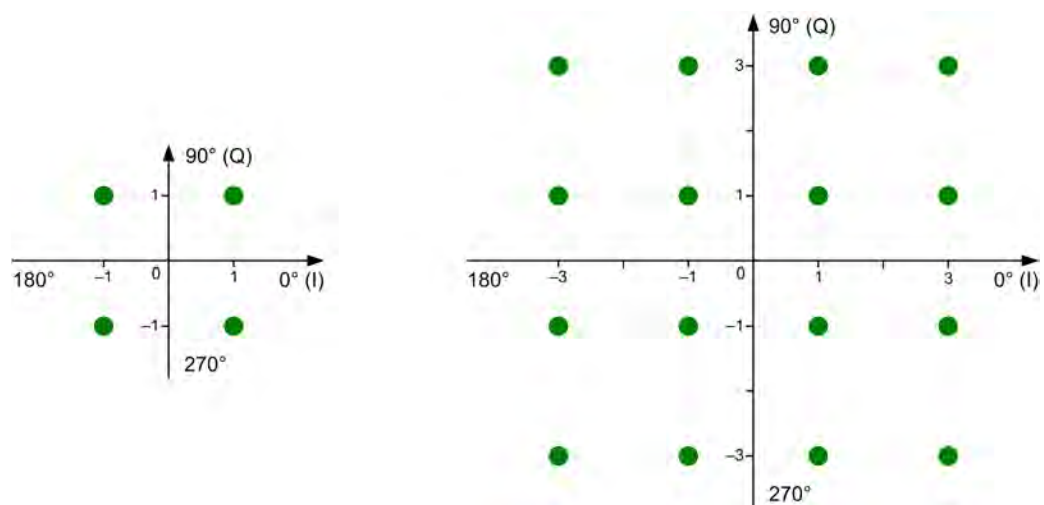


Fig. 2-8: QAM4 (left) and QAM16 (right).

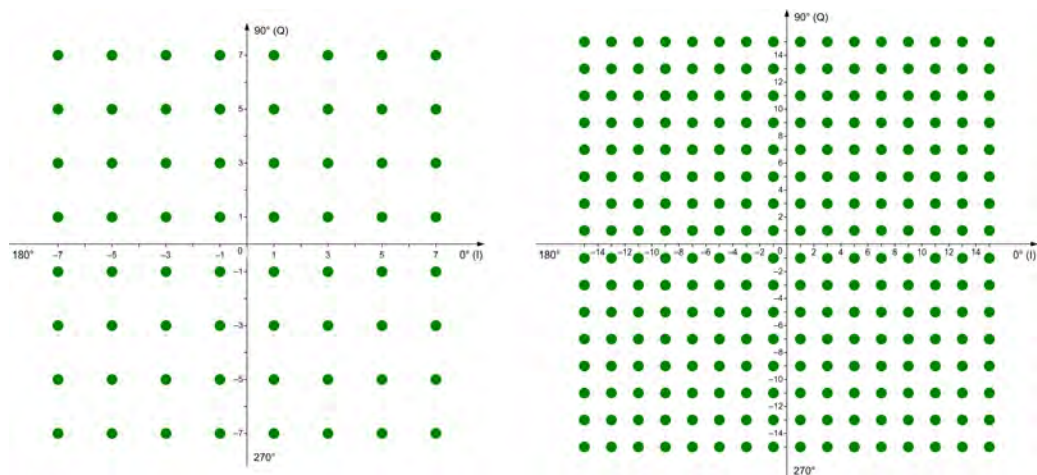


Fig. 2-9: QAM64 (left) and QAM256 (right).

2.4.2.3 Odd Case

Odd numbers of x result in a count of states being no square number (thus not possible to arrange them in a square). A way to do so anyhow is offered if the square number the next in size is selected instead and some states of it are left out (not used). The figure 2-10 shows the two variants of QAM32 ($x = 5$) (left) and QAM128 ($x = 7$) (right). It can be seen that with omitting the state in each "corner" of the resulting square the necessary count of 32 out of the originally 36 easily can be reached, or, with omitting 4 states each, 128 out of 144, respectively. The diagram is rotated by 45° compared to the even case, now forming a rhombus/diamond (square standing on its edge). Again, "higher" forms of this kind of QAM are not known to be in use.

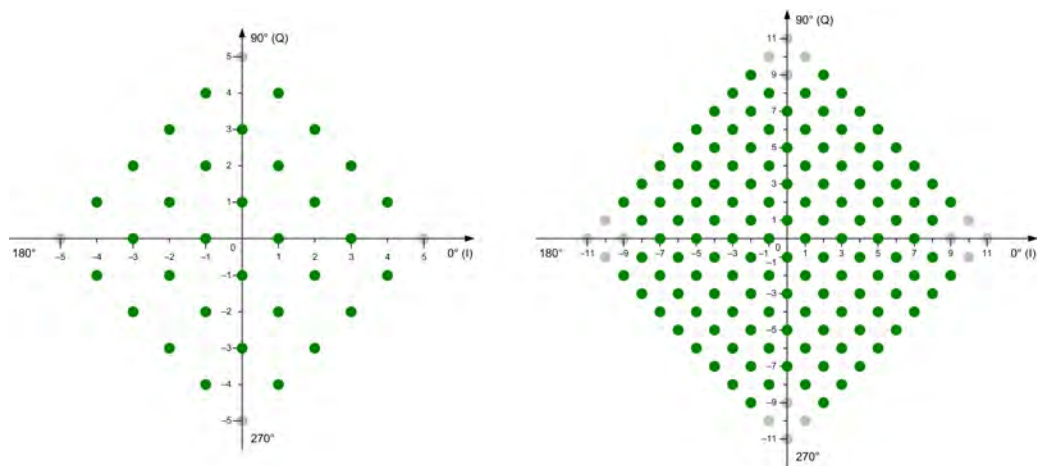


Fig. 2-10: QAM32 (left) and QAM128 (right).

green: = valid amplitude/phase states forming the number of 2^x (x odd): 32 (left), 128 (right)
 grey: = imaginary (surplus) states complementing diagram to rhombus (square) having 36 (left) or 144 elements (right)

2.4.2.4 Special Forms

Two additional variants of QAM, now forming a QAM8 and a type of QAM16 different from the one told above, are proposed in the [ITU-T V.29](#) standard ([figure 2-11](#)). They sometimes are also known as "8PSK/ASK", "4PSK/2ASK" or the like or "16PSK/ASK" etc., respectively.

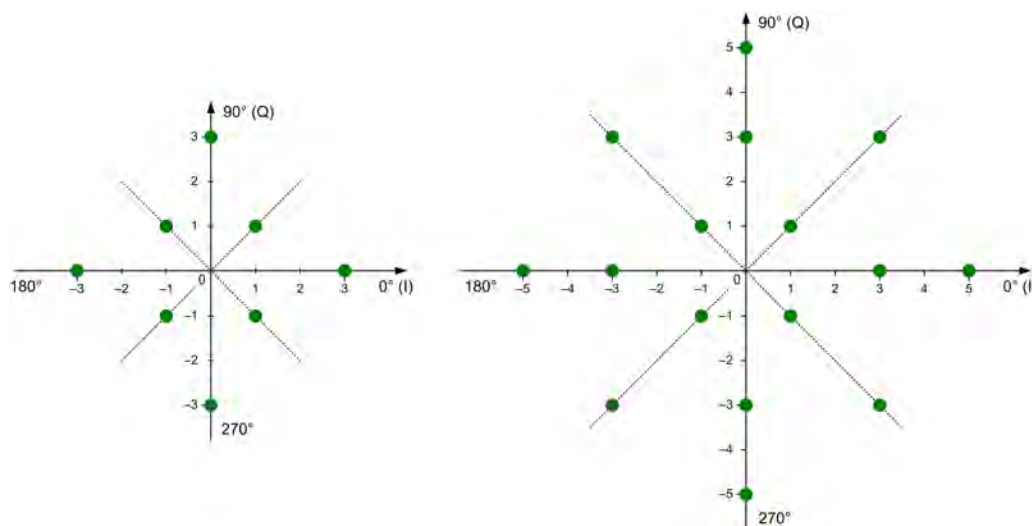


Fig. 2-11: QAM8 (left) and QAM16 (right) ("V.29 variants").

Find some further, special arrangements of states in [chapter 3.65](#), "MIL-STD-188-110B (Appendix C)", on page 192.

2.4.3 Amplitude/Phase States and Symbol Mapping

A general description of symbol mappings cannot be given here, because various assignments are commonly in use. Often a kind of "Gray" coding is applied, i.e. bit combinations of neighboring states differ in only one single bit so that erroneously selecting the adjacent instead of the correct state while symbol decoding leads to an error of just one bit. Another approach is to use some (for example 2) of the bits to establish a differential encoding (as known from [PSK](#)), e.g. a change of the quadrant, and the remaining for determining the state within the quadrant.

2.5 McFSKn

2.5.1 General

Modulation method	McFSKn
Explanation of name	M ulti- C hannel F requency S hift K eying, n frequency states
Other designations	
Variants existing	Keying with 2 or more frequency states, e.g. 4 or 8
Derived from method	FSKn
Typical users	
Kind of data	
Reference to standard	
Frequency band	HF, VHF/UHF
Modulation method	FSKn
Shift/tone spacing	
Baud rate	(universal method)
Modulating subcarrier	
Bandwidth	
Operating method	
Data protection	
Code table	

2.5.2 Description

McFSKn, the multichannel operating mode of FSKn (see [chapter 2.2, "FSKn"](#), on page 12), means that more carriers than just one exist in parallel. All of these carriers are modulated in the same modulation method [FSK](#), and especially with the same number of frequency states of 2 (in the case of McFSK2). There is no need for an equidistant positioning in frequency of the carriers, but commonly their maximum count is specified. The phase of the symbol clock must be the same for all channels (i.e. coherent signals), what normally is only the case if the modulating signals are not independent of each other, but derived from a single signal by splitting up the original bit stream.

The carriers are positioned in a way that the receiver can isolate a single channel by means of selective filtering without interchannel interference ([ICI](#)). As such McFSK2 is not an [OFDM](#)-like system.

2.6 McPSKn

2.6.1 General

Modulation method	McPSKn
Explanation of name	M ulti- C hannel P hase S hift K eying, n phase states
Other designations	
Variants existing	Keying with 2 or more phase states, e.g. 4
Derived from method	PSKn
Typical users	
Kind of data	
Reference to standard	
Frequency band	HF, VHF/UHF
Modulation method	PSKn
Shift/tone spacing	
Baud rate	(Universal method)
Modulating subcarrier	
Bandwidth	
Operating method	
Data protection	
Code table	

2.6.2 Description

McPSKn, the multichannel operating mode of PSK2 or PSK4 (see [chapter 2.3, "PSKn"](#), on page 14), means that more carriers than just one exist in parallel. All of these carriers are modulated in the same modulation method PSK, and especially with the same number of phase states of 2 or 4 (in the case of McPSK2 or McPSK4, respectively). There is no need for an equidistant positioning in frequency of the carriers, but commonly their maximum count is specified. The phase of the symbol clock must be the same for all channels (i.e. coherent signals), which normally is only the case if the modulating signals are not independent of each other, but derived from a single signal by splitting up the original bit stream.

The carriers are positioned in a way that the receiver can isolate a single channel by means of selective filtering without interchannel interference (ICI). As such McPSK2 is not an OFDM-like system.

2.6.3 Symbol mapping

See the [PSK mapping](#) (2.3.3, "Phase States and Symbol Mapping" in [chapter 2.3](#)) for details.

2.7 MTONE

2.7.1 General

Modulation method	MTONE
Explanation of name	Multi-TONE , FSK with number of frequency states of 6 or more is the same as sending the keyed frequencies sequentially
Other designations	MFSK (M ulti F requency S hift K eying) Polytone
Variants existing	Systems using MTONE: • MFSK-8 • MFSK-16 • MFSK-20 • AUM-13 • SP-14
Derived from method	FSK2
Typical users	Classic teletype systems Diplomatic services Private mobile radio (voice and data), e.g. by <i>Motorola</i>
Kind of data	
Reference to standard	
Frequency band	HF , VHF/UHF
Modulation method	FSK with more than 2 frequency states, number not necessarily a power of 2
Shift/tone spacing	
Baud rate	Up to 5 kBd
Modulating subcarrier	
Bandwidth	
Operating method	Simplex, broadcast
Data protection	Unprotected, FEC , ARQ
Code table	

2.7.2 Description

Multitone is a synonym for an [FSK](#) modulation method (see [chapter 2.2, "FSKn"](#), on page 12) using more than 2 frequencies. One frequency (also called tone) is activated for a certain duration, and it is assumed that all tones are equally spaced in the frequency domain. Applications include signaling in telephony or radio service, but also transmission of user data is covered by some multitone methods. In the latter case, normally the [ASCII](#) text to be transmitted, before assigning it to the available tones, first has to be converted to a more fitting format (e.g. Varicode, which encodes frequently used characters to short bit combinations and less frequently used ones to longer combinations, cf [chapter 4.9, "Varicode Code Table"](#), on page 350). Then the resulting bit stream is coded with an [FEC](#) algorithm, and this FEC bit stream, in order to combat frequency fading problems during transmission, is additionally interleaved.

3 Specific Transmission Methods

3.1 ACARS-HF

3.1.1 General

Transmission method	ACARS-HF
Explanation of name	A ircraft C ommunications A ddressing and R eporting S ystem, HF band
Other designations	HF-ACARS HFDL (HF Data Link) ARINC 635 (A eronautical R adio, INC orporated)
Variants existing	
Derived from method	ACARS-VUHF
Typical users	Aircraft communication
Kind of data	Messages according to <i>ARINC</i> standard 618-6: " <i>Air/Ground Character-Oriented Protocol Specification</i> " (see chapter 3.2, "ACARS-VUHF" , on page 34), e.g. fuel state, engine performance, crew identification
Reference to standard	<i>ARINC</i> 635-4: " <i>HF Data Link Protocols</i> " and others
Frequency band	HF
Modulation method	PSK2 , PSK4, PSK8
Shift/tone spacing	
Baud rate	1800 Bd User data rates: 300 bit/s, 600 bit/s, 1200 bit/s, 1800 bit/s
Modulating subcarrier	1800 Hz
Bandwidth	2250 Hz
Operating method	TDMA (T ime D ivision M ultiple A ccess)
Data protection	FEC
Code table	ITA-5 (ASCII) (table 4-9 and table 4-10 in chapter 4.2)

3.1.2 History

ACARS-HF is a relatively new network (derived from the ACARS [-VUHF] standard introduced in 1978) whose installation began in 1995 and was completed in 2001. It is responsible for new polar routes. Aircraft with ACARS-HF can fly polar routes and

maintain communication with ground based systems (**ATC** centers and airline operation centers). **ARINC** (*Aeronautical Radio, Inc.*) is the only service provider for ACARS-HF.

3.1.3 Description

As explained with ACARS-VUHF (see 3.2.3, "Description" in chapter 3.2, "ACARS-VUHF", on page 34), ACARS-HF (developed later) also is a data link for information exchange between aircraft and ground stations. The one difference is the modulation method: **PSK** modulation at 1800 **Bd** is used.

Another one is the structure of the entire data traffic: The **HF** data link air/ground protocols employ a slotted Time Division Multiple Access (**TDMA**) protocol. The ground stations maintain slot synchronization, so each aircraft should synchronize its slot timing clock to that of the ground station from an indication of the reception time of each uplink squitter transmitted by the ground station. Therefore, whenever the demodulator system detects reception of an HF data link transmission with a valid preamble, it should provide an indication at the time at which the first symbol in the data segment is received. The beginning of the slot may be determined from this indication and knowledge of the duration of the prekey and preamble segments.

3.1.4 Channel Coding/Structure of Data Blocks

Every frame (figure 3-1, **A** and **B**) has a duration of 32 seconds and is divided into 13 slots.

- The first slot (the so-called Squitter) carries various types of information, including slot acknowledgment and assignment codes.
- The next 12 slots (**C**) of a frame are called MPDUs (Medium access Protocol Data Unit).

They are used by aircraft and ground stations to exchange different kinds of data, e.g. aircraft logon/logoff requests, aircraft position, frequency assignment etc. Each

- MPDU (**D**)

contains several

- LPDUs (Link Protocol Data Unit, **E**),

which may consist of

- BDUs (Basic Data Unit).

Each slot (Squitter or MPDU) has the structure:

- pre-key (duration 249 **ms**, containing a 1440 **Hz** single tone),
- preamble (duration 295 **ms**, containing known **BPSK** symbols for synchronization purposes), and
- data (duration 1.8 **s** [single slot] or 4.2 **s** [double slot],

containing the Data section structured in data-probe pairs [45 **MPSK** symbols each:

- 30 user data symbols and
- 15 known BPSK symbols for synchronization purpose]).

For detailed information about frame and data organisation refer to standard [ARINC 635-4](#).

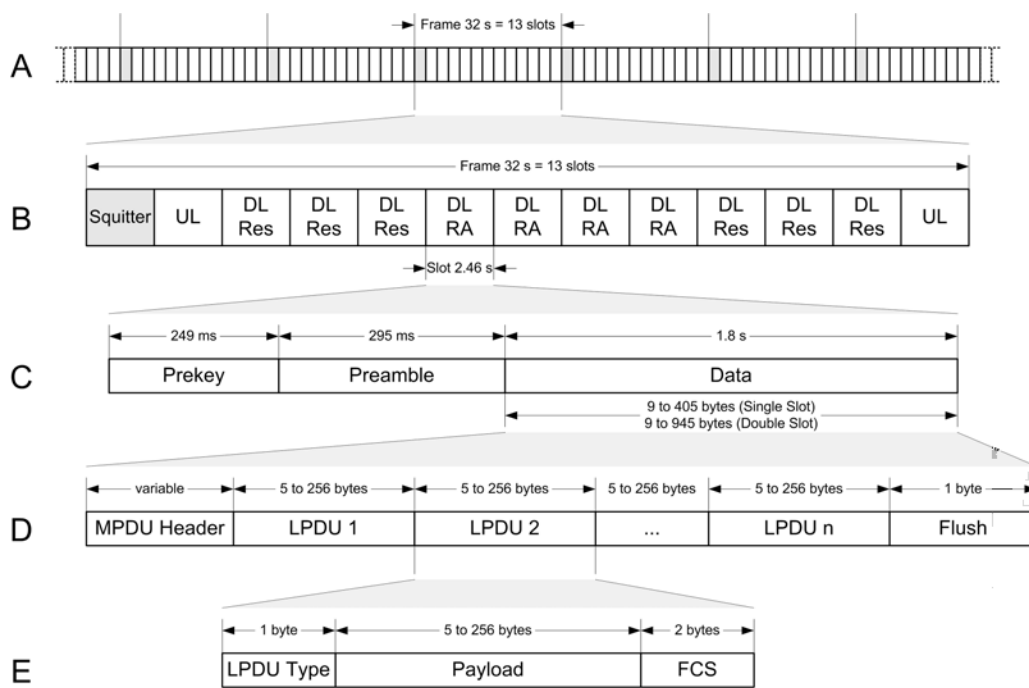


Fig. 3-1: Data block structure in ACARS-HF.

A = frame sequence

B = frame

C = slot

D = MPDU

E = LPDU

Squitter = reserved for use by the ground station

UL = uplink slot

DL Res = downlink slot reserved for specific aircraft

DL RA = downlink random access slot for use by all aircrafts; assignment of slots to uplinks and downlinks for the upcoming frame is broadcast in the squitter (assignment shown is an example)

MPDU = Medium access Protocol Data Unit

LPDU = Link Protocol Data Unit

FCS = CRC Frame Check Sequence

3.2 ACARS-VUHF

3.2.1 General

Transmission method	ACARS-VUHF
Explanation of name	Aircraft Communication Addressing and Reporting System, VHF/UHF band
Other designations	ACARS SITA (Société Internationale de Télécommunications Aéronautiques) ACARS ARINC (Aeronautical Radio, INCorporated) ARINC 618 ACARS
Variants existing	
Derived from method	
Typical users	Aircraft communication
Kind of data	(See 3.2.3, "Description")
Reference to standard	ARINC 618-6: "Air/Ground Character-Oriented Protocol Specification" ARINC 623: "Character-Oriented Air Traffic Service (ATS) Applications" ARINC 633: "AOC Air-Ground Data and Message Exchange Format" and others
Frequency band	VHF: • Frequencies Europe: 131.725 MHz, 131.525 MHz, 131.825 MHz • Frequencies U.S.A.: 131.550 MHz, 130.025 MHz, 129.125 MHz, 131.475 MHz, 130.450 MHz, 131.125 MHz, 136.700 MHz, 136.750 MHz, 136.800 MHz • Frequency Japan: 131.450 MHz • Generally: 118 MHz to 136.975 MHz
Modulation method	MSK , indirect AM
Shift/tone spacing	1200 Hz
Baud rate	2400 Bd
Modulating subcarrier	1800 Hz (MSK center frequency before AM modulation)
Bandwidth	12.5 kHz
Operating method	TDMA (Time Division Multiple Access)
Data protection	CRC : $g(x) = x^{16} + x^{12} + x^5 + 1$
Code table	ITA-5 (ASCII) (table 4-9 and table 4-10 in chapter 4.2)

3.2.2 History

Prior to the introduction of data link, all communication between the aircraft (i.e. the flight crew) and personnel on the ground was performed using voice communication

what led to overcrowded radiotelephony frequencies later on. The Engineering Department at *ARINC (Aeronautical Radio, Inc.)*, in an effort to reduce crew workload and improve data integrity, introduced the ACARS (-VUHF) system in July 1978. A few experimental ACARS systems were introduced earlier but ACARS did not start to get any widespread use by the major airlines until the 1980s.

Routine announcements like departure and arrival messages, freight and fuel messages, messages concerning engine status, etc., can be conveyed digitally in a short while since ACARS has been established. Also air traffic control transmits its clearances via ACARS since the early nineties.

HF data link (see [chapter 3.1, "ACARS-HF"](#), on page 31) is a relatively new network whose installation began in 1995 and was completed in 2001. Aircraft with HF data link can fly polar routes and maintain communication with ground based systems, thus, HF data link permits flights on new polar routes.

The third protocol existing is [SATCOM](#) (Satellite Communications) which provides worldwide coverage, but with the exception of operation at the high latitudes (i.e. polar regions, such as needed for flights over the poles).

3.2.3 Description

The ACARS-VUHF method uses signals that convey digital information according to the standard [ARINC 618-6](#). Those signals are exchanged between aircraft and ground stations.

ACARS messages may be of three types:

- Air Traffic Control ([ATC](#))
- Aeronautical Operational Control ([AOC](#))
- Airline Administrative Control ([AAC](#))

ATC messages are used to communicate between the aircraft and air traffic control (by aircraft crew to request clearances, and by ground controllers to provide those clearances). These messages are defined in the standard [ARINC 623](#). AOC and AAC messages are used to communicate between the aircraft and its base. These messages are either standardized according to standard [ARINC 633](#) or defined by the users, but must then meet at least the guidelines of standard [ARINC 618](#). Various types of messages are possible, and these include fuel consumption, engine performance data, aircraft position, as well as free text data. [ALE](#) is used with [VHF](#) data link.

ACARS signals use [MSK](#) modulation at 2400 Bd, additionally [AM](#) modulated into the VHF band by the standard aircraft transmission equipment. The ACARS frame consists of multiple control fields and a plain text field of at most 220 characters (see [table 3-1](#) and [table 3-2](#)).

In the absence of ground-initiated uplinks requiring responses, the airborne subsystem remains quiescent until the occurrence of a pre-defined event or a pilot-entered command to send a downlink to the ground arms the airborne subsystem for transmission. The uplink block(s) will be transmitted sequentially to the aircraft through a ground station. Each block should be successfully delivered to the aircraft before the transmission of the next block is attempted. Each downlink block (other than the General Response

message) sent by the aircraft should be acknowledged by the ground network to confirm its receipt. Similarly, the aircraft should acknowledge each uplink block to assure the ground network that delivery has been accomplished.

A preamble is sent before each transmission of an ACARS data block on the VHF frequency. The preamble consists of

- **Pre-key**
Each character of the Pre-key transmission should consist of all binary ones with all parity rules waived. During the Pre-key transmission, receiver AGC settling, transmitter power output stabilization and receiving modem local oscillator synchronization should be achieved. The length of the pre-key transmission should be kept to the minimum necessary to ensure the successful decoding of the data by the data link ground system. The maximum pre-key value is known as about 85 [ms](#).
- **Bit Sync**
The "plus" ("+") and the "asterisk" ("*") characters should be transmitted, in that order, to enable bit ambiguity resolution to be accomplished.
- **Character Sync**
Two consecutive Synchronization ("SYN") characters are transmitted to establish character synchronization.

3.2.4 Channel Coding/Structure of Data Blocks

The general format of an air-to-ground (downlink) message is shown in [table 3-1](#), the one of a ground-to-air (uplink) message in [table 3-2](#). (Be aware that, in contrast to the common denomination "uplink" for the direction from client to server and "downlink" for the reverse direction, in this context the "uplink" means the direction from ground to air[craft], and vice versa.) For more information, e.g. about the meaning of the individual data fields, refer to the [ARINC 618-6](#) standard.

Table 3-1: General format of downlink (air-to-ground) message.

Name ¹⁾	SOH	Mode	ARN	TAK	Label	DBI	STX	MSN	Flight ID	
Size	1	1	7	1	2	1	1	4	6	...
Example	SOH	2	.N123XX		5Z	2	STX	M01A	XX0000	

	Application text	Suffix	BCS	BCS suffix	Name
...	0 to 210	1	2	1	Size
		ETX		DEL	Example

Table 3-2: General format of uplink (ground-to-air) message.

Name ¹⁾	SOH	Mode	ARN	TAK	Label	UBI	STX	
Size	1	1	7	1	2	1	1	...
Example	SOH	2	.N123XX	NAK	10	A	STX	

...	Application text	Suffix	BCS	BCS suffix	Name
	0 to 220	1	2	1	Size
		ETX		DEL	Example

1)	with	SOH	Start Of Heading	UBI	Uplink Block Identifier
		Mode	Broadcast/Transmit	STX	Start of TeXt/End of Preamble
		ARN	Aircraft Registration Number	MSN	Message Sequence Number
		TAK	Technical AcKnowledgegment	BCS	CRC Block Check Sequence
		DBI	Downlink Block Identifier		

3.3 AIS

3.3.1 General

Transmission method	AIS
Explanation of name	Automatic Identification System
Other designations	UAIS (Universal Automatic Identification System) (used in the U.S.A.)
Variants existing	
Derived from method	
Typical users	Worldwide radio system for avoidance of ship collisions and navigational advice
Kind of data	Information about the ship, such as identification, position, course, speed, etc., all to be sent from ship to ship as well as from ship to shore
Reference to standard	ITU-R Recommendation M.1371-1: "Technical characteristics for a universal shipborne automatic identification system using time division multiple access in the VHF maritime mobile band (edition 1998-2001)."
Frequency band	VHF/UHF
Modulation method	GMSK
Shift/tone spacing	
Baud rate	9600 Bd
Modulating subcarrier	
Bandwidth	8 kHz
Operating method	SOTDMA (Self-Organizing Time Division Multiple Access)
Data protection	CRC
Code table	

3.3.2 History

The large number of maritime accidents over several years has led the international community to establish the new standard AIS. It is a contribution by the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) organization to improve safety at sea particularly when Radar cannot observe vessels, such as when a small ship is curtailed by a big one.

The AIS standard was refined by the International Maritime Organization (IMO) in 1998.

3.3.3 Description

AIS is a system used by ships to provide their information to other ships and to coastal authorities automatically. AIS uses TDMA techniques to transmit data on two channels with frequency 161.975 MHz and 162.025 MHz (AIS1 and AIS2 or VHF channel 87B and 88B). Transmission of NRZI encoded data occurs in 9600 Bd GMSK modulation using HDLC packet protocol.

Each minute is divided into 2250 slots. The default transmission packet occupies one slot. Long transmission packets can occupy up to 5 continuous slots. The system AIS demodulator recognizes transmission packets, and it obtains the information about the ship (such as identification, position, course, speed, etc.) and CRC checking result.

3.3.4 Channel Coding/Structure of Data Blocks

Each slot begins with an 8-bit ramp up and a 24-bit training sequence. The start and end of a packet are marked by the flag 0111 1110₂. Between the flags, 168 bit data and 16 bit CRC are sent, where CRC is calculated from the data using the polynomial

$$g(x) = x^{16} + x^{12} + x^5 + 1.$$

Data and CRC are subject to bit stuffing. The end flag is followed by a 24-bit buffer.

3.4 ALIS

3.4.1 General

Transmission method	ALIS
Explanation of name	Automatic Link Setup
Other designations	RS-ARQ
Variants existing	
Derived from method	

Transmission method	ALIS
Typical users	German, Italian (Ministry of Foreign Affairs [MFA] and Guardia di Finanza [GDF]), Kenyan and Turkish diplomatic services
Kind of data	
Reference to standard	CCIR Report 551-2 (1990): "Adaptive Automatic HF Radio Systems", Annex IV, later merged into ITU-R Recommendation F.1110-2: "Adaptive Radio Systems for Frequencies below about 30 MHz", Annex 5: "Digital transmission HF radio system for voice, data and telegraph traffic, capable of integration with integrated services digital network (ISDN)"
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	170 Hz
Baud rate	228.66 Bd
Modulating subcarrier	
Bandwidth	450 Hz
Operating method	Half-duplex ("Simplex-ARQ"), asynchronous
Data protection	ARQ (16 CRC bits per 32 data bits)
Code table	(Transparent)

3.4.2 History

ALIS is a system developed by *Rohde & Schwarz* in the early eighties. Advances in microprocessor technology permitted implementation of entirely new features to HF transmitters/receivers (e.g. automatic establishment of a radio link, self-acting selection of the optimum transmitter frequency due to current propagation conditions) as well as modular concepts (upgrade of a basic equipment by modems or error-protection devices).

3.4.3 Description

3.4.3.1 Scope

ALIS is an integrated HF system operating at a symbol rate of 228.66 Bd on the radio link. In its basic version it offers the following functions:

- Automatic link set-up, including passive channel analysis (occupancy of frequencies)
- Automatic channel (frequency) selection from a user-defined frequency pool, computation of maximum usable frequency (MUF, OMF, FOT)
- Data protection with ARQ

- Adaptive channel analysis, hence adaptive reaction to changing propagation conditions or interference (jamming)
- Operating modes Local or Remote Control

Options and extensions of an existing system can be:

- Forward error correction (FEC)
- Terminal speed of up to 432 Bd (link speed 700 bit/s)
- External modem for link speed of 2400 bit/s
- Frequency-management systems, evaluation of known (empirical) values
- Frequency-hopping module
- Interfaces for
 - Telephone (LPC)
 - FAX
 - Serial Bus (control and data)

3.4.3.2 Automatic Link Set-Up

A station working in an ALIS-based system always has the following data to be stored (permanent data, to be entered by the user):

- Address list of all other stations to communicate with, including geographic coordinates and range relative to own position (example in [table 3-3](#))
- Frequency pools with possible frequencies to operate on, one pool for each corresponding station in the list
- Date and time
- Current number of sun spots

Table 3-3: Address list example for station ALPHA.

Address	Station name	Coordinates or distance ¹⁾	Code
1234	ALPHA	C10.3E/40.5N	Own
2312	BRAVO	C11.3E/42.4N	
5436	CHARLIE	D456	

¹⁾ C geographical longitude/latitude [° (degrees)], D distance [km], N North, E East, S South, W West

The frequency pool is individual to each possible link (one for each pair of stations); maximum and lowest usable frequency (MUF and LUF, may vary daily) are derived therefrom. Each pool may contain up to 16 frequencies, and 25 pools can be stored (but a maximum total number of 100 frequencies).

Scan Mode: A station currently not linked to another one commonly stays in scan mode, i.e. it waits for a call from a co-station (one from the address list). All channels (frequencies) of a pool are connected cyclically; the dwell time is about 1 s per frequency (the time needed to transmit 3 call frames which are then added in the receiver). During this time, a call sign on the corresponding frequency is searched by a

correlation procedure (correlation to a known pattern), and the channel quality is determined by measuring the mean level and stored in a quality memory (passive channel analysis).

Call procedure: If a station is induced to issue a call (the station is given a Call command), the scan mode is aborted, and the station (the master station from now on) determines and then selects the optimum working frequency (OWF) for the connection to the intended partner station (then the slave station), using the corresponding frequency pool and the quality memory. Then a call is sent on this frequency; the structure of the call frame can be seen from [figure 3-2 \(A\)](#).

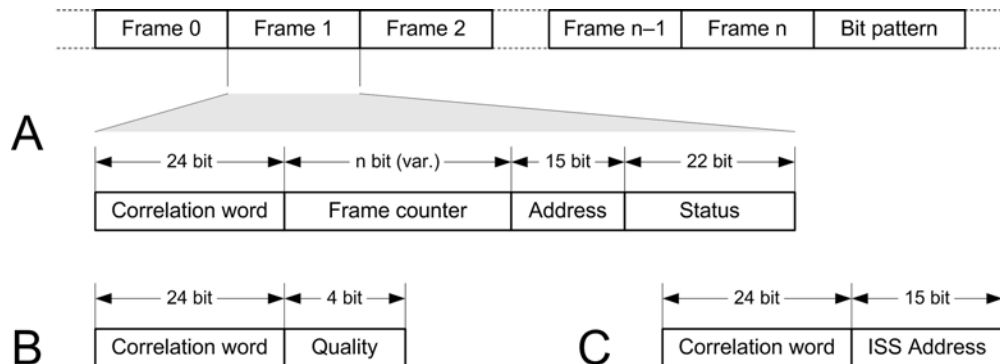


Fig. 3-2: Structure of frames in link set up mode.

A = Call frame(s)

B = Confirmation frame

C = Start frame

The correlation word is a fixed bit pattern needed for synchronization to frame and bit, the address is that of the station to call (including a parity bit), and the status field contains informations about the kind of connection to be established. All three fields are fixed in bit length, whereas the length of the frame counter varies; it depends on the number of channels in the frequency pool. The call frame is to be repeated often enough to make it possible to the partner station to recognize it on its proper frequency; i.e. the duration of a call sequence must cover a complete partner station scan cycle.

If a valid call is recognized by the partner station during its scan cycle, in case of a point-to-point link a confirmation frame is composed ([figure 3-2, B](#)) and transmitted 4 times. In case of a silent (broadcast) link, no answer is given, but the link state entered immediately after the call sequence.

The start frame ([figure 3-2, C](#)) is conveyed by the master station 3 times if the confirmation frame has been received correctly. It serves for fixing synchronization time for subsequent data exchange, and additionally tells the address of the master to the slave station.

A typical scan and call procedure is shown in [figure 3-3](#): The "blue" station is scanning on the 5 frequencies f_1 to f_5 , each scan state dwell time lasting for T . At T_4 , the "red" partner station starts a calling sequence which is then recognized by the blue station at T_7 . It has to wait until the end of the complete calling sequence (consisting of at least 5 iterations due to the 5 frequencies to be scanned by the station to call), then sends an ACK and, on a received Start frame (T_9), begins with data reception.

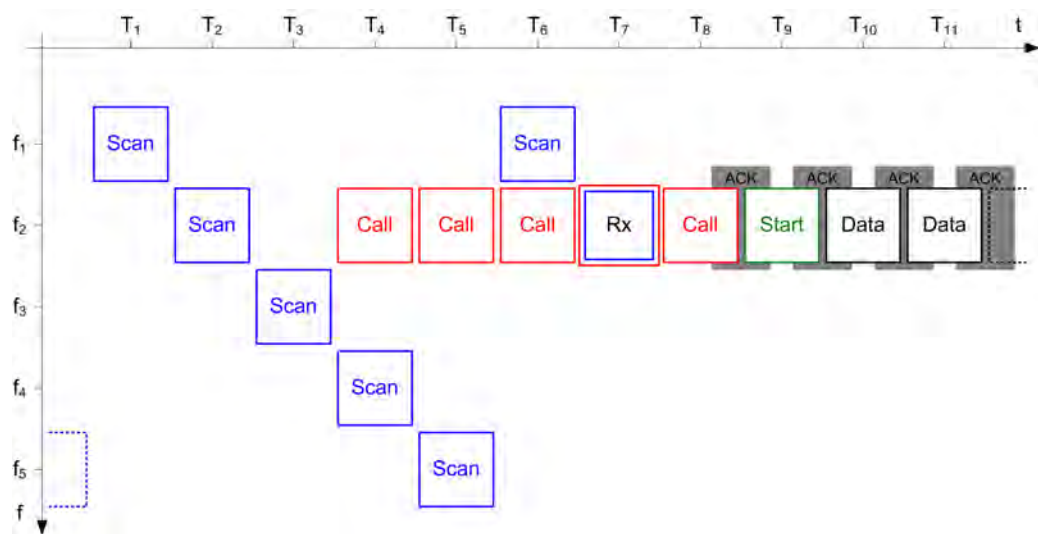


Fig. 3-3: Scan and call procedure.

A link always is tried to be set up on the first call because the selection of the appropriate channel is supported by passive channel analysis as described with scan mode (see above in this chapter) and link prediction analysis from empirical data entered in advance.

If a call for a point-to-point link is not answered by the slave station, the master retrys calling on the next frequency of the pool; this process is repeated until a link is set up.

3.4.3.3 ARQ operation

Standard ARQ operates at a data rate of 228.7 bit/s on the radio link; the complete Tx/Rx cycle has a duration of 485.4 ms. Some fixed timings are defined, as can be seen in figure 3-4: In case **A**, the "forward case" (master station [1] sends data to slave station [2]), after reception of the 210 ms data frame, the IRS sends its ACK frame only after 245 ms, related to start of cycle (or data frame), thus, the ISS needn't start its listen cycle earlier than these 245 ms. In case **B**, the "backward case" (slave station [2] sends data to master station [1]), the ACK frame is released at a fixed time of 140 ms from the cycle start, again, emission of the next frame (now the data frame) starts at 245 ms.

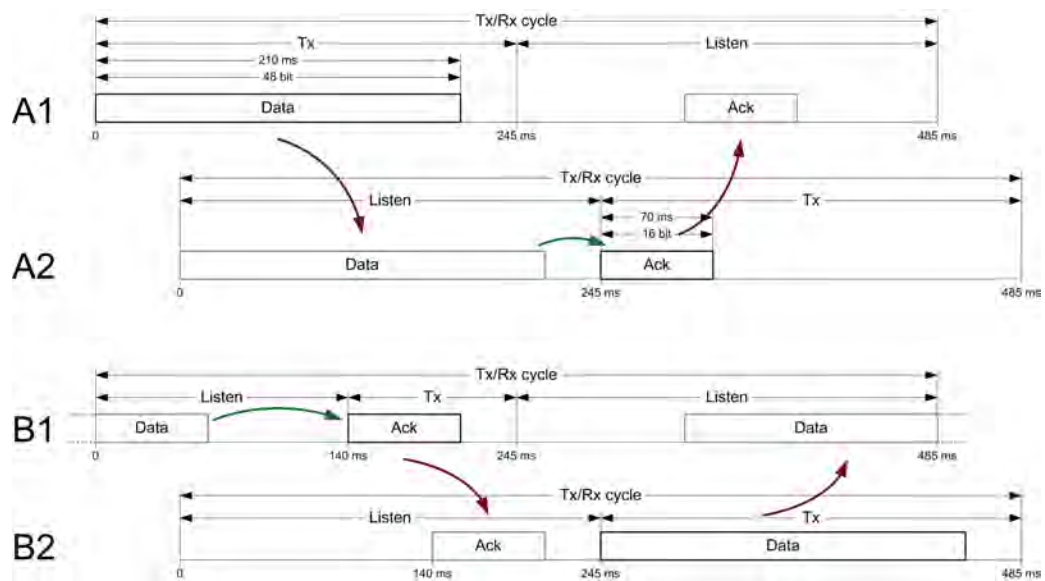


Fig. 3-4: Operation cycles in ARQ mode.

A = Master station is ISS, slave IRS
 B = Master station is IRS, slave ISS
 1 = Master station timing
 2 = Slave station timing

The structure of the used frames (data and ACK) is shown in [figure 3-5](#): The data frame (**A**) is composed of 2 bit data type information, 30 bit data and a 16-bit CRC checksum, the overall 48 bits together with the transmission rate of 228.7 bit/s resulting in a transmission period of 210 ms, and, transmitted in the frame length of 485 ms, in a bit rate of 100 bit/s (or baud rate of 100 Bd). The ACK frame (**B**) includes one of some special 8-bit characters, depending on what is to be signalled.

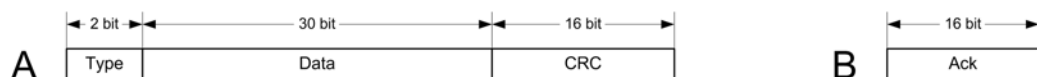


Fig. 3-5: Structure of frames in ARQ mode.

A = Data frame
 B = ACK frame

Active channel analysis: During ARQ transmission, the efficiency of a connection is determined by observing the block repetition rate and, if it drops below a threshold value, an adaptive reaction is initiated.

This adaptive reaction is an automatic switchover to another frequency, based on the daily variation of the maximum usable frequency (MUF). If necessary (i.e. if the selected new frequency also allows no connection of sufficient quality), frequency switchover is performed several times – if conditions are exceptionally bad, for all frequencies in the pool.

3.4.3.4 Data

A fixed code table is not defined in ALIS; in ARQ operation, data word length can be configured to 5 bits for telegraph characters, to 7 bits for standard ASCII characters or

to 8 bits for any other (transparent) data transmission. Digitalized voice ([LPC](#)) or [FAX](#) transmissions are also possible with suitable terminals.

3.5 ALIS-2

3.5.1 General

Transmission method	ALIS-2
Explanation of name	A utomatic L ink S etup, 2nd version
Other designations	ALIS-2000 RS-ARQ II RS-ARQ 240
Variants existing	
Derived from method	ALIS
Typical users	German, Italian and Turkish diplomatic stations
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK8 (FSK2 for link establishment)
Shift/tone spacing	240 Hz (for FSK8)
Baud rate	240.8165 Bd (for FSK8)
Modulating subcarrier	
Bandwidth	2 kHz
Operating method	Half-duplex ("Simplex-ARQ"), asynchronous
Data protection	ARQ (16 CRC bits per 128 data bits)
Code table	(Transparent)

3.5.2 History

ALIS-2 was a further development of the *Rohde & Schwarz* ALIS system ([chapter 3.4](#), "[ALIS](#)", on page 38), intended to be used in the *Rohde & Schwarz* MERLIN modem.

3.5.3 Description

ALIS-2 is a system similar in principle to ALIS and is derived therefrom. Fundamental differences are:

- Normal operation during **ARQ** data transmission goes off in **FSK8**, thus, every tone transmitted transports 3 bits (1 tribit). The tone duration of 4.15254 ms results in a baud rate of 240.8165 Bd.
- A transmission block (frame) now consists of 55 tribits or 165 bits, lasting 228.4 ms, see [figure 3-6](#). The frame is divided in
 - a 21-bit **preamble** (containing information about the operation mode, several modes besides the FSK8 operation may be selected),
 - again the 2 **type bits**,
 - a **data field** of now 126 bits length and also
 - the 16-bit **CRC section**.
- A complete Tx/Rx cycle (cf [figure 3-4](#) in [chapter 3.4](#)) takes 490 ms what is equivalent to 118 tribits or 354 bits. The on-air bit rate of 722.5 bit/s and the frame structure lead to an equivalent terminal baud rate of 552 bit/s.

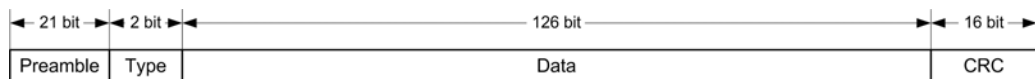


Fig. 3-6: Structure of data frame.

Establishing of a link between two stations (master and slave, i.e. calling and called station) is performed the same way as with ALIS and also at the rate of 228.66 Bd.

Alternatively to the described FSK8 operating mode, various other modes can be used – which one is to be set has to be signalled by the preamble mentioned above. This also implies that no special code table (alphabet) is defined for ALIS-2 (as also is with ALIS), but the structure of the data itself is determined by the mode currently in use.

3.6 APCO P25

3.6.1 General

Transmission method	APCO P25
Explanation of name	Association of Public Safety Communications Officials, Project 25
Other designations	P25 Project 25 APCO-25
Variants existing	
Derived from method	
Typical users	Public Safety and Government organizations
Kind of data	Voice and data applications

Transmission method	APCO P25
Reference to standard	TIA-102.BAAA-A: "Project 25; FDMA – Common Air Interface; New Technology Standards Project – Digital Radio Technical Standards" (U.S. Telecommunications Industry Association, Sept. 17, 2003)
Frequency band	(all examples of available equipment) VHF: • 136 MHz to 174 MHz UHF: • 403 MHz to 512 MHz • 746 MHz to 806 MHz • 806 MHz to 870 MHz
Modulation method	a) Phase 1: C4FM (FSK4) (Constant-envelope modulation) b) Phase 2: CQPSK (ASK/PSK) (linear amplifier required)
Shift/tone spacing	a) 1.2 kHz b) (not defined due to PSK modulation)
Baud rate	4800 Bd
Modulating subcarrier	
Bandwidth	a) 12.5 kHz b) 6.25 kHz (effectively: 2-channel TDMA in 12.5 kHz); 12.5 kHz (plain FDMA)
Operating method	
Data protection	FEC by various channel codes, interleaving
Code table	

3.6.2 History

The limitations in analog radio gave rise to efforts to establish digital radio solutions in North America, especially in public radio applications. From that, APCO (**A**ssociation of **P**ublic **S**afety **C**ommunications **O**fficials) created the "Project 16" to propose relevant standardization rules. Along with increasing employment of digital communications with public and emergency radio, the interoperability proved poor and showed up problems with disaster situations, so subsequently the "Project 25" was started in 1989 on the initiative of the U.S. congress.

Some more partners joined the project thereafter, as the NSA (**N**ational **S**ecurity **A**gency) and the DoD (Department of Defense). Establishing of APCO P25 goes slowly in the U.S.A. due to the cost, but use is now mandatory with newly installed infrastructure projects. Besides North America, APCO P25 is in use also in Australia, India, Russia and Singapur and partially in South America, in total in more than 50 countries.

However, in 60 states the competing TETRA ([chapter 3.96, "TETRA"](#), on page 287) system was (and is) in use; an essential reason is that P25 devices are more expensive many times over than TETRA devices. But preference for P25 in North America is because its operating range and bandwidth equal to that of the existing analog (FM) systems, and backward compatibility allows replacing them step by step. Additionally, one P25 station covers a larger area, what is beneficial in sparsely populated regions.

P25 is a comparatively open standard issuing a good deal of degrees of freedom (and allowing many vendors to offer their equipment), but thus limiting interoperability between individual applications – agreements have to be made in advance to establish correct operation.

3.6.3 Description

3.6.3.1 Scope

Also due to development progress, P25 radios are available in several phases:

- **Phase 1**

Objective of Phase 1 radio standard was to be able to work in existing 12.5 kHz (bandwidth) environment, whether in analog, digital or also mixed operation. Modulation used is FSK4 (here called C4FM, Continuous 4 level FM, by reason of pulse forming previous to modulating, see chapter 2.2, "FSKn", on page 12).

- **Phase 2**

Phase 2 radio systems will convey a voice channel or a 4800 bit/s data channel over a 6.25 kHz radio channel, thus optimizing bandwidth efficiency considerably. The modulation method applied is PSK4B (here the name CQPSK is used, Compatible Quadrature PSK). In addition to the FDMA solution exclusively pursued so far, a 2-slot TDMA scheme is also available.

- **Phase 3**

Implementation of Phase 3 addresses high-speed data traffic for public-safety use. Development is done by TIA (U.S. Telecommunications Industry Association) and ETSI (European Telecommunications Standards Institute) collaboratively, generally known as the MESA (Mobility for Emergency and Safety Applications) project.

A comparison between traditional analog equipment and digital radio shows, that with the former the voice information consumes 90 % of the 25 kHz channel whereas the signaling information is limited to the remaining 10 %, but with the latter two channels instead of one carry 4400 bit/s of voice each (both carrying as much information as the former 25-kHz channel), complemented by 2400 bit/s of signaling and 2800 bit/s of error correction amount.

3.6.3.2 Modulation

P25 radios are intended to work together with conventional (analog) equipment as well as with "new" (digital) components, thus they are backward compatible with existing analog radio systems and offer the option to replace them by digital systems step by step. A frequency modulation detector in the first stage of the demodulator permits reception of either analog FM, C4FM or CQPSK modulated signals.

C4FM (Phase 1)

C4FM (Continuous 4 level FM) is the modulation technique used in Phase 1 radios. In reality it is an FSK4 with the three shifts being 1.2 kHz, this is, the resulting four tones

are ± 1.8 kHz and ± 0.6 kHz, each of which represents a two-bit (dibit) combination. Assignment is shown in [table 3-4](#). This modulation method yields a moderate bandwidth consumption of 12.5 kHz, but (due to pulse forming before handing the bit stream to the modulator) a nearly perfect constant envelope of the modulating carrier, so that amplifiers of good linearity are essentially not needed.

CQPSK (Phase 2)

The technologically more advanced Phase 2 of APCO P25 employs CQPSK (**C**ompatible **Q**uadrature **P**SK) modulation, what is a PSK4B keying and also keys a dibit to each symbol. Again, dibit-to-symbol assignment can be seen from [table 3-4](#); every phase value told means a change related to the previous symbol. Pulse forming in advance to modulation is done the way that the modulated carrier signal (channel) only covers a frequency range (bandwidth) of 6.25 kHz, but this is bought for the amplitude of the time signal being not constant any longer, requiring now greatly linear amplifier equipment.

Table 3-4: Assignment with APCO P25 modulation.

Dibit	11	10	00	01
C4FM (FSK4)	−1.8 kHz	−0.6 kHz	+0.6 kHz	+1.8 kHz
CQPSK (PSK4B)	−135°	−45°	+45°	+135°

3.6.3.3 Frame Structure

In the following the essentials of the Common Air Interface (CAI) are described. Despite the nature of an open standard of P25, any P25 radio using the CAI should be able to communicate with any other P25 radio using the CAI, regardless of manufacturer.

Voice Messages

In APCO P25 the *IMBE*[®] (Improved Multi-Band Excitation) vocoder is in use mandatorily (or, from Phase 2 on, the *AMBE+2*[®] [Advanced Multi Band Excitation]). It encodes speech into a digital bit stream; this bit stream is split into voice frames each of which is 88 bits long (representing 20 ms). After protection of each frame by additional bits (redundancy) resulting in a frame size of now 144 bits, every 9 frames are taken to form a Logical Link Data Unit (LDU). A distinction is made between LDU1 and LDU2; the difference is their additional content exceeding the basic speech information. Subsequently, LDU1 and LDU2 are formed alternatingly; one LDU1 and one LDU2 are summarized to a superframe (360 ms). Digital representation of a speech message always starts with a Header Data Unit (HDU), LDUs follow in an arbitrary quantity; when the message is processed, the digital stream ends with a Terminator Data Unit (TDU), it can follow any other voice data unit.

In [figure 3-7](#) the structure of a voice message is shown; constructing the individual elements is explained in the following sections.

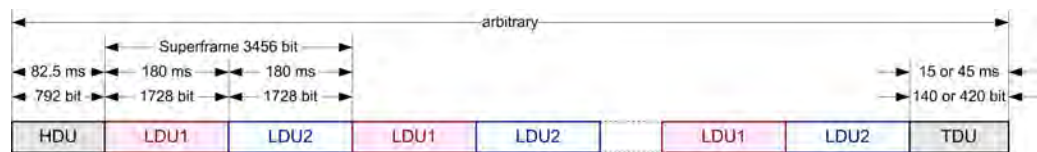


Fig. 3-7: APCO P25 voice message structure.

HDU = Header Data Unit

LDU = Logical Link Data Unit

TDU = Terminator Data Unit, two different lengths, see figure 3-13

See figure 3-8 for construction of an individual voice code word (VC): the 88 bits of the vocoder voice frame (A) are grouped in elements (called information vectors) of uneven length. The first four sections, U_0 to U_3 (length 12 bit each), are Golay coded (resulting in a length of 23 bit each), the subsequent three, U_4 to U_6 (11 bit), Hamming coded (15 bit) (B), the last, U_7 (7 bit), remains uncoded at all. A 114-bit PN (pseudo-random noise) sequence is generated from the original (uncoded) U_0 and then EXORed bitwise (C) to the concatenated (coded) U_1 to U_6, the coded U_0 is then added as the leading and the uncoded U_7 as the trailing section (D). An interleaving process (E) spreads the result throughout the voice frame to help avoid fading effects.

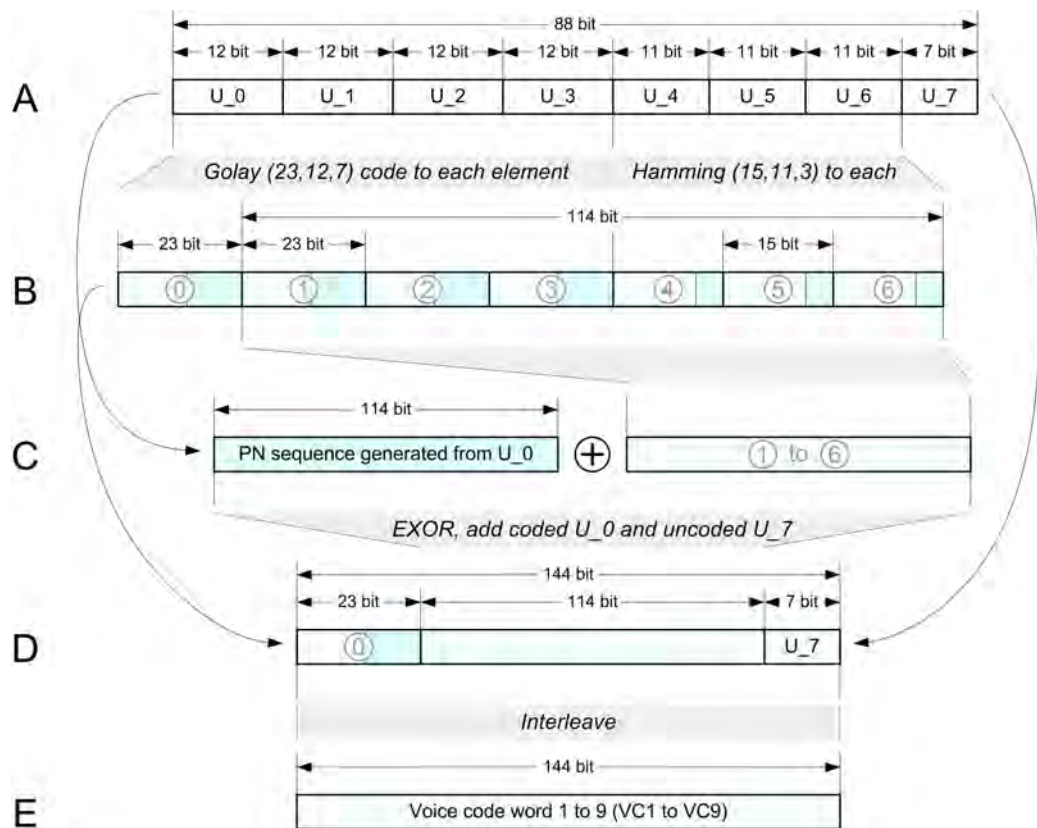


Fig. 3-8: APCO P25 construction of voice code word.

- A = Voice frame from vocoder
- B = Information vectors protected by Golay and Hamming codes
- C = PN sequence generated from U_0 (left), elements 1 to 6 of B (right)
- D = Both parts of C EXORed, element 0 of B and U_7 added

E = D interleaved throughout the 88-bit voice frame
U_0 to U_7 = Information vectors
PN = Pseudo-random noise

The top region of [figure 3-9](#) shows generating the additional information of an LDU. Pictured in the left half is encoding link information (**A** in the figure, two different examples, see relevant APCO P25 publications for details about the individual data fields), the right half depicts use of encryption information (**B**). Link information will always be included in the LDU1 and encryption information in the LDU2. Applying an [RS](#) (Reed-Solomon) code to the plain information sequences of (**A**) as well as (**B**) generates a 144-bit element (**C**), then a Hamming code leads to a final length of 240 bits (**D**), which are finally split into six sections of 40 bit length each, here called "240/1" to "240/6" (**E**).

The lower region illustrates generation of the Low Speed Data (LSD). The contents of LSD are not specified with APCO P25 and are therefore disposable to the user. The initial 32 bits available (**F**) are split into two 16-bit halves (**G**) and then protected by a shortened cyclic code, resulting in two 32-bit words, LSD1 and LSD2 (**H**).

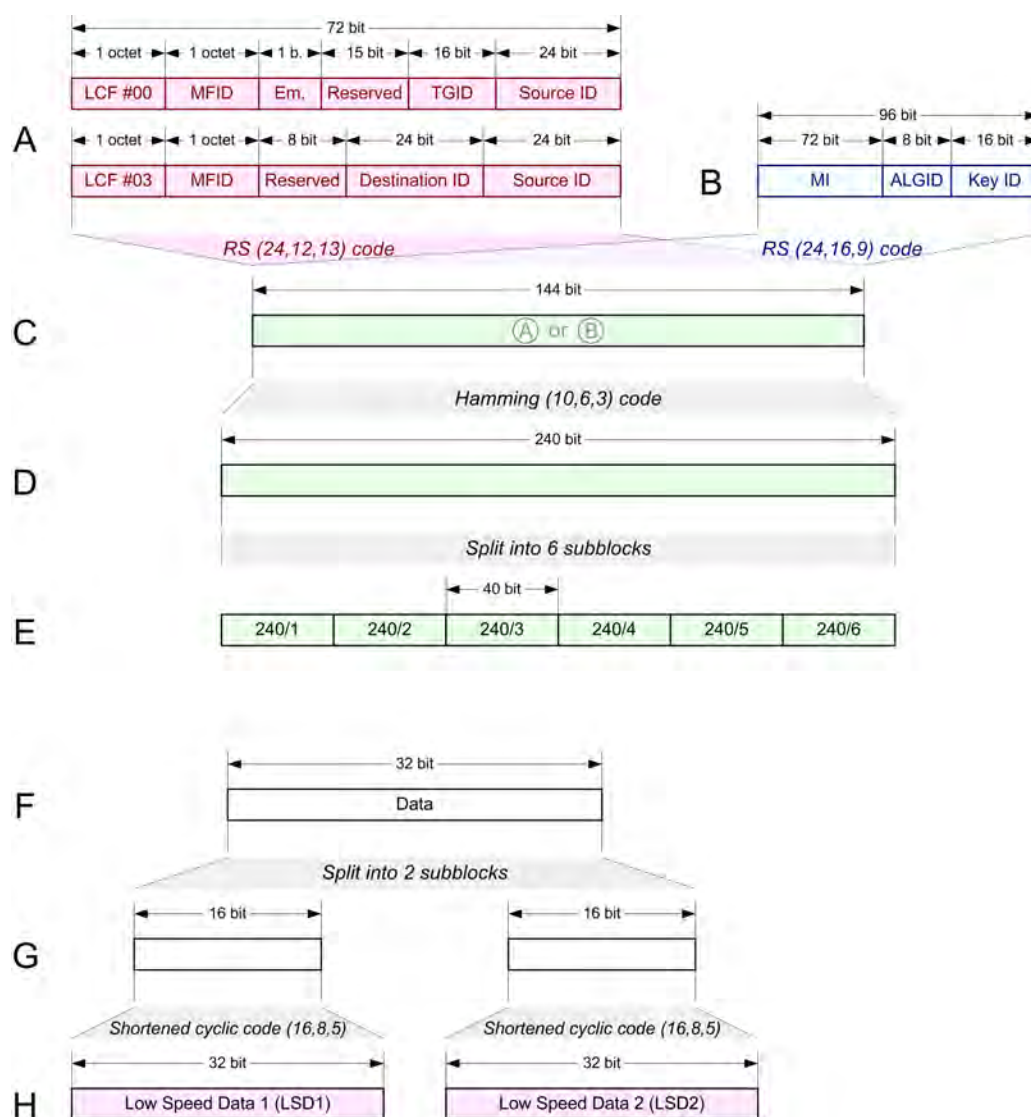


Fig. 3-9: APCO P25 construction of Link Control Word (top, left), Encryption Sync Word (top, right) and Low Speed Data (bottom).

- A = Link Control Info (two examples), resulting in LDU1
- B = Encryption Sync Word, resulting in LDU2
- C = A or B protected by RS (Reed-Solomon) codes
- D = C protected by Hamming code
- E = D split into 6 subblocks
- F = Low Speed Data
- G = F split into 2 subblocks
- H = G protected by shortened cyclic code
- LCF = Link Control Format
- MFID = Manufacturer's ID
- Em. = Emergency bit
- TGID = Talk Group ID
- MI = Message Indicator
- ALGID = Algorithm ID, see [table 3-5](#)

Combining the elements of [figure 3-8](#) and [figure 3-9](#) is shown in [figure 3-10](#): the voice code words VC1 to VC9 are concatenated, the Link Control Word (resulting in LDU1)

or Encryption Sync Word (LDU2) sections 240/1 to 240/6 inserted between them (starting after VC2 and ending before VC8) and the Low Speed Data between VC8 and VC9 (A in the figure). The leading FS and NID (see figure 3-11) are added, a subsequent additional protection by a channel code is not performed (B). The resulting bit sequence is then furnished by the so-called status symbols (2 bits) which are inserted every 70 bits (C and D).

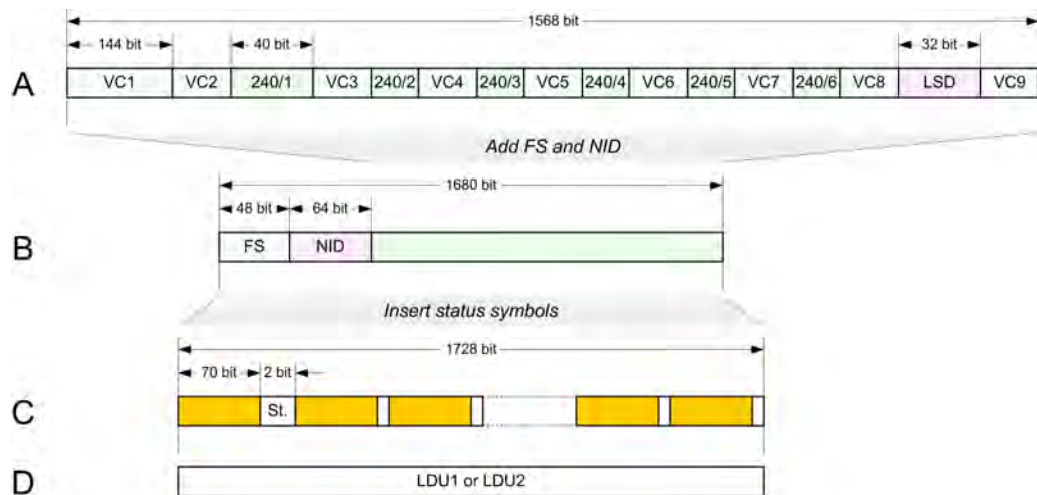


Fig. 3-10: APCO P25 construction of Logical Link Data Units (LDU1 and LDU2).

- A = Vector composed of VC1 to VC9 (figure 3-8), 240/1 to 240/6 and LSD1/LSD2 (figure 3-9)
- B = FS and NID added (see figure 3-11)
- C = Status symbol (2 bit) inserted every 70 bits
- D = LDU1 (with Link Control Word and LSD1) or LDU2 (with Encryption Sync Word and LSD2)
- St. = Status symbol

In figure 3-11 composition of Network Identifier (NID, left) and Frame Synchronization (FS, right) sections are illustrated. FS is just a constant (invariant) 48-bit sequence without any further protection (D and E), whereas a network access code and the Data Unit ID (representing the type of the following data and not accessible by the user, 16 bit altogether, A) form the 64-bit NID after having been protected by a primitive BCH code and a parity bit (B and C).

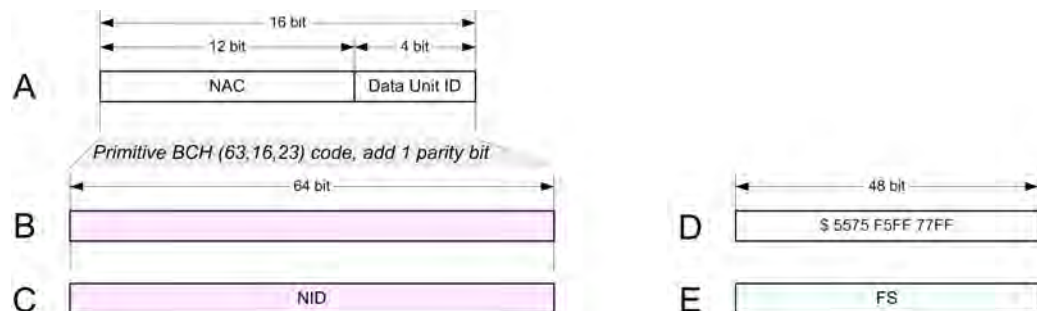


Fig. 3-11: APCO P25 construction of Network Identifier (NID, left) and Frame Synchronization (FS, right).

A = Network identifier information including network access code (NAC) and Data Unit ID
 B = A protected by primitive BCH code and 1 parity bit
 C = NID
 D = Fixed bit pattern
 E = FS

The Header Data Unit (HDU) is composed as shown in [figure 3-12](#): the 120 bits of data (A) are first grouped into 6-bit units (sextets, B), then protected by an RS (C) and a shortened Golay code (D) and subsequently surrounded by FS, NID and a 10-bit Null sequence (E). Again, the 2-bit status symbol is inserted after every 70th bit (F and G).

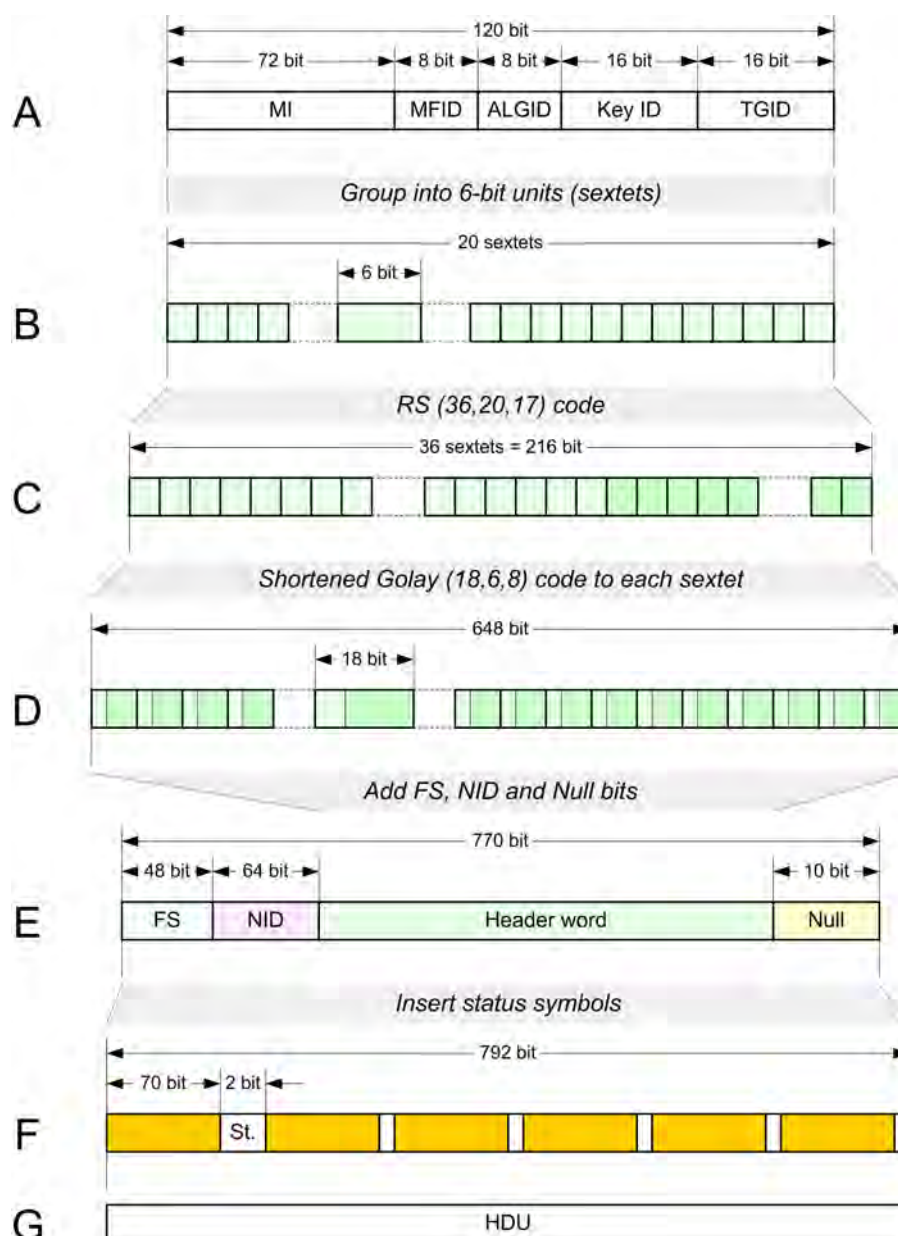


Fig. 3-12: APCO P25 construction of Header Data Unit (HDU).

A = Header code word (see [figure 3-9](#))
 B = A grouped in 20 6-bit units (sextets)
 C = Sextets protected by primitive RS code, yielding 36 sextets

D = Each sextet protected by shortened Golay code
 E = FS, NID and 10 Null bits added
 F = Status symbol (2 bit) inserted every 70 bits
 G = HDU

The Terminator Data Unit (figure 3-13) can be sent in two versions: with or without Link Control Word. In the latter case, just FS, NID and 28 Null bits form it (F), in the former case (only 20 Null bits) the Link Control Word (A) is inserted after having protected it by an RS (B) and an extended Golay code (C). In both cases, the 2-bit status symbol is added after every 70 bits as seen before (D and E or G and H, respectively).

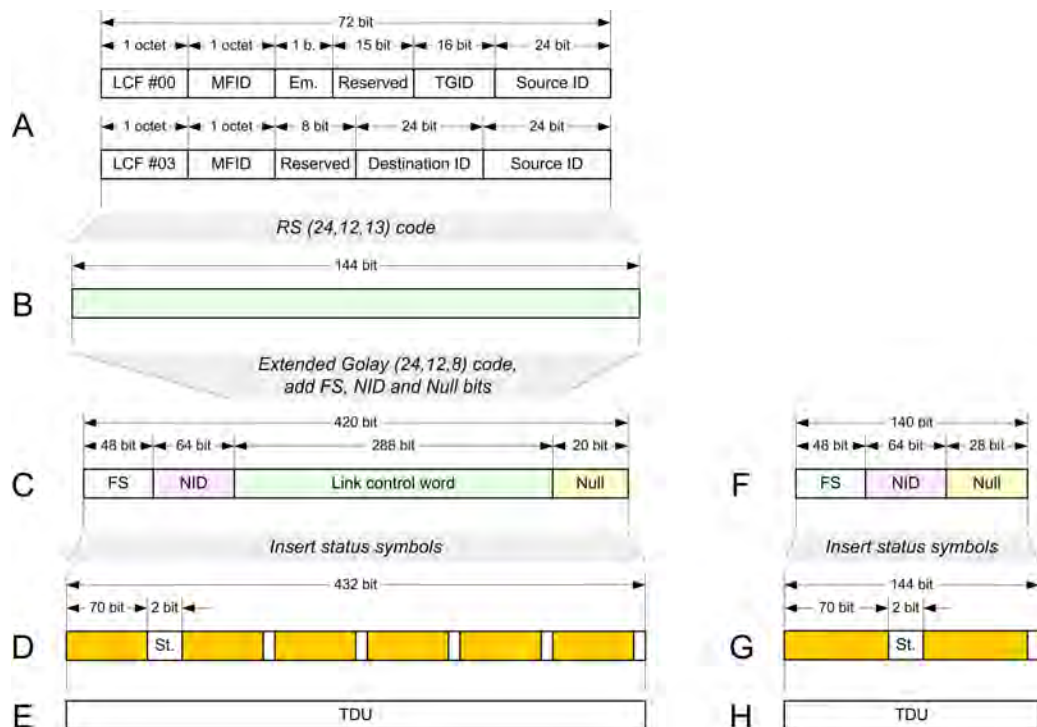


Fig. 3-13: APCO P25 construction of Terminator Data Unit (TDU) with (left) or without (right) Link Control Word.

A = Link Control Info (two examples, see figure 3-9)
 B = Protected by RS (Reed-Solomon) code
 C = B protected by extended Golay code, FS, NID and 20 Null bits added
 D = Status symbol (2 bit) inserted every 70 bits
 E = TDU
 F = FS, NID and 28 Null bits
 G = Status symbol (2 bit) inserted every 70 bits
 H = TDU

Data Messages

A data message (figure 3-14, A) in principle is of no definite length, and so are the fragments it is divided into in a first step (B). Each fragment is then segmented into blocks (C); their length depends on whether confirmed delivery (the recipient sends an acknowledgment: block length 16 bytes, here called octets) or unconfirmed delivery (no acknowledgment sent, block length 12 bytes) is appointed, this is done in the header block added next. A trellis code of rate 3/4 (confirmed) or 1/2 (unconfirmed and Header Block) is employed then to all blocks (D). The final Packed Data Unit (PDU)

emerges by adding FS and NID and then including the status symbol 70-bit-wise as above (E and F).

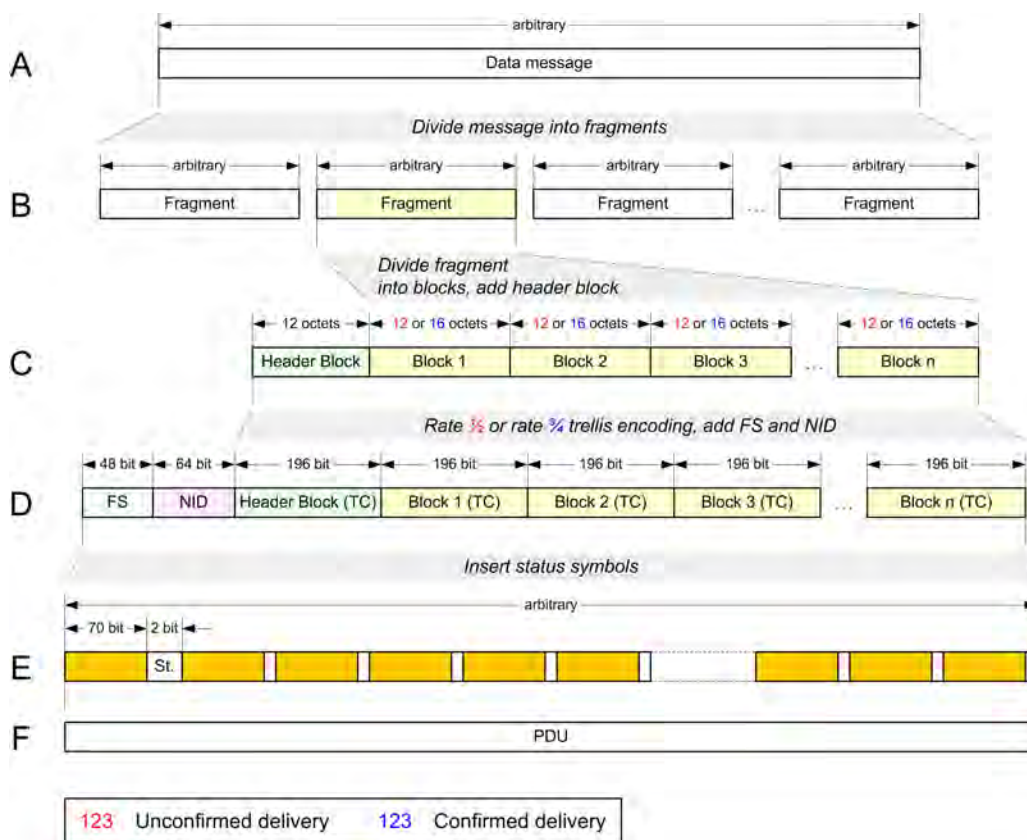


Fig. 3-14: APCO P25 construction of Packet Data Unit (PDU).

- A = Plain data message
- B = Message divided into fragments
- C = Fragment divided into blocks of 12 or 16 bytes (octets), header block added
- D = C protected by trellis coding, FS and NID added
- E = Status symbol (2 bit) inserted every 70 bits
- F = PDU
- TC = trellis coded

3.6.3.4 Encryption

An encryption feature (as known from analog systems) is also included in APCO P25; advantage of encryption in a digital system is that it has no influence nor on speech intelligibility neither on the usable range of the system. For encryption, a key has to be in use with the transmitter and the receiver, and this key must be the same for both (for so-called symmetric encryption, but asymmetric methods also exist). Most P25 equipment permits use of multiple keys (one key for one user group, another one for another). All of the four levels of encryption algorithms used in the U.S. are supported; the algorithm to be used with the key is identified by an Algorithm ID, see [table 3-5](#).

Table 3-5: Encryption algorithms in use and Algorithm IDs.

Algorithm ID (ALGID, see figure 3-9)		Algorithm in use
hex.	dez.	
	0	ACCORDION 1.3
	1	BATON (Auto Even)
	2	FIREFLY Type 1
	3	MAYFLY Type 1
	4	SAVILLE
41	65	BATON (Auto Odd)
80	128	Unencrypted message (no encryption algorithm)
81	129	DES-OFB (Data Encryption Standard, Output Feed Back) encryption algorithm
82	130	2-key triple DES encryption algorithm
83	131	3-key triple DES encryption algorithm
84	132	AES (Advanced Encryption Standard) encryption algorithm

Also available is a standardized Over the Air Rekeying (called OTAR) function, allowing to transfer encryption keys via radio so that radios need not be affected physically any longer if the key currently used has to be changed. A Key Management Facility (KMF) controls this process, OTAR signals are sent as packet data units over the air interface.

3.7 ARQ (Survey)

All methods called **ARQ-x** (Automatic Repeat Request) described subsequently have in common that the **IRS** (Information Receiving Station) is able to check the data received and to convey back transmission errors discovered to the **ISS** (Information Sending Station). The two things needed in any case to perform this are 1. a redundant code capable to recognize errors up to a certain severity level (number of incorrect bits) and 2. a backward channel to transmit back the acknowledge signal.

A wide variety of designs exist:

- The kind of code alphabet used,
- All bits sent erectly or particular bits intendedly inverted,
- The transmission mode, i.e., the number of channels available: duplex (two separate radio channels) or half duplex (one radio channel used in turn, commonly called "Simplex-ARQ"),
- The basic protocol
 - Each data unit has to be confirmed ("Stop-and-Wait"),

- More than one data unit can be sent before an acknowledge signal has to be awaited, in case of a fault all subsequent units have to be transmitted anew ("Go-Back-N"),
- All data units received are stored in a buffer, in case of a fault only the faulty unit has to be transmitted anew ("Selective Repeat"),
- Positive (**ACK**) or negative (**NAK**) acknowledge: confirmation is sent in case of no fault or in case of a fault. A timeout exists in any case, after its lapse the last unit is considered faulty.
- One data channel or more than one multiplexed (interleaved) to one radio channel (**TDMA**),
- The baud rate / character rate and duration of pauses between character blocks,
- Point-to-point communication or network communication with **SELCAL** facility.

Even though ARQ methods are plain coding and decoding methods and thus are not restricted or even coupled to certain modulation modes (i.e., could be operated with any modulation mode desired), virtually all known methods come with a **FSK** (mostly FSK2) modulation.

Additionally, all methods in use are operated in the synchronous mode, this is, periods with no transmission of valid data are bridged by sending "idle" characters in order to maintain the correct timing (instead of stopping transmission completely and resynchronizing afterwards as it would be in an asynchronous mode).

3.8 ARQ 6-70

3.8.1 General

Transmission method	ARQ 6-70
Explanation of name	A utomatic R epeat re Q uest, 6 characters payload data, 70 bit overall cycle length
Other designations	CCIR 476 variant
Variants existing	
Derived from method	SITOR-A
Typical users	Diplomatic service
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	
Baud rate	200 Bd

Transmission method	ARQ 6-70
Modulating subcarrier	
Bandwidth	610 Hz
Operating method	Half-duplex ("Simplex-ARQ")
Data protection	Mark to space ratio 3 to 4, ARQ
Code table	ITA-3 (CCIR 342-3) (table 4-5 in chapter 4.1.4)

3.8.2 Description

ARQ 6-70 is a half-duplex (so-called "Simplex-ARQ") synchronous system, i.e. two stations transmit commonly on the same frequency. (In some cases, two different frequencies might be used as well.) Synchronization between the two stations is maintained by sending idle signs if no user data are to transmit at present.

The alphabet in use is the ITA-3 (CCIR 342-3, see table 4-5 in chapter 4.1.4, "ITA-3 Code Table", on page 329); each 7-bit character contains 3 '1' ("mark") and 4 '0' ("space") bits for error recognition.

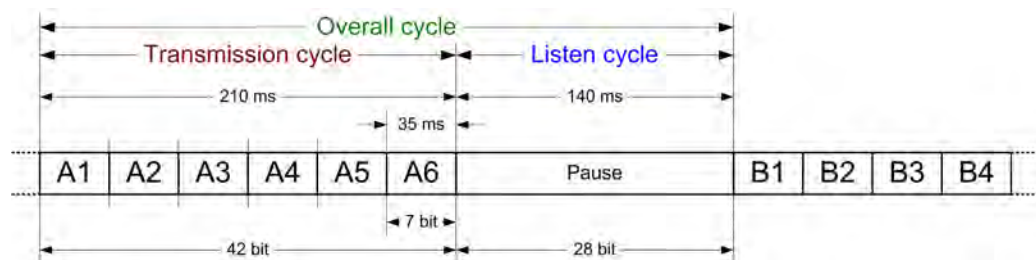


Fig. 3-15: Timing of an ARQ 6-70 cycle.

In figure 3-15 the timing is shown:

A complete cycle is divided in the transmission and the listen cycle. During the transmission cycle, the ISS sends 6 characters with 7 bits each, resulting in a length of the transmission period of 42 bits or, due to the fixed baud rate of 200 Bd (50 ms bit duration time), 210 ms. During the listen cycle, the IRS acknowledges correct reception of the (i.e. error-free) data or requests repetition of received erroneous data by retransmitting an answer signal. This cycle lasts 140 ms, corresponding to a nominal length of 28 bits and yielding an overall cycle duration of 350 ms (70 bits).

3.9 ARQ 6-90

3.9.1 General

Transmission method	ARQ 6-90
Explanation of name	Automatic Repeat reQuest, 6 characters payload data, 90 bit overall cycle length
Other designations	CCIR 476 variant
Variants existing	
Derived from method	SITOR-A ARQ 6-70
Typical users	Diplomatic services
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	
Baud rate	200 Bd
Modulating subcarrier	
Bandwidth	560 Hz
Operating method	Half-duplex ("Simplex-ARQ")
Data protection	Mark to space ratio 3 to 4, ARQ
Code table	SITOR (CCIR 476-5) (table 4-7 in chapter 4.1.6)

3.9.2 Description

ARQ 6-90 works exactly the same way as ARQ 6-70 (see [chapter 3.8, "ARQ 6-70"](#), on page 57), with the following exceptions:

- The alphabet used is [SITOR](#) (CCIR 476-5, see [table 4-7](#) in [chapter 4.1.6, "SITOR Code Table"](#), on page 332); again, each 7-bit character contains 3 '1' ("mark") and 4 '0' ("space") bits for error recognition.
- The listen cycle (see [figure 3-16](#) for timing) lasts 240 ms, corresponding to a nominal length of 48 bits and yielding an overall cycle duration of 450 ms (90 bits).

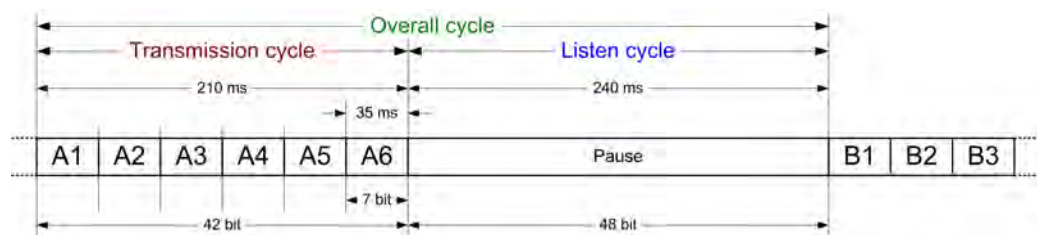


Fig. 3-16: Timing of an ARQ 6-90 cycle.

3.10 ARQ 6-98

3.10.1 General

Transmission method	ARQ 6-98
Explanation of name	Automatic Repeat reQuest, 6 characters payload data, 98 bit overall cycle length
Other designations	CCIR 476 variant
Variants existing	
Derived from method	SITOR-A ARQ 6-70 ARQ 6-90
Typical users	Diplomatic services
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	
Baud rate	200 Bd
Modulating subcarrier	
Bandwidth	625 Hz
Operating method	Half-duplex ("Simplex-ARQ")
Data protection	Mark to space ratio 3 to 4, ARQ
Code table	SITOR (CCIR 476-5) (table 4-7 in chapter 4.1.6)

3.10.2 Description

ARQ 6-98 is the same system as ARQ 6-90 (cf [chapter 3.9, "ARQ 6-90"](#), on page 59 and also [chapter 3.8, "ARQ 6-70"](#), on page 57), with the difference that the listen cycle (see [figure 3-17](#) for timing) lasts 280 ms, corresponding to a nominal length of 56 bits and yielding an overall cycle duration of 490 ms (98 bits).



Fig. 3-17: Timing of an ARQ 6-98 cycle.

3.11 ARQ-E

3.11.1 General

Transmission method	ARQ-E
Explanation of name	Automatic Repeat reQuest, Error correction
Other designations	ARQ-1000 D ARQ-1000 Duplex
Variants existing	Repetition cycles of 4, 5 or 8 characters
Derived from method	(Universal ARQ)
Typical users	Diplomatic and military stations, government
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	
Baud rate	46.2 Bd, 48 Bd, 50 Bd, 64 Bd, 72 Bd, 86 Bd, 96 Bd, 144 Bd, 184.6 Bd, 192 Bd and 288 Bd, 30 Bd to 650 Bd variable
Modulating subcarrier	
Bandwidth	460 Hz
Operating method	Duplex, synchronous

Transmission method	ARQ-E
Data protection	Parity bit (odd), ARQ
Code table	ITA-2P (ARQ-1A) (table 4-6 in chapter 4.1.5)

3.11.2 History

The ARQ-E system was invented by *Siemens* (Germany).

3.11.3 Description

ARQ-E is a full-duplex synchronous system, i.e. two stations transmit on two independent frequencies. Synchronization between the two stations is maintained by sending "Idle" signs if no user data are to transmit at present.

The system in principle uses the [ITA-2](#) alphabet, but extends it by 3 additional characters:

- the "α" (or "a") character represents the "Idle" signal for a steady start polarity
- the "β" (or "b") character represents the "Idle" signal for a steady stop polarity
- the repetition request ([RQ](#)) character "RQ"

All 5-bit characters (e.g. delivered by a landline connection) are turned into 7-bit characters by adding

- a leading '0' for all original ITA-2 or
- a leading '1' for the last-mentioned three "new" characters

and a trailing parity bit, chosen the way that the resulting sum of the stop polarity bits ('1's) is an odd – i.e. the sum of the start polarity bits ('0's) an even – number. This newly composed alphabet is called ITA-2P (or ARQ-1A, [table 4-6](#) in [chapter 4.1.5](#), "[ITA-2P Code Table](#)", on page 330).

All characters are transmitted consecutively; if an error (another character received than the 35 combinations permitted) is detected by the receiver (or if a predefined distortion value is exceeded), it sends a repetition request ("RQ" character) back to the transmitter ([NAK](#) principle). Continuous transmission is interrupted then, a confirming "RQ" signal is sent back and the last characters (character block) are transmitted again (see [figure 3-18](#)). All characters within a repetition cycle are checked for errors, if necessary, additional repetition cycles are initiated. Standard repetition cycles are 4-character (confirming "RQ" and 3 retransmitted characters) or 8-character (confirming "RQ" and 7 retransmitted characters, in case of long signal delays). For facilitated block synchronization, every 4th or 8th character sign, respectively, is bit-inverted.

As also can be seen in [figure 3-18](#), an "RQ" character is always followed by the last character block, i.e. if the station having received the error on its part was involved in sending data, it also interrupts its data stream to transmit and sends, following the "RQ" character, the last character block again.

If encryption methods are applied to data traffic, it is extremely important not to lose any single character – also not the "RQ" sign. Thus, in this case the "RQ" character is sent duplicatedly (two times), resulting in a 5-character repetition cycle.

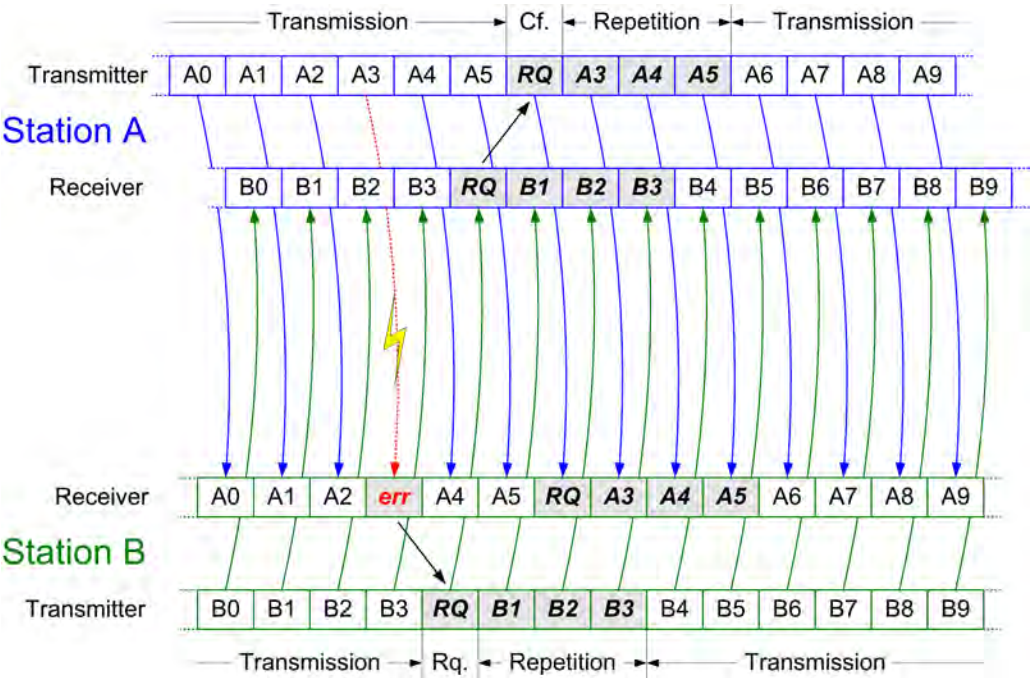


Fig. 3-18: Transmission with error (4-character repetition cycle).

Cf. = Confirmation
Rq. = (Repeat) Request
err = Error

A selective calling (SELCAL) facility also exists, enabling one station to call any other station.

3.12 ARQ-E3

3.12.1 General

Transmission method	ARQ-E3
Explanation of name	Automatic Repeat reQuest, Error correction, ITA-3 code table
Other designations	E3 CCIR 519 variant TDM 342-1 channel
Variants existing	Repetition cycles of 4 or 8 characters
Derived from method	ARQ-E

Transmission method	ARQ-E3
Typical users	Diplomatic and military stations
Kind of data	
Reference to standard	ITU-R Recommendation F.342-2: "Automatic Error-Correcting System for Telegraph Signals Transmitted over Radio Circuits" ITU-R Recommendation F.519: "Single-Channel Duplex ARQ Telegraph System"
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	
Baud rate	48 Bd, 50 Bd, 96 Bd, 192 Bd and 288 Bd
Modulating subcarrier	
Bandwidth	680 Hz
Operating method	Duplex
Data protection	Mark to space ratio 3 to 4, ARQ
Code table	ITA-3 (CCIR 342-3) (table 4-5 in chapter 4.1.4)

3.12.2 Description

ARQ-E3 works exactly as ARQ-E (chapter 3.11, "ARQ-E", on page 61), but it uses the code table ITA-3 (or CCIR 342-3, table 4-5 in chapter 4.1.4, "ITA-3 Code Table", on page 329), which features a strict mark ('1') to space ('0') ratio of 3 to 4 in each character. Character repetition cycles of 4 or 8 are used by known ARQ-E3 systems, and baud rates of 48 Bd, 50 Bd, 96 Bd, 192 Bd and 288 Bd.

3.13 ARQ-M

3.13.1 General

Transmission method	ARQ-M			
Explanation of name	Automatic Repeat reQuest, Multichannel			
Other designations	ARQ-M2-242:	ARQ-TDM-242 96-TDM	TDM-242	TDM-2
	ARQ-M4-242:	ARQ-TDM-242 192-TDM	TDM-242 ARQ-28	TDM-4 ARQM 2
	ARQ-M2-342:	ARQ-TDM-342 96-TDM	TDM-342	TDM-2

Transmission method	ARQ-M			
	ARQ-M4-342:	ARQ-TDM-342 192-TDM CCIR 342-2	TDM-342 ARQ-56	TDM-4 ARQM 4
Variants existing	ARQ-M2-242	ARQ-M4-242	ARQ-M2-342	ARQ-M4-342 Repetition cycles of 4, 5 or 8 characters (242) and 4 or 8 characters (342)
Derived from method	ARQ-E			
Typical users	Diplomatic and military stations, embassies (M4)			
Kind of data				
Reference to standard	CCIR Recommendation 242 (Los Angeles, 1959) ITU-R Recommendation F.342-2: "Automatic Error-Correcting System for Telegraph Signals Transmitted over Radio Circuits"			
Frequency band	HF			
Modulation method	FSK2			
Shift/tone spacing				
Baud rate	M2: 87 Bd, 96 Bd, 128.5 Bd, 192 Bd, 200 Bd M4: 87 Bd, 96 Bd, 192 Bd, 200 Bd			
Modulating subcarrier				
Bandwidth	ARQ-M2-242:	525 Hz	ARQ-M4-242:	680 Hz
	ARQ-M2-342:	580 Hz	ARQ-M4-342:	680 Hz
Operating method	Duplex			
Data protection	Mark to space ratio 3 to 4, ARQ			
Code table	ITA-3 (CCIR 342-3) (table 4-5 in chapter 4.1.4)			

3.13.2 Description

ARQ-M is a system working similarly to ARQ-E3 (chapter 3.12, "ARQ-E3", on page 63 and chapter 3.11, "ARQ-E", on page 61), i.e. it uses the code table ITA-3 (or CCIR 342-3, table 4-5 in chapter 4.1.4, "ITA-3 Code Table", on page 329), which features a strict mark ('1') to space ('0') ratio of 3 to 4 in each character. The special feature here is the capability to convey up to four independent data channels by interleaving (character and bit interleaving), additional to the one-channel mode. It is commonly subdivided into the older (CCIR-) 242 and the more sophisticated 342 versions, which differ in the manner the data words are to be sent in erect or inverted mode.

3.13.2.1 ARQ-Mx-242

In figure 3-19 the interleaving scheme of the 242 variant can be seen (up to four channels [A], no difference between 4-, 5- and 8-character repetition cycle):

- Emissions with just one channel exist in the erect [**B**] and also in the (bit-) inverted mode (shown in grey color, **C**) of the data.
- In two-channel emissions (M2 variant), the one, the so-called A-channel is used completely erected, whereas the other, the B-channel is entirely bit-inverted. Both channels are then interleaved in a character-by-character manner (**D**). (This mode of operation involves that no attention has to be paid to the designation of the particular elements.)
- In the M4 variant with all four channels occupied, again channel A is character-interleaved to channel B (**E1**), and so is the respective channel C to channel D (**E2**). After that, the two new "channels" A/B and C/D are interleaved bit-by-bit (**E3**, note that it would have made no difference if these two interleaving procedures would have been swapped, the correct use of the channels provided).

This manner of character inversion implicates that the frame cycle (4, 5 or 8) cannot be recognized automatically because no unambiguous bit patterns exist in the (error-free) received signal to derive this matter from.

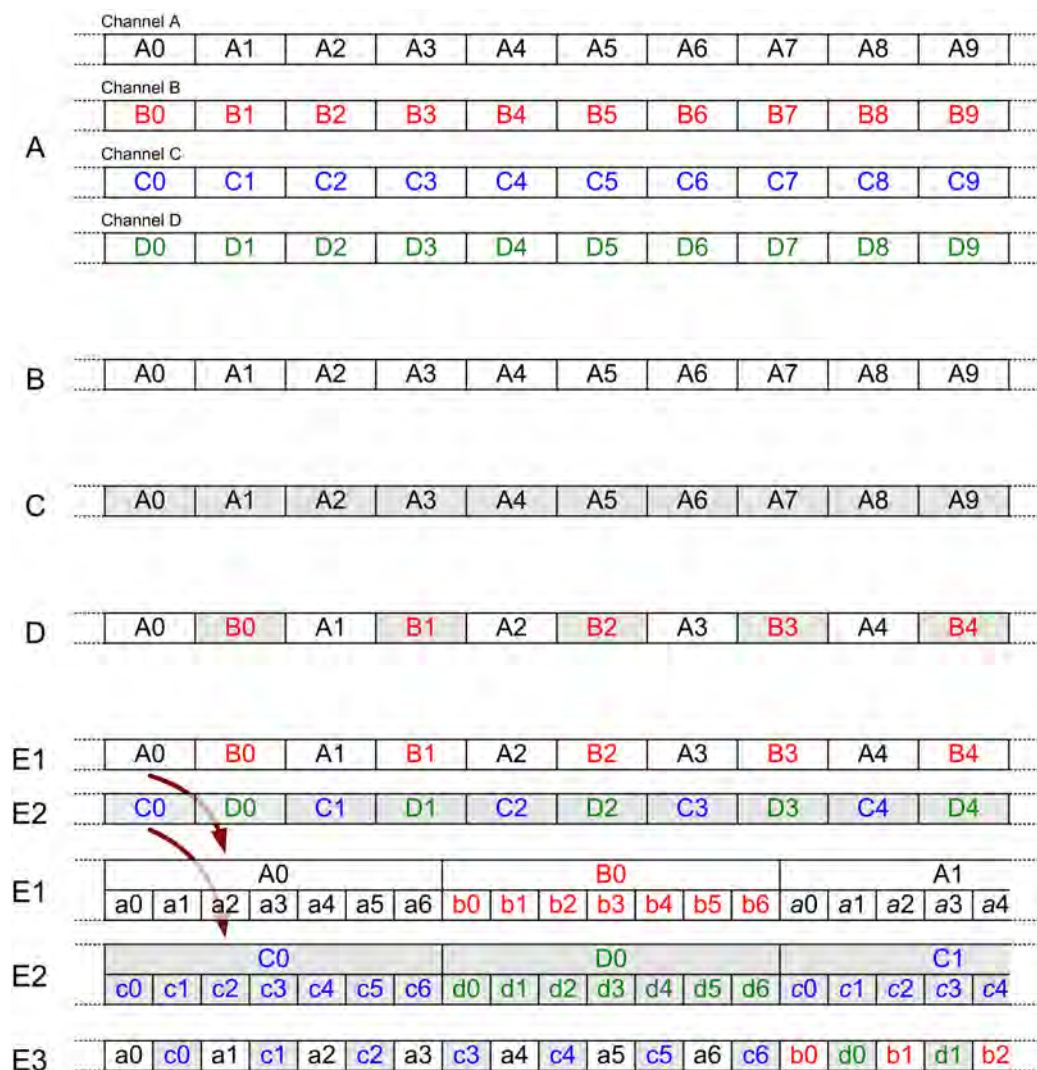


Fig. 3-19: Interleaving scheme for ARQ-Mx-242 (any repetition cycle length).

A = 4 original data channels: channel A to channel D
B = 1 channel, erect: channel A
C = 1 channel, inverted: channel A
D = 2 channels: channel A (erect) and channel B (inverted), character-interleaved
E = 4 channels
E1 = channel A and channel B (erect), character-interleaved
E2 = channel C and channel D (inverted), character-interleaved
E3 = channel A/B (erect) and channel C/D (inverted), bit-interleaved

3.13.2.2 ARQ-Mx-342

In [figure 3-20](#), the interleaving scheme for the 342 variant is shown (up to four channels **[A]**, only the 4-character repetition cycle case considered, 8-character case can be imagined easily). At first glance the different inverting mode can be observed, which, now, demands correct consideration of the particular characters, i.e. their designation in the figure. Also one sees that the C/D channel pair is treated differently from the A/B pair in queueing the elements, thus,

- a "Channel A and B" (**B1**) and a "Channel C and D" mode (**B2**) have to be distinguished in the two-channel mode (a one-channel mode has not been observed).
- The bit interleaving procedure for the four-channel operation (**C1** to **C3**) is the same as with the 242 variant; it now reveals bit patterns to derive the frame cycle length from.

In contrast to the 242 variant, no frame cycle of 5 is known.



Fig. 3-20: Interleaving scheme for ARQ-Mx-342 (4-character repetition cycle).

A = 4 original data channels: channel A to channel D
 B = 2 channels
 B1 = channel A and channel B, character-interleaved
 B2 = channel C and channel D, character-interleaved
 C = 4 channels
 C1 = channel A and channel B, character-interleaved
 C2 = channel C and channel D, character-interleaved
 C3 = channel A/B and channel C/D, bit-interleaved

3.14 ARQ-N

3.14.1 General

Transmission method	ARQ-N
Explanation of name	Automatic Repeat reQuest, No character polarity reversal
Other designations	ARQ-1000
Variants existing	Repetition cycle of 4 or 8 characters

Transmission method	ARQ-N
Derived from method	ARQ-E
Typical users	Diplomatic and military stations
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	
Baud rate	96 Bd
Modulating subcarrier	
Bandwidth	560 Hz
Operating method	Duplex
Data protection	Parity bit (odd), ARQ
Code table	ITA-2P (ARQ-1A) (table 4-6 in chapter 4.1.5)

3.14.2 Description

ARQ-N works exactly as ARQ-E ([chapter 3.11, "ARQ-E"](#), on page 61), i.e. it uses the same code table ([ITA-2P](#), [table 4-6](#) in [chapter 4.1.5, "ITA-2P Code Table"](#), on page 330), but without character polarity reversal (all characters sent in erect position). Automatic detection of the [RQ](#) cycle therefore is not possible. Known ARQ-N systems, however, exclusively use a repetition cycle of 4 characters ("RQ" and 3 retransmitted characters), and solely a baud rate of 96 [Bd](#).

3.15 ARQ-S

3.15.1 General

Transmission method	ARQ-S
Explanation of name	A utomatic R epeat re Q uest, S ynchronous
Other designations	ARQ 1000S SI-ARQ Siemens Simplex ARQ Siemens ARQ 1000
Variants existing	3, 4, 5, 6 or 7 characters per frame
Derived from method	SITOR-A

Transmission method	ARQ-S
Typical users	Diplomatic services
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	170 Hz
Baud rate	96 Bd, 144 Bd, 192 Bd, 200 Bd
Modulating subcarrier	
Bandwidth	300 Hz
Operating method	Half-duplex ("Simplex-ARQ"), synchronous; duplex
Data protection	Mark to space ratio 3 to 4, ARQ
Code table	ITA-3 (CCIR 342-3) (table 4-5 in chapter 4.1.4)

3.15.2 Description

ARQ-S is a half-duplex (so-called "Simplex-ARQ") synchronous system, i.e. two stations transmit commonly on the same frequency. (In some cases, two different frequencies might be used as well.) Synchronization between the two stations is maintained by sending idle signs if no user data are to transmit at present.

The system is known in several types, with frames conveying various counts of bits, from 3 to 7 bits being found (most frequently 5 and 6). Also, some different baud rates have been observed: 96 Bd, 144 Bd, 192 Bd, 200 Bd. As can be seen from figure 3-21 (only 96 Bd timing shown), the overall repetition cycle falls in a transmission cycle comprising the bits to be conveyed (from 3 [3 in the figure] to 7 [7], respectively) by the ISS and a listen cycle ("pause") of, in any case, the same duration as the transmission cycle. During the listen cycle, the IRS sends an acknowledgment signal (character); if data have been received correctly, this character is an "RQ" alternating in polarity from frame to frame, but, in case of erroneous reception, the "RQ" has the same polarity as the "RQ" of the previous frame. Thereby, the ISS retransmits the last data block. In normal transmission (data transmitted correctly), payload data blocks come with alternating polarity as well (inverted data are shown in grey color in the figure), whereas a retransmitted block has the same polarity for the second time.



Fig. 3-21: Timing of an ARQ-S cycle at 96 Bd baud rate.

3 = 3 chars/cycle
 4 = 4 chars/cycle
 5 = 5 chars/cycle
 6 = 6 chars/cycle
 7 = 7 chars/cycle

Table 3-6: Duration of transmission or listen cycle for the different baud rates.

Chars/cycle	Payload bits	96 Bd	144 Bd	192 Bd	200 Bd
3	21	218.8 ms	145.8 ms	109.4 ms	105.0 ms
4	28	291.7 ms	194.4 ms	145.8 ms	140.0 ms
5	35	364.6 ms	243.1 ms	182.3 ms	175.0 ms

Chars/cycle	Payload bits	96 Bd	144 Bd	192 Bd	200 Bd
6	42	437.5 ms	291.6 ms	218.8 ms	210.0 ms
7	49	510.4 ms	340.3 ms	255.2 ms	245.0 ms

The alphabet in use is the [ITA-3](#) ([CCIR 342-3](#), see [table 4-5](#) in [chapter 4.1.4](#), "[ITA-3 Code Table](#)", on page 329); each 7-bit character contains 3 '1' ("mark") and 4 '0' ("space") bits for error recognition.

3.16 ASCII

3.16.1 General

Transmission method	ASCII
Explanation of name	A merican S tandard C ode for I nformation I nterchange
Other designations	ITA5 (International Telegraph Alphabet) IRA-ARQ (International Reference Alphabet, Automatic Repeat Request) RTTY7 (RadioTeleTYpe)
Variants existing	7 and 8 data bits 1 and 2 stop bits Even, odd and no parity
Derived from method	BAUDOT
Typical users	Radio amateurs
Kind of data	
Reference to standard	ASA X3.4-1963 : "American Standard Code for Information Interchange" (June 17, 1963) ANSI X3.4-1968 : ditto (1968)
Frequency band	
Modulation method	FSK2
Shift/tone spacing	
Baud rate	50 Bd to 600 Bd (typically 100 Bd or 300 Bd)
Modulating subcarrier	
Bandwidth	910 Hz
Operating method	Asynchronous
Data protection	Parity bit or none
Code table	ITA-5 (ASCII) (table 4-9 and table 4-10 in chapter 4.2)

3.16.2 History

The today most widely spread computer code [ASCII](#) historically developed from telegraphic codes. Its first commercial use was as a seven-bit teleprinter code promoted by *Bell* data services.

The first existing form of character coding was the Morse code, which, when teletyping was introduced, was displaced from telegraph networks and replaced by the Baudot and the Murray code (both 5 bit, see [chapter 3.21, "BAUDOT"](#), on page 84). But, in order to include all alphabetic (26), all numeric (10) and some special graphic (11 to 25) characters and additionally all control characters compatible with the [CCITT](#) standard, more than 64 codes were required and so a new code table was to be established; because the shift key function known from the Baudot code seemed disadvantageous (compact coding possible, but with erroneous reception of a shift character long text passages being unreadable), a 7-bit solution was chosen (128 codes).

Originally, ASCII served for representing the characters of English language; a first version, without lower case letters and with some deviations from today's ASCII still, arose in 1963. The ASCII code valid until today was then decided in 1968. Newer codings to be capable also to represent special signs of other languages also used ASCII as the basis for their 8-bit code tables – but they also proved unable to accomodate all signs of human culture of writing.

3.16.3 Description

The original ASCII (or [ITA-5](#)) alphabet with its 7 bits includes definitions for 128 characters:

- 33 are non-printing control characters (now mostly obsolete) that affect how text and space is processed
- 94 are printable characters
- the space is considered an invisible graphic

The [RTTY](#) method "ASCII" derived from this is, like the BAUDOT method ([chapter 3.21](#)), an asynchronous system and therefore in need of start and stop bits for character synchronization. Again,

- the start bit (always only 1) is of '0' or "Space" polarity
- the stop bit(s) (1 [**A** and **C** in [figure 3-22](#)] or 2 [**B** and **D**], the "1.5" variant does not exist here) of '1' or "Mark" polarity

The number of data bits may be 7 (**A** and **B**) or 8 (**C** and **D**). For a slight error recognition capability, a single parity bit can be present (**A** to **D**, no parity bit: **E**); both variants,

- "odd" (parity bit set when number of '1's in the code word is odd, otherwise reset)
- "even" (bit set when number of '1's is even) parity

are known. In code recognition, the parity bit, together with the start and stop bits, also can be used for concluding whether the received signal is in erect or inverted polarity.

All variants mentioned are given in [figure 3-22](#). Be aware that only the variants with the parity bit present can be recognized automatically, not variants without parity checking

(E in the figure). Transmission of the code words formed the explained way is performed without pauses, giving a quasi-synchronous transmission.

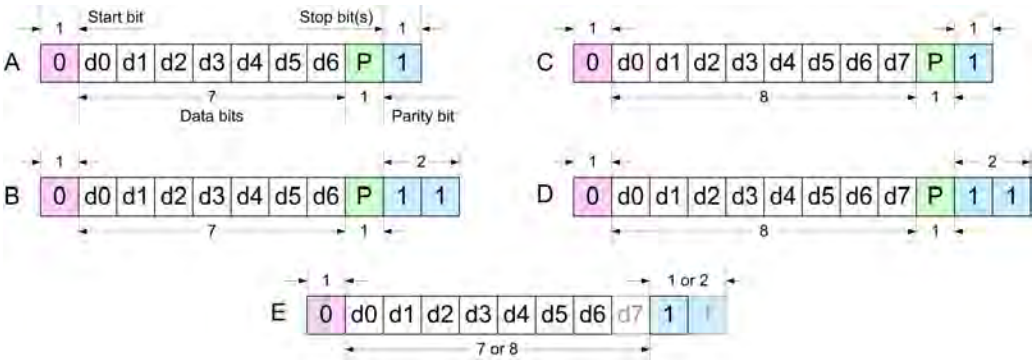


Fig. 3-22: Bit patterns with ASCII.

- A = 7 data bits, 1 stop bit, 1 parity bit
- B = 7 data bits, 2 stop bits, 1 parity bit
- C = 8 data bits, 1 stop bit, 1 parity bit
- D = 8 data bits, 2 stop bits, 1 parity bit
- E = 7 or 8 data bits, 1 or 2 stop bits, no parity bit

3.17 ATIS



Denotation

ATIS is not to be confused with Automatic Terminal Information Service or ATIS (Air) (see [chapter 3.18, "ATIS \(Air\)"](#), on page 76) used as an analogous announcement service on busy airports and having in common just the abbreviation.

3.17.1 General

Transmission method	ATIS
Explanation of name	Automatic Transmission Identification System
Other designations	
Variants existing	
Derived from method	
Typical users	Inland navigation
Kind of data	Maritime identification information

Transmission method	ATIS
Reference to standard	Regional Arrangement concerning the Radiotelephone Service on Inland Waterways (RAINWAT) ITU-R Recommendation 493-12 : " <i>Digital selective-calling system for use in the maritime mobile service</i> " ITU-R Report M.1159: " <i>Characteristics of an automatic identification system for VHF and UHF transmitting stations in the maritime mobile service</i> "
Frequency band	VHF/UHF
Modulation method	FSK2
Shift/tone spacing	800 Hz
Baud rate	1200 Bd
Modulating subcarrier	1700 Hz
Bandwidth	12.5 kHz
Operating method	Simplex
Data protection	FEC
Code table	7-bit decimal code with redundancy

3.17.2 History

The specifications are directed at all river Rhine nautical radio installations (fixed and mobile stations). ATIS has been in use there since 1994, and also internationally since 1995.

3.17.3 Description

ATIS makes it possible to identify an inland navigation radio station and to determine its owner by automatic transmitting of a permanently programmed ATIS identification code. It is a mandatory part of inland navigation radio stations in many European countries due to the [RAINWAT](#) (Regional Arrangement concerning the Radiotelephone Service on **IN**land **WAT**erways).

The ATIS identification code is emitted automatically after releasing the [PTT](#) button by keying a low frequency subcarrier; used tone frequencies are 1300 [Hz](#) (representing '1') and 2100 Hz ('0') with a baud rate of 1200 [Bd](#) (in lengthy transmissions, the ATIS code is required to be transmitted at least once every five minutes). Inland navigation radio stations are equipped with an "ATIS killer" filtering out from the received signal the ATIS code in order to make it inaudible.

3.17.4 Source Coding

The 10-figure ATIS identification code consists of several parts:

- the digit "9" for "inland navigation"

- a 3-figure MID (**M**aritime **I**dentification **D**igit) (211 or 218 for Germany)
- the coded voice call sign of the ship (e.g. 03 6580 for the voice call sign DC6580)

So the complete ATIS identification code in this example would be 9 211 03 6580.

3.17.5 Channel Coding/Structure of Data Blocks

10-bit code: 7 bit decimal representation, bits 8, 9 and 10 binary representation of the number of '0' bits.

3.18 ATIS (Air)



Denotation

ATIS (Air) is not to be confused with Automatic Transmission Identification System (ATIS, see [chapter 3.17, "ATIS"](#), on page 74) used in maritime inland navigation and having in common just the abbreviation.

3.18.1 General

Transmission method	ATIS
Explanation of name	A utomatic T erminal I nformation S ervice
Other designations	
Variants existing	
Derived from method	
Typical users	Information service on busier airport areas
Kind of data	Information essential to pilots, such as weather information, active runways, available approaches, visibility, air pressure
Reference to standard	
Frequency band	Air-to-ground radio frequencies: 117.975 MHz to 137 MHz
Modulation method	AM
Shift/tone spacing	
Baud rate	
Modulating subcarrier	
Bandwidth	8 kHz
Operating method	Simplex

Transmission method	ATIS
Data protection	
Code table	

3.18.2 Description

Automatic Terminal Information Service (ATIS) is a continuous broadcast of tape-recorded noncontrol information in busier terminal (i.e. airport) areas. ATIS broadcasts contain essential information, such as weather information, which runways are active, available approaches, and any other information required by the pilots. Pilots are bound to listen to the available ATIS broadcast before contacting the local control unit, in order to reduce the controllers' workload and relieve frequency congestion.

ATIS (Air) is just an analogous announcement emitted periodically; updates are done every 30 minutes or when there is a significant change in the information, like a change in the active runway. Announcement is usually given by an automated voice, allowing faster updating of an ATIS message than by time-consuming voice recording. Each update is given a letter designation (e.g. "B"), pronounced according to the ICAO spelling alphabet (e.g. "Bravo").

Like any other air-to-ground radio communication, ATIS (Air) is always amplitude modulated (AM). Frequencies used are in the normal air-to-ground radio communication band from 117.975 MHz to 137 MHz; each airport using the service is assigned an individual ATIS (Air) frequency.

Example:

This is Schiphol arrival information Kilo^① – Main landing runway 18 Right^② – Transition level 50^③ – Two zero zero degrees, one one knots^④ – Visibility 10 kilometres^⑤ – Few 1300 feet, scattered 1800 feet, broken 2200 feet^⑥ – Temperature 15, dewpoint 13^⑦ – QNH 995 hectopascal^⑧ – No Significant change^⑨ – Contact Approach and Arrival call-sign only^⑨ – End of information Kilo^⑨

- ① Indicates the broadcast is for aircrafts inbound to Schiphol, and the bulletin's identification letter "K".
- ② Main runway used for landing is 18 Right (indicates the direction: 180° magnetic), "Right" implies also a "18 Left" runway existing, perhaps more such as "18 Center".
- ③ Level where switching of barometric altimeter setting from "above sea level" to "above ground" is done (5000 ft).
- ④ Wind direction azimuth 200° [magnetic] (i.e. south-southwest), average wind speed 11 kn.
- ⑤ General visibility 10 km or more.
- ⑥ Intensity of cloud layers at altitudes 1300 ft, 1800 ft, 2200 ft above the airport.
- ⑦ Temperature 15 °C and dewpoint 13 °C.
- ⑧ Air pressure related to sea level 995 hPa.
- ⑨ No significant change in weather expected.

- ⑩ When instructed to contact the Approach and Arrival controller, check in with callsign only (for the sake of brevity).
- ⑪ End of bulletin, and the bulletin's identification letter "K" again.

3.19 AUTOSPEC

3.19.1 General

Transmission method	AUTOSPEC
Explanation of name	AUTO matic S ingle P ath E rro R C orrecting telegraph equipment
Other designations	BAUER (BAUER code) AUTOSPEC-BAUER SPREAD-1 (Variant of SPREAD with bit distance of 1 bit, i.e. no interleaving)
Variants existing	
Derived from method	
Typical users	Coastal stations to communicate with North Sea oil rigs
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	
Baud rate	62.3 Bd , 68.5 Bd , 102.6 Bd or 137 Bd
Modulating subcarrier	
Bandwidth	550 Hz
Operating method	Simplex, synchronous
Data protection	FEC
Code table	Bauer code (ITA-2 derivative) (table 4-8 in chapter 4.1.7)

3.19.2 History

In early days of **HF** telegraphy, many devices did not use any protection of the data to transmit. Reasons could have been: the small amount of traffic seemed not to be worth a high-tech terminal, or in broadcast environment a return circuit for **ARQ** operation could not be realized. Thus, the only way out was an **FEC** mode of operation, established by appending some additional bits to the original five of the **ITA-2** code.

Considerations that were made for the requirements of such a system were:

- Errors consisting of the mutilation of a single bit (whether in the original code word or the parity bits) should be able to be corrected.
- Errors concerning more than one bit (especially two) should be detected, but should not be corrected to a false result, an error sign printed to the output device in this case indicating the error rather than false characters being printed.
- Undetectable errors should be as few as possible.
- Due to the fact that asynchronous operation would degrade performance significantly, operation should be synchronous.
- Automatic phasing should be performed in order not to have to establish completely new equipment, but to be able to add the coding device to existing one.
- As explained above, a return circuit should not be needed (pure FEC).

These considerations led to the Bauer code (said to be invented by German computer scientist *Friedrich Ludwig Bauer*, see [3.19.3.1, "Bauer Code"](#)) and the AUTOSPEC method, designed especially for one-way radio, but of course also suited for two-way operation.

3.19.3 Description

3.19.3.1 Bauer Code

The Bauer code is a 10-bit code consisting of 5 data bits (e.g. the [ITA-2](#) code words) and 5 additional parity bits. Each of the 5 parity checks to be made to obtain these bits is performed from 4 bits, excluding in turn the 5th bit left. The system is shown in [figure 3-23](#) with the two possible cases: **A** to **C** original code word with odd parity (the bit excluded from calculation in each case shown in grey) and **D** to **F** original code word with even parity. **B** and **E** are the results obtained if parity bits are to give odd parity and **C** and **F** if parity bits are to give even parity. It can easily be seen that in case **B** and **F** the resulting parity bits form just the original code word (thus, the code word is simply sent twice), whereas in case **C** and **E** the parity bits are the bit-inverted original code word. (Be aware that "parity" does not describe the parity of the resulting overall 10-bit code word!) This code is capable to correct any single-bit error and additionally to detect two-bit errors, thereby offering greater simplicity of the executing circuit than would be needed for the theoretical minimum code having 9 bits (Hamming distance of 4).

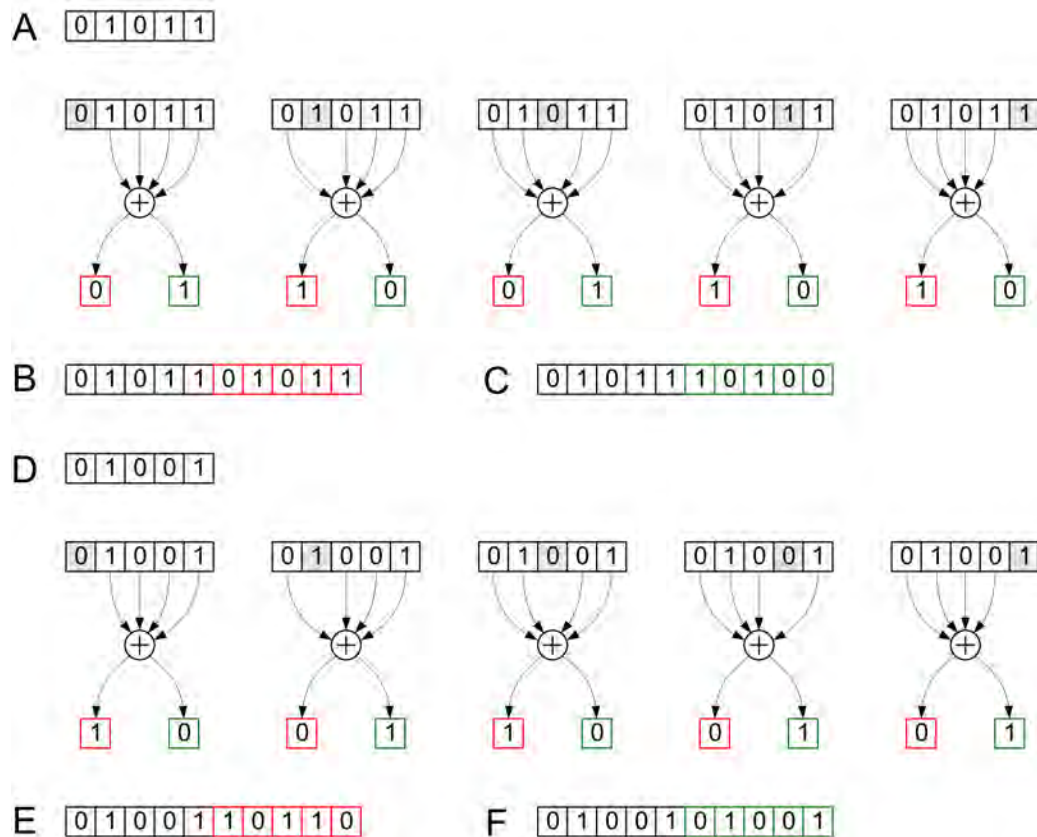


Fig. 3-23: Bauer code calculation.

- A = original ITA-2 code word with odd parity
 D = original ITA-2 code word with even parity
 B, E = Bauer code word, parity bits to give odd parity
 C, F = Bauer code word, parity bits to give even parity

A complete code table for the ITA-2 case can be seen in [table 4-8](#) ([chapter 4.1.7](#), "[Bauer Code Table](#)", on page 334).

3.19.3.2 Correct and Erroneous Reception

Some cases of reception of a character coded in Bauer code / AUTOSPEC can be seen from [figure 3-24](#), again shown for the two cases odd (left) and even parity (center) with the resulting output character (right): A control register collects the results of the receiver parity checks, again done from the appropriate four bits and the dedicated parity bit. (The same result would be obtained in a possibly easier way in just comparing the first five bits to the second five, indicating bits not coinciding in the control register by a '1', then deciding from the number of '1's of the first five whether the original character was of even or odd parity and eventually – compare [figure 3-23](#) – invert the complete control register.)

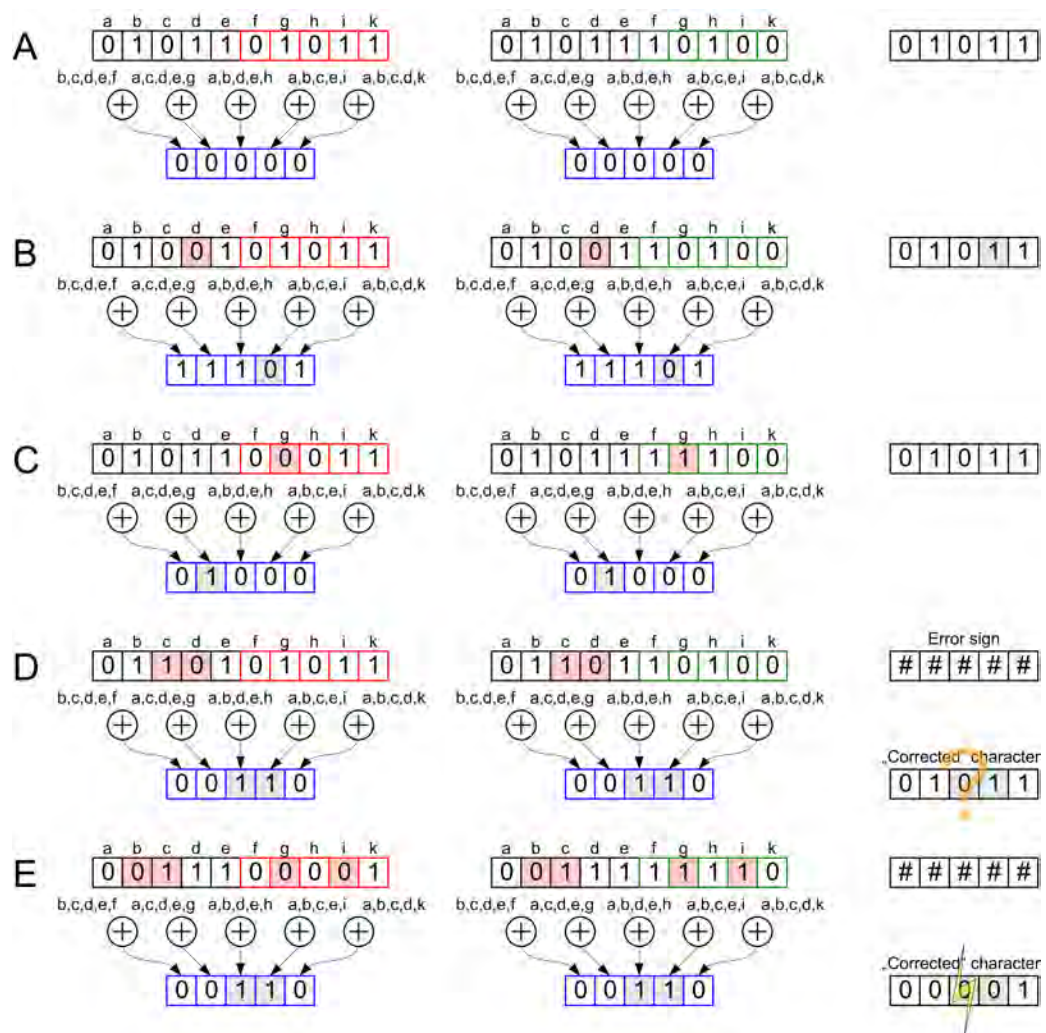


Fig. 3-24: Correct and erroneous reception of AUTOSPEC signals.

A = transmitted and correctly received code word with control register

B = incorrect bit (bit d) in character part of code word

C = incorrect bit (bit g) in parity part of code word

D = two incorrect bits (bits c and d)

E = four incorrect bits (bits b, c, g and i), same control register indication as case D

- In case **A**, the correct reception case, this control register of course contains only '0's. The character (left half of the code word received) can be output without modification.
- Case **B** describes an error (position d, shown in red) in reception in the "left", the original character part of the code word: the control register indicates a '0' at the position of the wrong bit and '1's at all other positions. The measure to be taken is thus to invert the respective bit (shown in grey) of the character and then to output the corrected character.
- Case **C** contains an error in the parity ("right") part (position g) of the code word: all control register positions show '0' except the position of the wrong bit. Nothing has to be done, the character again can be output without modification.

- The two-bit error case is given in case **D**: bits c and d are wrong, the control register shows another pattern than the two described with **B** and **C**. As explained in 3.19.3.1, "Bauer Code", two bits received falsified are just detectable, but not correctable, thus, the only thing remaining to do is to output an error sign.
- Case **D** seemed to indicate with its two '1' bits the two positions to invert to obtain a correct character word (labeled with the questionmark). In the concluding case **E** an example is shown producing proof of the contrary: four wrong bits result in the same control register pattern as that of case **D**; "correction" (inverting) of the bits in question (the bits indicated pretendedly) would lead to a completely wrong character (labeled with the "flash" sign).

The conclusion to draw from these descriptions is that all control register patterns containing just one '0' or just one '1' are the 1-bit error cases, the former case of which has to initiate a bit correction in the received character, the latter just to output the unmodified character. Any other pattern (except of course the hopefully most frequent correct reception case) shows a detection of a more-than-1-bit error and may not cause a correction attempt, but must output an error sign.

3.19.3.3 Synchronizing and Phasing

As mentioned in 3.19.2, "History", only synchronous operation offers a great deal of benefit of using an error correcting code in comparison to just transmitting unmodified ITA-2 code. If an ITA-2 code (5 bits) with 1 start and 1.5 stop bits, resulting in overall 7.5 bits, and transmitted with 50 Bd is used for comparison to the 10-bit Bauer code, an increase of the keying speed of

$$10 / 7.5 * 50 \text{ Bd} = 66.67 \text{ Bd}$$

results; this should not cause problems to most telegraph devices.

When no traffic is sent, the special idle signal 00000 11011₂ is transmitted instead. It is a bit combination not in use otherwise and maintains synchronism between sending and receiving device.

Correct phasing (the 10 bits of a code word being placed in proper order) could be lost in some situations, especially if signal-to-noise ratio (SNR) underruns a certain threshold. This commonly results in a rapid escalation of bit and thus character errors (the detected error rate and frequency of corrections). If these values exceed a threshold having been set in advance, an automatic phasing sequence can be initiated, correct phasing being reestablished when the error rate falls down again. During phasing, the teleprinter outputs continuous stop polarity.

3.20 BARRIE 6028

3.20.1 General

Transmission method	BARRIE 6028
Explanation of name	
Other designations	BARRIE BR 6028 USA 7 or USA 7 channel modem 6028
Variants existing	
Derived from method	
Typical users	Military, diplomatic institutions
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK
Shift/tone spacing	7 tones from 850 Hz to 2890 Hz, spacing 340 Hz, shift 170 Hz; pilot tone 560 Hz
Baud rate	45.45 Bd, 50 Bd, 75 Bd, 100 Bd, 103.7 Bd, variable 30 Bd to 110 Bd
Modulating subcarrier	
Bandwidth	2.6 kHz
Operating method	
Data protection	FEC
Code table	ITA-2 (table 4-2 in chapter 4.1.2) ITA-5 (ASCII) (table 4-9 and table 4-10 in chapter 4.2)

3.20.2 Description

BARRIE 6028 is a VFT (Voice-Frequency Telegraphy) system, i.e. transmission of the telegraphy characters is done over a voice bandwidth channel (3 kHz approx.). Both a frequency division multiplex (FDM) and a time division multiplex (TDM) are used: 7 equal-spaced frequencies are frequency keyed (170 Hz shift) by the same binary teletype signal, but this modulating signal is delayed by an additional time interval of 1 s before keying each frequency channel. The frequencies are in a distance of 340 Hz as can be seen in table 3-7, an unmodulated pilot tone of 560 Hz is also transmitted. Note that the sequence of the used frequencies normally is not the numeric sequence of 1, 2, 3, 4, 5, 6, 7, but more often (in most cases observed) another one like

3, 7, 1, 4, 6, 2, 5. On the receiving end, each frequency is decoded, the results (decoded data streams) are compared (after having eliminated the time delays), and the presumed correct data stream is selected on a majority basis. Furthermore, channels with heavy interference can be excluded from transmission entirely; this also can be the reason for systems having been observed with less than 7 channels.

Spirit and purpose of this is to defeat strong fading effects. Although the method is not a means for exact error correction, the probability of obtaining a correct message is increased to a large degree.

Some diplomatic institutions use a system with channel 2 never being present and with a baud rate of 100 Bd and a time delay of 0.5 s.

Table 3-7: Frequency table for BARRIE 6028.

Channel	Pilot tone	1	2	3	4	5	6	7
Frequency [Hz]	560	850	1190	1530	1870	2210	2550	2890
Space [Hz]		765	1105	1445	1785	2125	2465	2805
Mark [Hz]		935	1275	1615	1955	2295	2635	2975

3.21 BAUDOT

3.21.1 General

Transmission method	BAUDOT
Explanation of name	After the french inventor <i>Jean-Maurice-Émile Baudot</i>
Other designations	ITA2 (International Telegraph Alphabet) RTTY (RadioTeleTYpe) RTTY5
Variants existing	1, 1.5 and 2 stop bits Code alphabets with some bits inverted Different character sets
Derived from method	
Typical users	Many military and government services Radio amateurs
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	

Transmission method	BAUDOT
Baud rate	Typically 50 Bd, 75 Bd or 100 Bd Many divergent rates known, like as 45.45 Bd, 70 Bd, 150 Bd, 180 Bd
Modulating subcarrier	
Bandwidth	720 Hz
Operating method	Asynchronous
Data protection	None
Code table	ITA-2 (table 4-2 in chapter 4.1.2)

3.21.2 History

The first method after the invention of electric telegraphy to transmit text was Morse transmission. From the beginnings, possibilities had been searched for to deliver a more simple, direct transmission of text without the need to have it translated into a code and entered by the operating staff in the telegraph centers, i.e. the goal was an automatic code translation by the telegraph device itself. (The variable code length of the Morse code seemed a big obstacle in this concern.) 5- or 6-bit codes proved a good tradeoff between the count of voltage values and transmission lines needed.

The original Baudot code was designed by *Jean-Maurice-Émile Baudot* for a telegraph device he had developed; the characters were entered via a keyboard with five keys (pressing a key or not corresponded to setting or resetting a bit in the character to send). Two fingers of the left and three of the right hand were used for that; speeds of 180 characters per minute were reached this way.

Five bits (or keys) would of course not have been enough ($2^5 = 32$ possible combinations) to even represent just the 26 letters of the Latin alphabet and 10 digits, thus, Baudot introduced a shift code to occupy nearly all codes twice: after reception of the "Letter shift" code, the decoding mode was switched to *Letter* level and all subsequent characters were to interpret according to a letter table, after "Figure shift", in *Figure* level, according to a table with digits and symbols.

This so-called CCITT-1 code table was modified later on by *Donald Murray*, keeping the bit count of 5 and therefore also the code shifting; his intention was to have to move mechanics in the transmitting and receiving devices less often, thus reducing abrasion and need for maintenance. In 1932, his code was standardized by the CCITT as the CCITT-2 or ITA-2 code. Both CCITT-1 and CCITT-2 code have spawned many variations according to the differing alphabets (Cyrillic, Greek, Arabic etc.), applications (weather service, stock market or other networks) and further needs.

The start and stop bits had to be added when the original synchronous operation mode was replaced by an asynchronous one, thus enabling the receiving device to resynchronize itself on every character.

3.21.3 Description

Baudot is a completely asynchronous system; its bit patterns are formed (see [figure 3-25](#)) by the 5 data bits of the ITA-2 code table (each combination delivering a valid character, i.e. no error detection or correction possible), additionally 1 start bit of '0' or "Space" polarity and 1 (A in the figure), 1.5 (B) or 2 (C) (depending on variant) stop bits of '1' or "Mark" polarity for synchronization purposes. Thus a resynchronization, if necessary, can be performed with every word received.

As explained in [3.21.2, "History"](#), basically the ITA-2 code table is used, involving the "code shift" peculiarity, i.e. with the two shift characters "Letter shift" (combination 29) and "Figure (or Number) shift" (combination 30) a switch between a letters and a digits decoding table (called *Letter* and *Figure* level) is performed – the 32 possible codes of the normal code table would not have been enough to picture all characters needed.

Transmission is commonly performed **LSB** first. Not frequently observed, but sometimes encountered is an inversion of some of the bits, ultimately resulting in a different code table – due to the 5 bits available, 32 possible arrangements for this inversion are imaginable. Also existing are stations sending Baudot, but using a completely different code table, examples are Arabic [ATU-70](#), Fourth-shift Arabic ATU-80 or Cyrillic. Transmissions of this kind may, at first glance, look like scrambled Baudot.

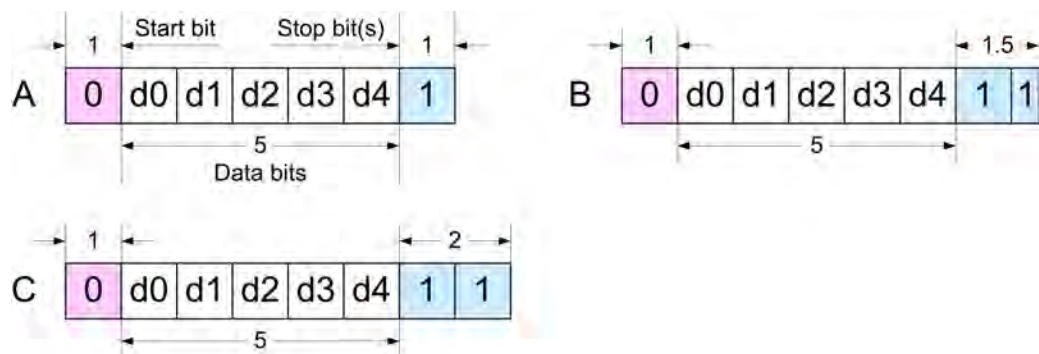


Fig. 3-25: Bit patterns with Baudot.

A = 1 stop bit
B = 1.5 stop bits
C = 2 stop bits

3.22 BULG-ASCII

3.22.1 General

Transmission method	BULG-ASCII
Explanation of name	BULGarian ASCII
Other designations	

Transmission method	BULG-ASCII
Variants existing	
Derived from method	ASCII
Typical users	Bulgarian Ministry of Foreign Affairs (MFA)
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	500 Hz
Baud rate	110 Bd, 120 Bd, 150 Bd, 180 Bd, 200 Bd, 300 Bd, 600 Bd
Modulating subcarrier	
Bandwidth	910 Hz
Operating method	Duplex, asynchronous
Data protection	Parity bit, Go-back-7-frames ARQ
Code table	ITA-5 (ASCII) (table 4-9 and table 4-10 in chapter 4.2) National alphabet(s)

3.22.2 Description

BULG-ASCII is a system found rarely, users seem to be some Bulgarian institutions. Thus, besides the standard [ITA-5 \(ASCII\)](#) alphabet, (a) national (Cyrillic) alphabet(s) is (are) also in use.

Character length has been observed to be 11 bit: 7 data bits, 2 start and 2 stop bits, but no parity bit (i.e. no error detection or correction with characters).

Frames can be of variable length, they are transmitted with a preceding frame counter ([Tx](#) and [Rx](#) frames) and a [CRC](#) checksum appended. The mode is full duplex with Go-back-7-frames ARQ. Messages and files may be encrypted and/or compressed.

A very large variety of ASCII modes with different frame lengths, with systems being possibly adaptive (Baud rate varying due to propagation conditions), makes the situation confusing to monitor or even to keep track. Definitions what might be BULG-ASCII or another ASCII mode are not unambiguous all over relevant literature.

3.23 CIS-11

3.23.1 General

Transmission method	CIS-11
Explanation of name	Commonwealth of Independent States (successor organisation of the former Soviet Union), 11 bits
Other designations	TORG-10 TORG-11
Variants existing	
Derived from method	
Typical users	Russian (CIS) meteorological stations
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	500 Hz
Baud rate	50 Bd, 100 Bd, 150 Bd, 192 Bd, 200 Bd, 300 Bd
Modulating subcarrier	
Bandwidth	650 Hz
Operating method	Duplex, synchronous
Data protection	Parity bits, FEC, ARQ
Code table	MTK-2 (Russian [Cyrillic] Third-shift ITA-2) (table 4-4 in chapter 4.1.3)

3.23.2 Description

CIS-11 is a synchronous, full duplex system used mainly in the CIS (the successor organisation of the former Soviet Union). Thus, transmissions normally take place in MTK-2 alphabet (Russian [Cyrillic] Third-shift ITA-2, sometimes also called "ITA-2 Cyrillic M2", see code table from table 4-4 in chapter 4.1.3, "MTK-2 Code Table", on page 327).

A code word to transmit (figure 3-26) consists of

- the 5 bits of the ITA-2 alphabet d_4 to d_0 (but in reversed bit order: d_0 to d_4)
- 2 system state bits s_0 and s_1
- 4 parity bits p_0 to p_4 , calculated by modulo-2 addition from all 7 other bits d_4 to d_0 , s_0 and s_1 as shown with the figure

If no data to transmit is available at the moment, idle characters are emitted to maintain synchronization from transmitting to receiving station. Idle sign α is $01101\ 00\ 1100_2$, β is $10101\ 00\ 0001_2$.

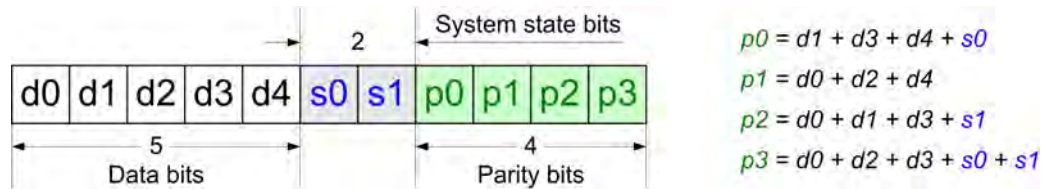


Fig. 3-26: Bit patterns with CIS-11.

3.24 CIS-12

3.24.1 General

Transmission method	CIS-12
Explanation of name	Commonwealth of Independent States (successor organisation of the former Soviet Union), 12 channels
Other designations	Fire MS5 CIS AT-3104 Modem
Variants existing	
Derived from method	
Typical users	
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	PSK: PSK2 (DBPSK), PSK4 (DQPSK)
Shift/tone spacing	200 Hz
Baud rate	120 Bd
Modulating subcarrier	1800 Hz
Bandwidth	2600 Hz
Operating method	
Data protection	
Code table	MTK-2 (Russian [Cyrillic] Third-shift ITA-2) (table 4-4 in chapter 4.1.3)

3.24.2 Description

CIS-12 is a 12-tone modem used in the CIS (the successor organisation of the former Soviet Union). The 12 tones (see figure 3-27) come in a distance of 200 Hz from each other, each of them is modulated in PSK2 (BPSK) or PSK4 (QPSK) with a rate of 120 Bd, resulting in a maximum overall transmission rate of 2880 bit/s.

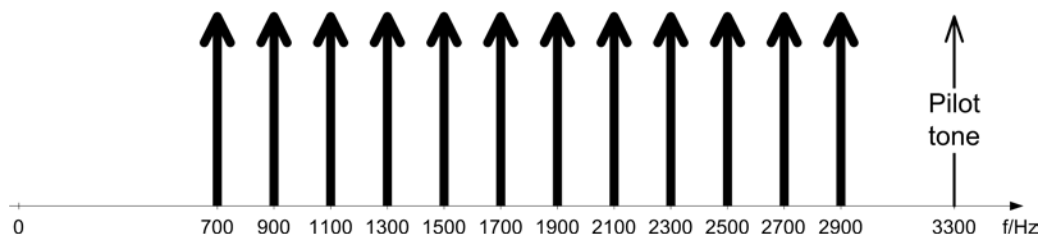


Fig. 3-27: CIS-12 frequency channels.

3.25 CIS-14

3.25.1 General

Transmission method	CIS-14
Explanation of name	Commonwealth of Independent States (successor organisation of the former Soviet Union), 14 bits per frame
Other designations	CIS-96 AMOR AMOR 96 PARITY 14 TORG 14
Variants existing	Frames with 28 bits
Derived from method	
Typical users	Russian PTT stations on links to the former republics
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	
Baud rate	42.1 Bd, 47.5 Bd, 48 Bd, 50 Bd, 70.5 Bd, 72 Bd, 83.3 Bd, 84.21 Bd, 94.11 Bd, 96 Bd, 100 Bd, 144 Bd, 192 Bd, 200 Bd, 288 Bd
Modulating subcarrier	

Transmission method	CIS-14
Bandwidth	650 Hz
Operating method	Duplex
Data protection	Parity bits
Code table	MTK-2 (Russian [Cyrillic] Third-shift ITA-2) (table 4-4 in chapter 4.1.3)

3.25.2 Description

CIS-14 is a full duplex system using FSK2. Data of two independent data channels can be processed; they are in MTK-2 alphabet (Russian [Cyrillic] Third-shift ITA-2, sometimes also called "ITA-2 Cyrillic M2", see code table from table 4-4 in chapter 4.1.3, "MTK-2 Code Table", on page 327), thus have 5 bits per character, but are transmitted in 14-bit frames, each containing two characters:

As shown in figure 3-28, the data code words (**A** in the figure) of the two channels are amended with two leading "channel state" bits and then either word- (case **B**) or bit-interleaved (case **C**). Two parity bits are calculated over the complete 12-bit frame generated and expand it to the final 14-bit frame. The calculating scheme is given in table 3-8.

The two bits indicating the channel state signify whether the channel contains traffic (bit = 0) or idle (bit = 1) sequences at the moment.

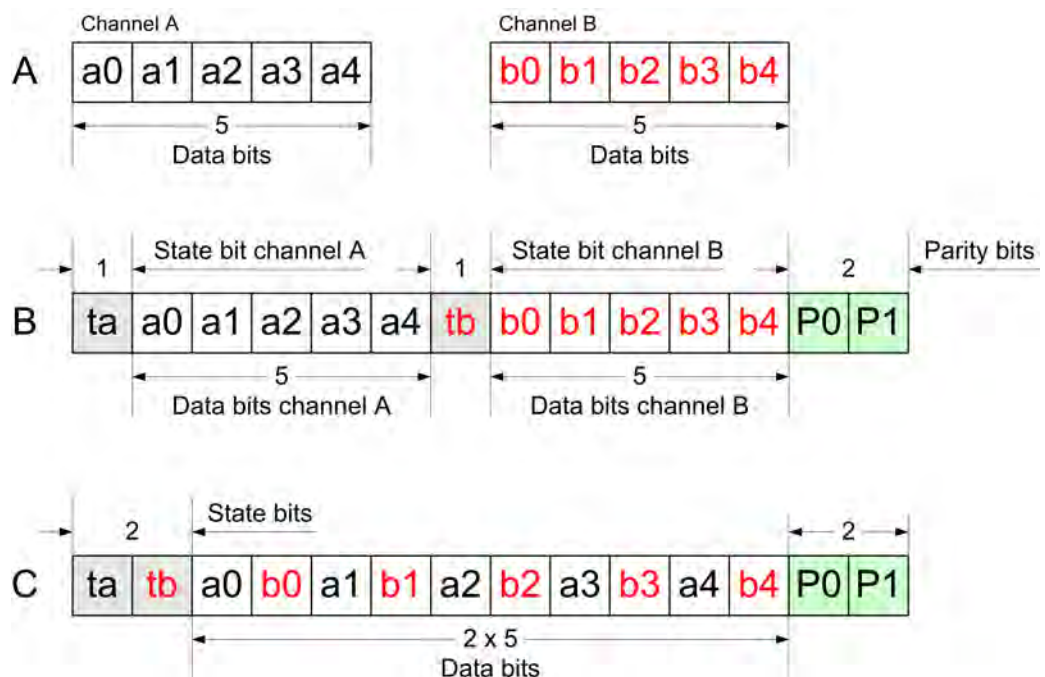


Fig. 3-28: Interleaving schemes for CIS-14, 14-bit frame.

A = 2 independent data channels

B = word-interleaving with 47.5 Bd, 50 Bd, 84.21 Bd, 94.11 Bd

C = bit-interleaving with 100 Bd

Table 3-8: Parity bits in CIS-14.

Count of '1's	Baud rate [Bd]						Encrypted (all rates)	
	47.5 / 50 / 94.11		84.21		200			
	P0	P1	P0	P1	P0	P1	P0	P1
0, 4, 8, 12	0	1	1	0	1	1	0	0
1, 5, 9	1	0	0	1	0	1	1	1
2, 6, 10	1	1	1	1	1	0	1	0
3, 7, 11	0	0	0	0	0	0	0	1

Additionally, a variant of CIS-14 has been observed using frames of 28 bits. As can be seen in figure 3-29, after having established the 14-bit frame(s) (B) from the data words (A) as explained above, two of these frames are bit-interleaved (C) to the new 28-bit frame.

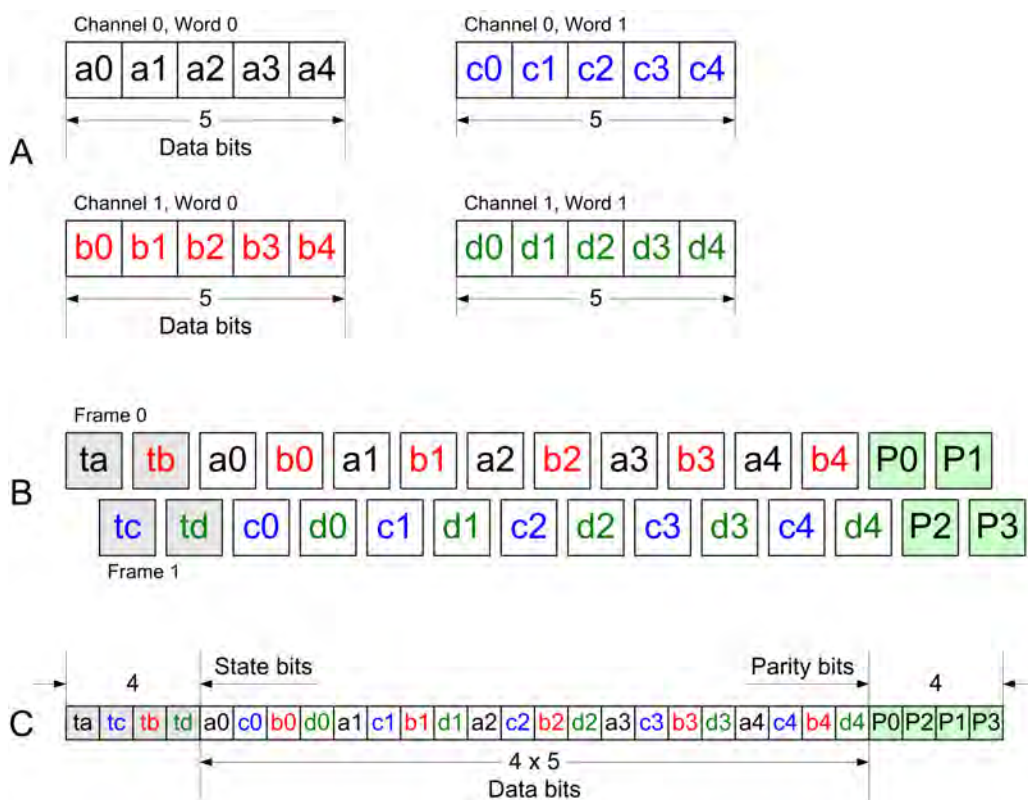


Fig. 3-29: Interleaving scheme for CIS-14, 28-bit frame.

A = 2 independent data channels

B = Channel 0 interleaved with channel 1 to Frame 0 and Frame 1

C = Frame 0 interleaved with Frame 1

3.26 CIS-36

3.26.1 General

Transmission method	CIS-36			
Explanation of name	Commonwealth of Independent States (successor organisation of the former Soviet Union), 36 tones			
Other designations	CROWD-36 CIS/Russian Piccolo URS multitone CIS 10-11-11 MFSK			
Variants existing				
Derived from method	Piccolo MK 1			
Typical users	CIS Diplomatic service CIS Intelligence and Military services			
Kind of data				
Reference to standard				
Frequency band	HF			
Modulation method	FSK: MTONE (MFSK)			
Shift/tone spacing	40 Hz			
Baud rate	Tone duration	25 ms	50 ms	100 ms
	thus "tone speed"	40/s	20/s	10/s
Modulating subcarrier				
Bandwidth	1280 Hz			
Operating method	Duplex, simplex			
Data protection	FEC, ARQ (probably)			
Code table	MTK-2 (Russian [Cyrillic] Third-shift ITA-2) (table 4-4 in chapter 4.1.3)			

3.26.2 Description

CIS-36 is an MFSK system used in the CIS (the successor organisation of the former Soviet Union). It is based on and therefore probably derived from the ancient British system Piccolo MK 1 (Mark I) (chapter 3.78, "Piccolo-6 (MK 6)", on page 242) and, similar to this system, uses 32 tones, one for each character of the ITA-2 alphabet – here the MTK-2 alphabet (Russian [Cyrillic] Third-shift ITA-2, sometimes also called "ITA-2 Cyrillic M2", see code table from table 4-4 in chapter 4.1.3, "MTK-2 Code Table", on page 327). In contrast to Piccolo MK 1, these tones are grouped in three sections of (in order of ascending frequency) 10, 11 and 11 frequencies each, delimi-

ted and additionally surrounded by in sum 4 more frequencies; thus, an overall count of 36 tones (frequencies) arises. Frequency distance from tone to tone is 40 Hz (theoretical bandwidth demand 1400 Hz); the "border tones" (when numbering tones from 1 to 40), i.e. tones 1, 12, 24 and 36, are rarely used, so 80 Hz gaps are likely to be seen between the three groups. Tone durations are 100 ms, 50 ms and 25 ms.

Operation mode is full duplex: two distinct frequencies are existing that can also be used separately in simplex mode.

Switching between 100 ms and 50 ms or 25 ms tone duration often is performed automatically; in the 100 ms mode, operator chat and control sequences are transmitted mostly unencrypted. When payload data are sent, 50 ms or 25 ms mode are used, and data are coded or online encrypted in almost all transmissions.

Emissions commonly are provided by an error protection: after every 5 characters a parity character is inserted, all together forming a data frame, and 10 frames are followed by a parity frame. Thus, a horizontal and vertical block error correction is implemented. If a frame has not been received correctly, the receiving station asks for a frame repetition (NAK is sent instead of ACK); the frame in question is transmitted again from the last frame on having been received completely and without errors.

CIS-36 also owns capabilities for selective calling, link establishment and automatic baud rate change (see above).

Transmissions of Cyrillic and also Latin text have been observed with CIS-36.

3.27 CIS-36-50

3.27.1 General

Transmission method	CIS-36-50
Explanation of name	Commonwealth of Independent States (successor organisation of the former Soviet Union), idle sequences 36 Bd and traffic 50 Bd
Other designations	CIS-Navy BEE BEE-36 T-600
Variants existing	
Derived from method	
Typical users	Russian navy Polish military
Kind of data	
Reference to standard	
Frequency band	HF, VLF

Transmission method	CIS-36-50
Modulation method	FSK2
Shift/tone spacing	85 Hz, 125 Hz, 250 Hz, 500 Hz
Baud rate	36 Bd, 50 Bd
Modulating subcarrier	
Bandwidth	360 Hz
Operating method	Synchronous, simplex, broadcast
Data protection	FEC
Code table	Special alphabet derived from ITA-3 used for decoding (table 4-12 in chapter 4.3)

3.27.2 Description

CIS-36-50 is a transmission method that can be heard on fixed frequencies in regular intervals. For example, emissions of 5 minutes of duration are heard every 20 minutes (8 min, 28 min and 48 min from full hour) on 10.535 MHz (HF range), the baud rate within a particular emission toggling between 36 Bd and 50 Bd. Similar emissions have been monitored on 18.1 kHz in the VLF range (which commonly is utilized for submarine communications). The method is mainly in use with Russian marine forces, significance there is considered to be high.

The method exclusively conveys encrypted messages, from that readable text is not expectable, and a special alphabet to be in use cannot be told. All payload data, however, has a fixed ratio of '0's vs. '1's of 3 to 4 (or vice versa, depending on polarity of reception), therefore, for reasons of intelligible representation of the received characters, a more or less arbitrary alphabet can be allocated. The alphabet selected here can be seen in chapter 4.3, "CIS-36-50 Code Table", on page 339.

A special peculiarity of CIS-36-50 is utilisation of two different baud rates: 36 Bd and 50 Bd. This is not atypical with user circles mentioned, but here the 36 Bd rate is encountered to be in use only with chains of reversals of '0's and '1's that introduce and finish a data transmission, whereas data traffic itself is only done in 50 Bd.

Modulation in use is FSK2, emissions are observed with varying frequency shifts: 85 Hz, 125 Hz, 250 Hz, rarely 500 Hz.

3.27.3 Channel Coding/Structure of Data Blocks

Frames are constructed from data blocks consisting of 7-bit elements: a packet of payload data of basically arbitrary length is surrounded by a start and an end sequence. Sometimes blocks of data already transmitted are observed to be repeated, verifying the contents by the recipient can be performed easily this way. Idle sequences of reversals, i.e. strictly alternating sequences of '0's and '1's, of 36 Bd and 50 Bd are used to introduce and to terminate a transmission or also (50 Bd only) to separate data blocks.

An example for the frame structure with CIS-36-50 is shown in [figure 3-30](#):

- A section with 50 Bd data blocks is introduced (**A** in the figure) by first a sequence of (approx. 90) 36 Bd reversals, subsequently the baud rate changes to 50 Bd and another approx. 30 reversals follow. The block of reversals that terminates the transmission features the reverse order, their count appearing is less than 10 (e.g. 5 or 7). At the very end, the carrier of the lower FSK2 frequency is found to be switched on for another approx. 1 s.
- The data section (**B**) is made up of data blocks with a length basically not determined in advance and separated again by "some" reversals of 50 Bd.
- A data block itself (**C**) consists of the three sections start sequence, payload data and end sequence.
- After a single '0' bit (following the last 50 Bd '1'-'0' reversal pair), the *start sequence* (**D**) is transmitted, built from four 7-bit words; the ratio of three '0's to four '1's is not followed here to make the start sequence distinguishable from the actual data. This *payload data* ('1' to '0' ratio followed) comes next; its first part are two equal words, followed by a ten-word (7 bits each) group, which, in this case, is repeated once. All subsequent data (arbitrary length) do not obey a special regularity anymore. The *end sequence* shows five equal 7-bit words, again disregarding the bit ratio of the data section.

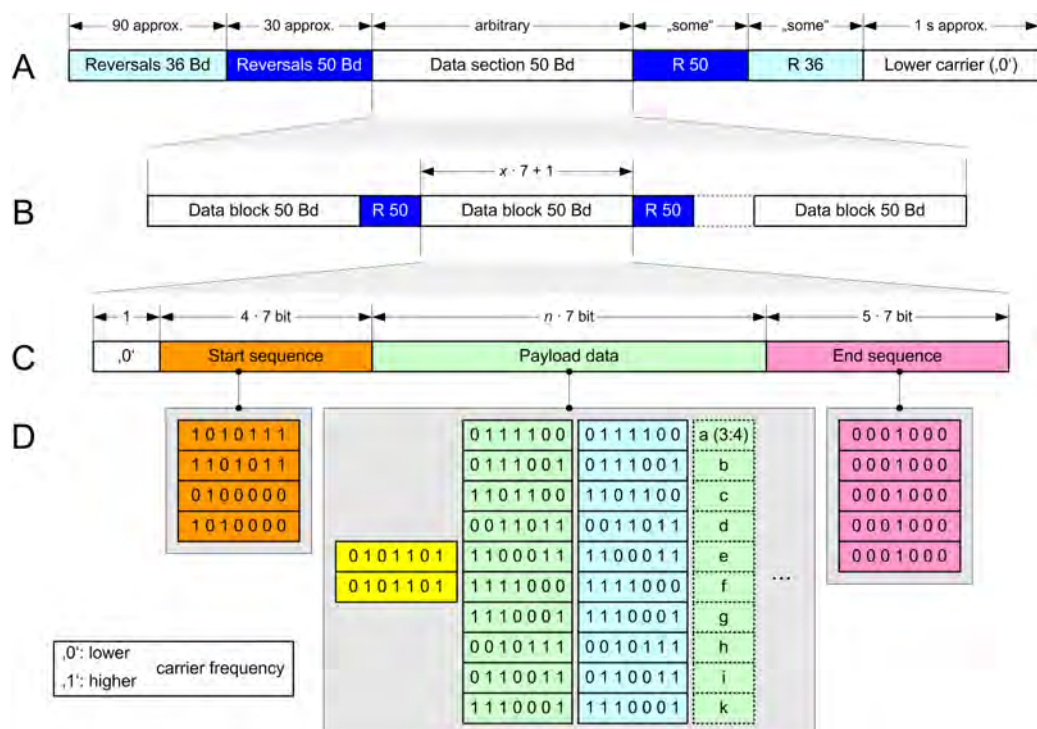


Fig. 3-30: CIS-36-50 frame architecture, example.

- A = complete transmission
 B = data section without surrounding reversals
 C = data block
 D = message example including start and end sequences

3.28 CIS-50-50

3.28.1 General

Transmission method	CIS-50-50
Explanation of name	Commonwealth of Independent States (successor organisation of the former Soviet Union), idle sequences 50 Bd and traffic 50 Bd
Other designations	BEE T-600
Variants existing	
Derived from method	
Typical users	Russian navy Polish military
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	85 Hz, 125 Hz, 250 Hz, 500 Hz
Baud rate	50 Bd, 100 Bd
Modulating subcarrier	
Bandwidth	425 Hz
Operating method	Synchronous, simplex, broadcast
Data protection	FEC
Code table	Special alphabet derived from ITA-3 used for decoding (table 4-12 in chapter 4.3)

3.28.2 Description

CIS-50-50 is a transmission method that is very similar to CIS-36-50 ([chapter 3.27](#), "CIS-36-50", on page 94). As with this, it is emitted by Russian forces on fixed frequencies in regular intervals, and contents are always encrypted.

Also, modulation is always FSK2; baud rate is normally 50 Bd, sometimes 100 Bd can also occur. Frequency shift varies from 85 Hz, 125 Hz, 250 Hz to 500 Hz.

See explanations concerning the alphabet in use in [chapter 3.27](#) and [chapter 4.3](#), "CIS-36-50 Code Table", on page 339.

During idle periods (no specific information sent) reversals (sequences of '0' and '1') are conveyed; they also come in the 50 Bd baud rate.

3.28.3 Channel Coding/Structure of Data Blocks

As with CIS-36-50, data blocks are composed of start sequence, payload data section and end sequence.

1. The *start sequence* is also 28 bit (four 7-bit words) long here, but different from the one of CIS-36-50. The sequence is
 - $100\ 0010_2\ 100\ 1011_2\ 111\ 0000_2\ 101\ 0011_2$,
 in contrast to CIS-36-50, two of the four words (the second and the fourth one) also have the ratio of three '0's to four '1's actually scheduled only to the payload data.
2. *Payload data* (all with the three-to-four ratio) also begins with two equal words, followed by a 10-word group being repeated once; all other data are not regular anymore.
3. The *end sequence* is the same as described with CIS-36-50: five words $000\ 1000_2$.

3.29 CLOVER-II

3.29.1 General

Transmission method	CLOVER-II
Explanation of name	(The visualization of the signal looks like a four-leaf clover)
Other designations	CLOVER CLOVER-2
Variants existing	
Derived from method	
Typical users	North American Radio Amateurs Balkan military and paramilitary stations Diplomatic services of African states
Kind of data	
Reference to standard	Engineering Document E2006 Rev A: " <i>CLOVER-II Waveform & Protocol</i> ", <i>HAL Communications Corp.</i> , December 17, 1997
Frequency band	HF

Transmission method	CLOVER-II
Modulation method	PSK: - PSK2A ("BPSM": "PSM" for "Phase Shift Modulation") - PSK4A ("QPSM") - PSK8A ("8PSM") - dual PSK2A ("2DPSM" for "Dual Diversity BPSM") QAM: - QAM16 (ASK2PSK8: "8P2A"; "ASM" for "Amplitude Shift Modulation") - QAM64 (ASK4PSK16: "16P4A")
Shift/tone spacing	4 tone channels with 4 tones each from 562.5 Hz to 2437.5 Hz, spacing 125 Hz
Baud rate	31.25 Bd
Modulating subcarrier	1500 Hz
Bandwidth	460 Hz
Operating method	Half-duplex
Data protection	ARQ, FEC
Code table	

3.29.2 History

CLOVER-II was the first CLOVER waveform sold commercially, developed by *Ray Petit* and *HAL Communications Corp.* in 1990 to 1992.

3.29.3 Description

CLOVER-II is an adaptive modulation system with ARQ and FEC (broadcast) modus. It uses Reed-Solomon (RS) coding to achieve a remarkable performance even under poor HF propagation conditions. Data is modulated onto four single carriers (tones) spaced 125 Hz, which are emitted cyclically (in ascending frequency order) with a duration of 8 ms each. One cycle lasting for 32 ms represents one symbol, so the overall symbol rate is 31.25 Bd. The supported modulation techniques (for each individual carrier) include

- binary phase-shift keying (PSK2A)
- quaternary PSK (PSK4A)
- PSK8 (PSK8A)
- binary amplitude-shift keying combined with PSK8 (QAM: ASK2PSK8)
- quaternary ASK combined with PSK16 (QAM: ASK4PSK16)
- two-channel diversity binary PSK ("2DPSM")

There are 4 coding levels (called RS efficiency; percent values express information-to-blocklength ratio):

- robust = 60 %
- normal = 75 %

- fast = 90 %
- off = 100 % (i.e. no error correction)

3.29.4 Channel Coding/Structure of Data Blocks

Reed-Solomon coding

3.30 CLOVER-2000

3.30.1 General

Transmission method	CLOVER-2000
Explanation of name	(The visualization of the signal looks like a four-leaf clover) 2000 Hz bandwidth, or with a view to the year 2000
Other designations	
Variants existing	
Derived from method	CLOVER-II
Typical users	North American Radio Amateurs Balkan military and paramilitary stations Diplomatic services of African states
Kind of data	
Reference to standard	Engineering Document E2007 Rev C: " <i>CLOVER-2000 Waveform & Protocol</i> ", <i>HAL Communications Corp.</i> , May 07, 1999
Frequency band	HF
Modulation method	PSK : • PSK2A ("BPSM": "PSM" for "Phase Shift Modulation") • PSK4A ("QPSM") • PSK8A ("8PSM") QAM : • QAM16 (ASK2PSK8: "8P2A"; "ASM" for "Amplitude Shift Modulation") • QAM64 (ASK4PSK16: "16P4A")
Shift/tone spacing	8 tones from 625 Hz to 2375 Hz, spacing 250 Hz
Baud rate	62.5 Bd
Modulating subcarrier	1500 Hz
Bandwidth	2 kHz
Operating method	Half-duplex

Transmission method	CLOVER-2000
Data protection	ARQ, FEC
Code table	

3.30.2 History

CLOVER-2000 is a higher-rate and wider bandwidth version of CLOVER-II (see [chapter 3.29, "CLOVER-II"](#), on page 98) developed by *HAL Communications Corp.* in 1995.

3.30.3 Description

CLOVER-2000, in contrast to CLOVER-II (see [chapter 3.29](#)), uses eight single carriers spaced 250 Hz with an individual duration of 2 ms (not in ascending frequency order), so the overall symbol rate is 62.5 Bd.

3.30.4 Channel Coding/Structure of Data Blocks

Reed-Solomon coding

3.31 CODAN 3012

3.31.1 General

Transmission method	CODAN 3012
Explanation of name	(Released by the Australian company CODAN Ltd.)
Other designations	CODAN CODAN 16 tone
Variants existing	CODAN 9001 CODAN 9002
Derived from method	
Typical users	United Nations, aid agencies and various public authorities in Australia and Africa Civilian and military usage
Kind of data	Computer-generated documents, Fax
Reference to standard	
Frequency band	HF
Modulation method	PSK4A

Transmission method	CODAN 3012
Shift/tone spacing	Minimum tone spacing 112.5 Hz
Baud rate	75 Bd per carrier, up to 16 carriers, so overall up to 1200 Bd Throughput up to 1475 bit/s (uncompressed data mode) Up to 6000 bit/s (compressed mode)
Modulating subcarrier	
Bandwidth	1680 Hz
Operating method	Half-duplex
Data protection	ARQ
Code table	

3.31.2 History

CODAN 3012 is a method released by the Australian company CODAN Ltd. together with their correspondent 3012 modem (the method denomination used here is directly derived from the modem name).

3.31.3 Description

CODAN 3012 is the denotation for a CODAN modem type. Usually the modem works in ARQ point-to-point mode, but it can also be used in a group call mode or a broadcast mode. The modem can use 4, 8, 12 or 16 subcarriers (table 3-9) whose burst length can vary from 2.5 s, 4.3 s, 6 s, 7.8 s, 9.6 s to 11.4 s for the data transmission. The minimum tone spacing is 112.5 Hz. The symbol rate of each carrier is always set to 75 Bd, and the modulation type is a differential quaternary phase shift keying (differential PSK4A, DQPSK). The modem can use an internal data compression for a better data throughput. Furthermore, the modem has a secure mode against interception (eavesdropping).

Table 3-9: Tones and frequencies.

Tone	1	2	3	4	5	6	7	8
Frequency [Hz]	656.25	768.75	881.25	993.75	1106.25	1218.75	1331.25	1443.75
Tone	9	10	11	12	13	14	15	16
Frequency [Hz]	1556.25	1668.75	1781.25	1893.75	2006.25	2118.75	2231.25	2343.75

3.32 CODAN 8580

3.32.1 General

Transmission method	CODAN 8580
Explanation of name	(Released by the Australian company CODAN Ltd.)
Other designations	CODAN-SELCAL (SE lective CA lling) CODAN 8580-SELCAL CCIR M493-4 compatible ITU-R M493-4 compatible
Variants existing	
Derived from method	GMDSS/DSC-HF
Typical users	
Kind of data	
Reference to standard	ITU-R Recommendation M.493-12 : " <i>Digital selective-calling system for use in the maritime mobile service</i> "
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	170 Hz
Baud rate	100 Bd
Modulating subcarrier	
Bandwidth	300 Hz
Operating method	Simplex, broadcast, asynchronous
Data protection	FEC
Code table	GMDSS/DSC (table 4-22 in chapter 4.8)

3.32.2 History

CODAN 8580 is a [SELCAL](#) method created by the Australian company CODAN Ltd. and utilized in their corresponding 8580 modem.

3.32.3 Description

The system follows very closely the GMDSS/DSC-HF method (see [chapter 3.48](#), "[GMDSS/DSC-HF](#)", on page 138) and therewith the [ITU-R M.493-12](#) standard.

Thus, the FSK2 modulation scheme together with the 100 Bd transmission speed are also found here, as is the usage of the GMDSS/DSC code table. Code words consist

of 7 bits coding each two-digit decimal number plus 3 bits indicating the number of '0' bits in these 7 bits, resulting in a complete word length of 10 bits. For details, see [chapter 4.8, "GMDSS/DSC Code Table"](#), on page 348.

Differences to GMDSS/DSC-HF arise in the format of the data frame. The frame, as known from there, is introduced by the dot pattern (again bit changes between '0' and '1', but of differing length) and the phasing preamble (synchronization sequence) formed by a fixed series of control characters. The data blocks of characters follow, slightly differing from the pattern known from GMDSS/DSC-HF ([figure 3-42 in chapter 3.48](#)).

Due to the company ownership of CODAN Ltd. of this method, no public documentation of it is available so far.

3.33 COQUELET-8

3.33.1 General

Transmission method	COQUELET-8			
Explanation of name	French for "cockerel", onomatopoeic description of the sound of the signal, 8 tones			
Other designations	COQ-8 COQUELET Mk II			
Variants existing				
Derived from method	COQUELET-13			
Typical users	Diplomatic services and customs			
Kind of data				
Reference to standard				
Frequency band	HF			
Modulation method	FSK: MTONE (MFSK)			
Shift/tone spacing	26.67 Hz			
Baud rate	Tone duration	37.5 ms	50 ms	75 ms
	thus "tone speed"	26.67/ s	20/s	13.33/s
Modulating subcarrier				
Bandwidth	190 Hz			
Operating method	Simplex, synchronous			
Data protection	None			
Code table	ITA-2 (table 4-2 in chapter 4.1.2)			

3.33.2 Description



Denotation

- **Tone n**

means the **tone (frequency) no. n** out of the underlying tone table, whereas

- **m-th tone**

denotes the **m-th (sent) tone** out of the transmitted tone sequence.

COQUELET-8 is an **MTONE (MFSK)** system designed in France. It is similar to Piccolo ([chapter 3.78, "Piccolo-6 \(MK 6\)"](#), on page 242) and translates an **ITA-2** (5-bit) character into a sequence of two tones.

The system is derived from COQUELET-13 ([chapter 3.34, "COQUELET-13"](#), on page 106). Like there,

- the 1st tone is selected from a stock of 8 tones,

but, in contrast,

- the 2nd tone is selected from the upper 4 of these same tones,

thus (only 8 instead of 13 tones required) reducing bandwidth consumption and, however, offering the feasibility to (in contrast to Piccolo) differ the 1st tone of a sequence from the 2nd tone unambiguously by statistics observations in the received signal. The frequency distance of the tones here is 26.67 Hz each.

When regarding the code table and tone assignment of COQUELET-8 ([table 4-25 in chapter 4.11, "COQUELET-8 Tone Table"](#), on page 354), it can be seen that the three **MSBs** (bit 4 to bit 2) only depend on the 1st tone and the two **LSBs** (bit 1 and bit 0) only on the 2nd tone, and thus the tone assignment shown in [table 3-10](#) results. However, be aware that this assignment might not be valid any longer if differing alphabets are in use (especially if not based on Latin letters, but on Greek, Arabic, Cyrillic etc.).

Table 3-10: Tone assignment in COQUELET-8.

Tone	Freq.	MSB		Bit		LSB	Tone	Freq.	MSB		Bit		LSB
		4	3	2	1	0			4	3	2	1	0
1st Tone													
0	773 Hz	0	0	0			4	880 Hz	1	0	0		
1	800 Hz	0	0	1			5	907 Hz	1	0	1		
2	826 Hz	0	1	0			6	933 Hz	1	1	0		
3	853 Hz	0	1	1			7	960 Hz	1	1	1		
2nd Tone													
4	880 Hz				0	0	6	933 Hz				1	0
5	907 Hz				0	1	7	960 Hz				1	1

For determining a baud rate, refer to [chapter 3.78](#). When no payload signals are to be processed, an idle sequence is transmitted, consisting of tones 0 and 7 sent alternately.

3.34 COQUELET-13

3.34.1 General

Transmission method	COQUELET-13		
Explanation of name	French for "cockere!", onomatopoeic description of the sound of the signal, 13 tones		
Other designations	COQ-13 COQUELET Mk I		
Variants existing	Tone table 0 and Tone table 1		
Derived from method			
Typical users			
Kind of data			
Reference to standard			
Frequency band	HF		
Modulation method	FSK : MTONE (MFSK)		
Shift/tone spacing	30 Hz		
Baud rate	Tone duration	50 ms	75 ms
	thus "tone speed"	20/ s	13.33/s
Modulating subcarrier			
Bandwidth	360 Hz		
Operating method	Simplex, asynchronous		
Data protection	None		
Code table	ITA-2 (table 4-2 in chapter 4.1.2)		

3.34.2 Description



Denotation

- **Tone n**

means the **tone (frequency) no. n** out of the underlying tone table, whereas

- **m-th tone**

denotes the **m-th (sent) tone** out of the transmitted tone sequence.

COQUELET-13 is an **MTONE (MFSK)** system designed in France. It is similar to Piccolo ([chapter 3.78, "Piccolo-6 \(MK 6\)"](#), on page 242) and translates an **ITA-2** (5-bit) character into a sequence of two tones.

13 tones (frequencies) are in use, they are divided in two (or three) groups:

- the 1st tone of a sequence is taken from the first group of 8 tones (tone 0 to tone 7),
- the 2nd tone from the second group of 4 tones (tone 9 to tone 12);
- a 13th frequency (tone 8, whether considered as a third group or not) forms an idle or start tone being transmitted if no payload data are to be processed.

The frequency distance of the tones is 30 Hz each. An unambiguous distinction of the 1st from the 2nd tone is easy this way, but the use of 13 tones entails consumption of a large amount of bandwidth.

When sorting the tone table of COQUELET-13 ([table 4-27](#) in [chapter 4.12, "COQUELET-13 Tone Table"](#), on page 355) according to the ITA-2 code table, it is evident that the 1st tone determines the 3 **LSBs** bit 2 to bit 0, and the 2nd tone the 2 **MSBs** bit 4 and bit 3. Two code tables are known to be defined, the bit assignment of both is shown in [table 3-11](#) together with the frequency values.

Table 3-11: Tone assignment in COQUELET-13.

Tone	Freq.	Table										Tone	Freq.	Table									
		0					1							0					1				
		M	Bit	L	M	Bit	L	M	Bit	L	M			Bit	L	M	Bit	L					
		4	3	2	1	0	4	3	2	1	0			4	3	2	1	0	4	3	2	1	0
1st Tone																							
0	812 Hz	1	1	1			1	1	1			4	932 Hz	1	0	1			1	0	0		
1	842 Hz	0	1	1			1	1	0			5	962 Hz	1	1	0			0	1	1		
2	872 Hz	0	0	1			0	1	0			6	992 Hz	0	1	0			1	0	1		
3	902 Hz	1	0	0			0	0	1			7	1022 Hz	0	0	0			0	0	0		
2nd Tone																							
9	1082 Hz			1	1				0	0		11	1142 Hz			0	1			0	1		
10	1112 Hz			1	0				1	1		12	1172 Hz			0	0			1	0		

Tone	Freq.	Table										Tone	Freq.	Table									
		0					1							0					1				
		M	Bit			L	M	Bit			L			M	Bit			L	M	Bit			L
		4	3	2	1	0	4	3	2	1	0			4	3	2	1	0	4	3	2	1	0
Idle or Start Tone																							
8	1052 Hz																						

For determining a baud rate, refer to [chapter 3.78](#).

3.35 COQUELET-80

3.35.1 General

Transmission method	COQUELET-80			
Explanation of name	French for "cockerel", onomatopoeic description of the sound of the signal, 8 tones, additional variant			
Other designations	COQUELET-8 FEC COQ-8 FEC			
Variants existing	COQUELET-80S COQUELET-82S			
Derived from method	COQUELET-8			
Typical users				
Kind of data				
Reference to standard				
Frequency band	HF			
Modulation method	FSK : MTONE (MFSK)			
Shift/tone spacing	26.67 Hz			
Baud rate	Tone duration	37.5 ms	50 ms	75 ms
	thus "tone speed"	26.67/s	20/s	13.33/s
Modulating subcarrier				
Bandwidth	190 Hz			
Operating method	Simplex, synchronous			
Data protection	FEC			
Code table	ITA-2 (table 4-2 in chapter 4.1.2)			

3.35.2 Description



Denotation

- **Tone n**

means the **tone (frequency) no. n** out of the underlying tone table, whereas

- **m-th tone**

denotes the **m-th (sent) tone** out of the transmitted tone sequence.

COQUELET-80 is an [FEC](#) variant of COQUELET-8 (see [chapter 3.33, "COQUELET-8"](#), on page 104) and thus derived therefrom. It is also a synchronous system and uses the same tone frequencies.

Error recognition is achieved the way that all tone sequences are transmitted twice, but with a delay in time. Like as explained in [chapter 3.88, "SITOR-B"](#), on page 268, a direct transmitting (**DX**) and a repeated transmitting (**RX**) level are distinguished, but, in contrast to SITOR-B, delay between direct and repeated transmission is 62, i.e. for example, sequence 1 and sequence 64 represent the same character. Additionally the RX tone sequence is not just equal to the unmodified DX sequence, but (not for the idle sequence) is calculated from the DX sequence with a modulo 8 method, in detail:

The tone numbers of the original sequence (counted from 0 to 7) are added and subjected to modulo 8 for the tone number of the first tone to repeat, and subtracted and subjected to modulo 8 for the tone number of the second tone to repeat, e.g.

DX tone sequence tones number 3 and 6:

$$3 + 6 = 9; \quad 9 \bmod 8 = 1$$

$$3 - 6 = -3; \quad -3 \bmod 8 = 5$$

Thus, RX tone sequence is tones number 1 and 5. All resulting RX tone sequences can be taken from [table 3-12](#).

Table 3-12: RX level tone sequences.

DX level 1st tone																	
	DX level 2nd tone									DX level 2nd tone							
	4		5		6		7			4		5		6		7	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd		1st	2nd	1st	2nd	1st	2nd	1st	2nd
0	4	4	5	3	6	2	7	1	4	0	0	1	7	2	6	3	5
1	5	5	6	4	7	3	0	2	5	1	1	2	0	3	7	4	6
2	6	6	7	5	0	4	1	3	6	2	2	3	1	4	0	5	7
3	7	7	0	6	1	5	2	4	7	3	3	4	2	5	1	6	0

3.36 DGPS

3.36.1 General

Transmission method	DGPS
Explanation of name	Differential Global Positioning System
Other designations	
Variants existing	
Derived from method	
Typical users	Widely spread usage: United States NDGPS (Nationwide DGPS): U.S. Department of Transportation (Federal Highway Administration, Federal Railroad Administration and National Geodetic Survey, Coast Guard) European DGPS Network: Maritime administrations, General Lighthouse Authorities (GLA; UK and Ireland)
Kind of data	Correction data for improvement of GPS satellite information due to atmospheric and delay conditions
Reference to standard	RTCM (Radio Technical Commission for Maritime Services) 10401.2: "Standard for Differential Navstar GPS Reference Stations and Integrity Monitors (RSIM)" RTCM paper 134-89/SC104-68: "RTCM Recommended Standards for Differential Navstar GPS Service 2.0" ITU-R Recommendation M.823-3: "Technical characteristics of differential transmissions for global navigation satellite systems from maritime radio beacons in the frequency band 283.5-315 kHz in Region 1 and 285-325 kHz in Regions 2 and 3" (transmission protocol) IEC 61108-4: "Maritime navigation and radiocommunication equipment and systems – Global navigation satellite systems (GNSS) – Part 4: Shipborne DGPS and DGLONASS maritime radio beacon receiver equipment – Performance requirements, methods of testing and required test results" (1st edition, July, 2004) (DGPS correction data receiver [beacon receiver]) IEC 61108-1: ditto, "Part 1: Global positioning system (GPS) – Receiver equipment – Performance standards, methods of testing and required test results" (2nd edition, July, 2003) (GPS receiver)
Frequency band	LW : 283.5 kHz to 315 kHz (Europe), 283.5 kHz to 325 kHz (other regions), in steps of 500 Hz
Modulation method	MSK
Shift/tone spacing	
Baud rate	100 Bd, 200 Bd, 300 Bd
Modulating subcarrier	
Bandwidth	160 Hz
Operating method	Simplex, broadcast

Transmission method	DGPS
Data protection	FEC
Code table	ITA-5 (ASCII) (table 4-9 and table 4-10 in chapter 4.2)

3.36.2 History

When GPS was first being put into service, a serious degradation was introduced to the signals available to public receivers, resulting in a lack of precision for the positioning, the remaining fuzziness being about 100 meters of distance. More accurate guidance was possible only for authorized users with encryption keys, normally restricted to military use.

This presented a problem for civilian users who relied upon ground-based radio navigation systems costing millions to be maintained each year. A global navigation satellite system could deliver enhanced quality at a fraction of the cost. But the military remained steadfast in its objection to all requests from Aviation Administration, Coast Guard, Department of Transportation and other institutions.

This led to considerations how to avoid the artificial degradation of the GPS signals. Because the disturbing signal was changed very slowly, the positioning offset caused by it was true for a relatively wide area, so GPS receivers with known location could measure the current offset and broadcast it to all local GPS receivers. This procedure could also compensate other GPS errors due to transmission delays in the ionosphere.

The U.S. Coast Guard finally established a DGPS broadcasting system in 1996, transmitting the correction signals on longwave frequencies; all major GPS vendors offered units with DGPS inputs, also for signals to be received in other bands like VHF or commercial AM radio bands.

In 2000 the disturbing signal (so-called SA, **S**elective **A**vailability) was turned off permanently, because it had been seen that the harm it caused to the U.S. was larger than its benefit. DGPS, however, remained established with GPS users, because elimination of the other errors mentioned (sharing the characteristics of the former SA signal like being true in a wide area and changing slowly over time) proved rather useful, the best implementations offering accuracies of under 10 cm.

3.36.3 Description

A reference station calculates differential corrections for its own location and time. Users may be up to 200 nautical miles (370 km) from the station, however, and some of the compensated errors vary with space: specifically, satellite ephemeris errors and those introduced by ionospheric and tropospheric distortions. For this reason, the accuracy of DGPS decreases with distance from the reference station. The problem can be aggravated if the user and the station lack "inter visibility" – when they are unable to see the same satellites.

DGPS data is mainly transmitted in the low frequency band, e.g. between 285 kHz and 315 kHz. Data, which is formatted according to RTCM (SC-104/Special Committee) Version 2.0 or 2.1, is continuously transmitted in frames consisting of a varying number

of data words. A data word has a length of 30 bits: 24 data bits and 6 parity bits. The first two words of each frame contain

- the reference station ID
- the message type
- a sequence number
- the frame length in words
- information about the health of data (if data are indicated as transmitted from a reference station not working properly at the moment, they cannot be used for navigation)

The last two bits of a word are used as an EXOR function for selected bits of the succeeding data word. The value of the last bit indicates whether the next data word is sent with inverse or normal polarity.

3.37 DPMR

3.37.1 General

Transmission method	DPMR
Explanation of name	Digital Private Mobile Radio
Other designations	dPMR Tier 1
Variants existing	dPMR446: Peer-to-peer mode only (unlicensed) dPMR Mode 1 to 3: For existing land mobile service (licensed)
Derived from method	
Typical users	Authorities and organizations with security concerns (emergency call services, public services, airports, ports) Professional mobile radio (industry, transportation, private safety enterprises) Private mobile radio (stockkeeping, retail trade) License-free radio (hotel and catering industry, personal radio service)
Kind of data	Voice and data applications

Transmission method	DPMR
Reference to standard	dPMR446: ETSI TS (Technical Specification) 102 490: "<i>Electromagnetic compatibility and Radio spectrum Matters (ERM); Peer-to-Peer Digital Private Mobile Radio using FDMA with a channel spacing of 6.25 kHz with ERP of up to 500 mW</i>" dPMR Mode 1 to 3: ETSI TS 102 658: "<i>Electromagnetic compatibility and Radio spectrum Matters (ERM); Digital Private Mobile Radio (dPMR) using FDMA with a channel spacing of 6.25 kHz</i>" Both comply to: ETSI EN (European Standard) 301 166-2: "<i>Harmonized European Standard (Telecommunications series) Electromagnetic compatibility and Radio spectrum Matters (ERM); Land Mobile Service; Radio equipment for analogue and/or digital communication (speech and/or data) and operating on narrow band channels and having an antenna connector; Part 2: Harmonized EN covering essential requirements of article 3.2 of the R&TTE (RTTE) Directive</i>"
Frequency band	VHF: 149.01875 MHz to 149.11875 MHz UHF: 446.100 MHz to 446.200 MHz
Modulation method	FSK4
Shift/tone spacing	700 Hz - 700 Hz - 700 Hz
Baud rate	2400 Bd (data rate 4800 bit/s)
Modulating subcarrier	
Bandwidth	6.25 kHz
Operating method	Simplex, half-duplex, broadcast, asynchronous
Data protection	FEC: shortened Hamming code (12,8) with polynomial $g(x) = x^4 + x + 1$, interleaving, scrambling
Code table	

3.37.2 History

dPMR is a fully digital radio standard developed by the European Telecommunications Standards Institute (ETSI). The goal was to establish an open (not restricted to a special structure of data) standard to be operated in the available frequency bands of analog radio (12.5 kHz channel bandwidth), i.e. to enjoy the benefits of digital transmission inside existing frequency structures.

3.37.3 Description

3.37.3.1 Scope

dPMR, similar to NXDN ([chapter 3.70, "NXDN"](#), on page 211), uses a narrowband channel architecture capable to accomodate two transmission channels of 6.25 kHz in one channel (12.5 kHz) of the former analog frequency raster. Division is done in the

conventional [FDMA](#) way; modulation is [FSK4](#) (conveying 2 bits [1 dibit] per transmission symbol).

dPMR is supported by European standards, whereas NXDN is preferably used in North and South America.

Occasionally, dPMR446 ([3.37.3.2](#), "dPMR446") is also denoted as "dPMR Tier 1", whereas dPMR modes 1 to 3 ([3.37.3.3](#), "dPMR Mode 1" to [3.37.3.5](#), "dPMR Mode 3") are summarized as "dPMR Tier 2".

3.37.3.2 dPMR446

dPMR446 is the simplest form of dPMR, only peer-to-peer mode (operation from one mobile radio to another) without any base station or repeater is permitted ([figure 3-31](#)). A license is not needed; from that, some limitations apply, comparable to the analog equivalent [PMR446](#). Hence, radio power to be emitted is 0.5 W maximum and only handheld sets may be used.

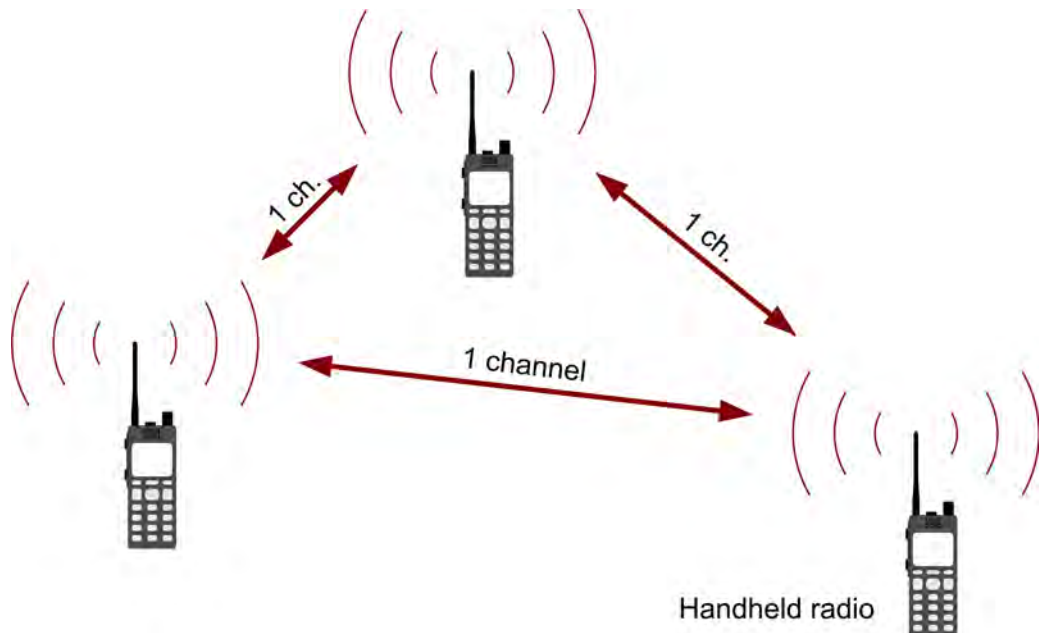


Fig. 3-31: dPMR446 configuration.

Speech and data modes are offered by dPMR446 (also combinable), this is, embedding of data information in speech messages or automatic appending it after end of a speech call are possible. [SMS](#) services, [GPS](#) data or text messages with status informations can be conveyed this way.

Simplified addressing modes, comparable for instance to CTCSS (Continuous Tone Coded Subaudio Squelch/Continuous Tone Coded Squelch System) (as with [PMR446](#)), or also enhanced addressing modes as with fully equipped dPMR are in use.

3.37.3.3 dPMR Mode 1

dPMR Mode 1 may be considered as enhanced dPMR446 mode, i.e. it is still a peer-to-peer mode (no base stations or repeaters), but without the limitations mentioned (no restrictions on radio power and also other radios permitted than only handhelds). This allows functions to be offered like emergency calls, priority calls, interrupts etc. See [figure 3-32](#) for an example configuration.

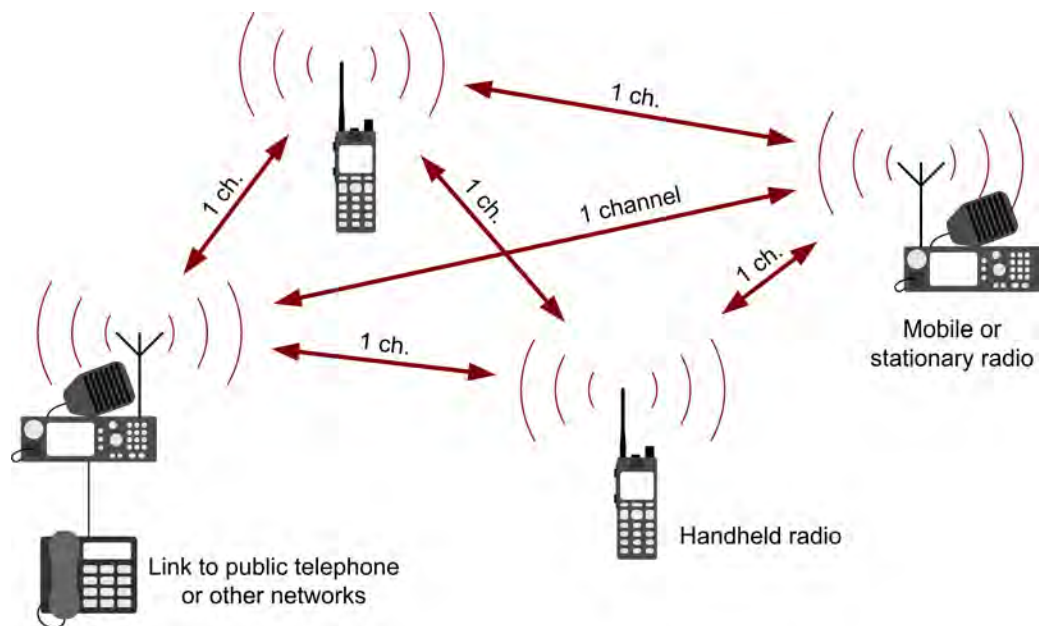


Fig. 3-32: dPMR mode 1 configuration.

A dPMR Mode 1 radio may communicate without any problem with a dPMR446 radio if the parameters of both, frequency channel, Colour Code (representing the frequency channel) and addressing mode, are programmed in agreement.

3.37.3.4 dPMR Mode 2

With dPMR Mode 2, use of repeaters and other infrastructure is added; an example is shown in [figure 3-33](#). This enables supplementary functionality, especially interfaces to networks foreign to the dPMR system in use can be established. Simple analog interfacing as well as IP based protocols are possible. With that, coverage areas are enlarged dramatically, even more if several repeaters are deployed.

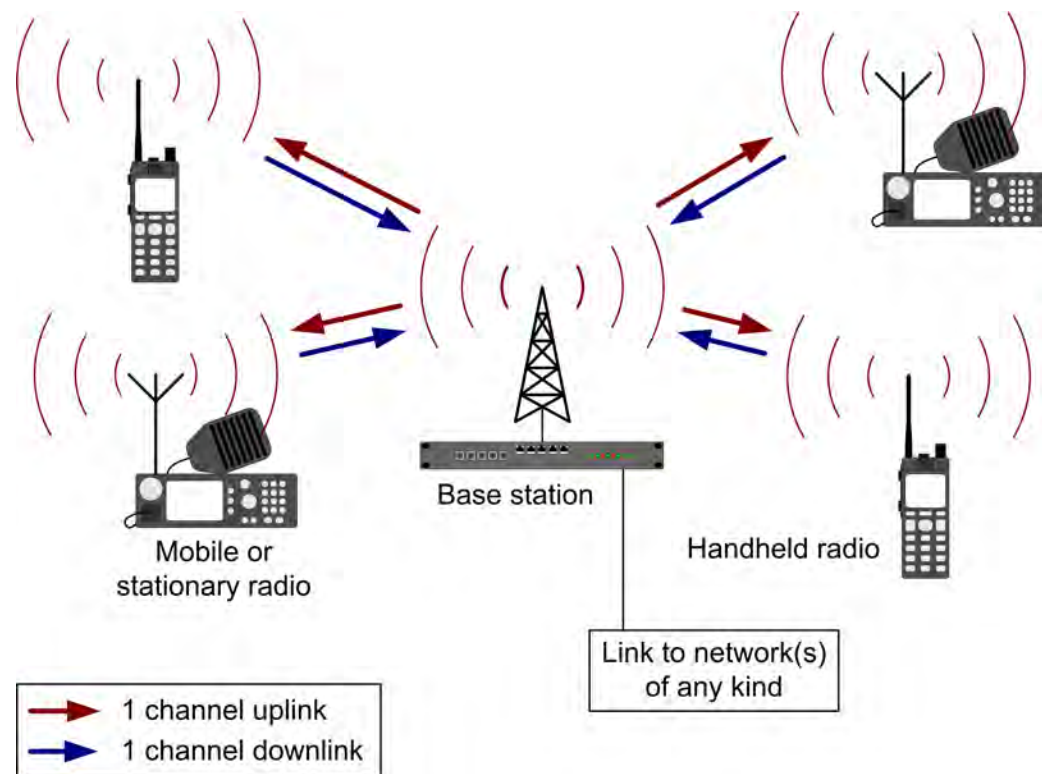


Fig. 3-33: dPMR mode 2 configuration.

Administration of these repeaters may be done by dynamic channel selection or also by a special function offered with dPMR Mode 2.

Thus, connectivity beyond the wireless part of the network allows involving of (e.g. PC based) remote terminals at other sites (offices, divisions, countries), therefore remote controlling a repeater or a base station from a fixed network termination.

3.37.3.5 dPMR Mode 3

Multichannel-multisite radio networks are offered by dPMR Mode 3, the frequency allocation of which is done dynamically (trunked radio system). Administration is performed by specific control channels at each site of the network. Optimum utilization of the available frequency band (enhanced density of radio traffic) is achieved this way. In [figure 3-34](#) an example of a configuration is given.

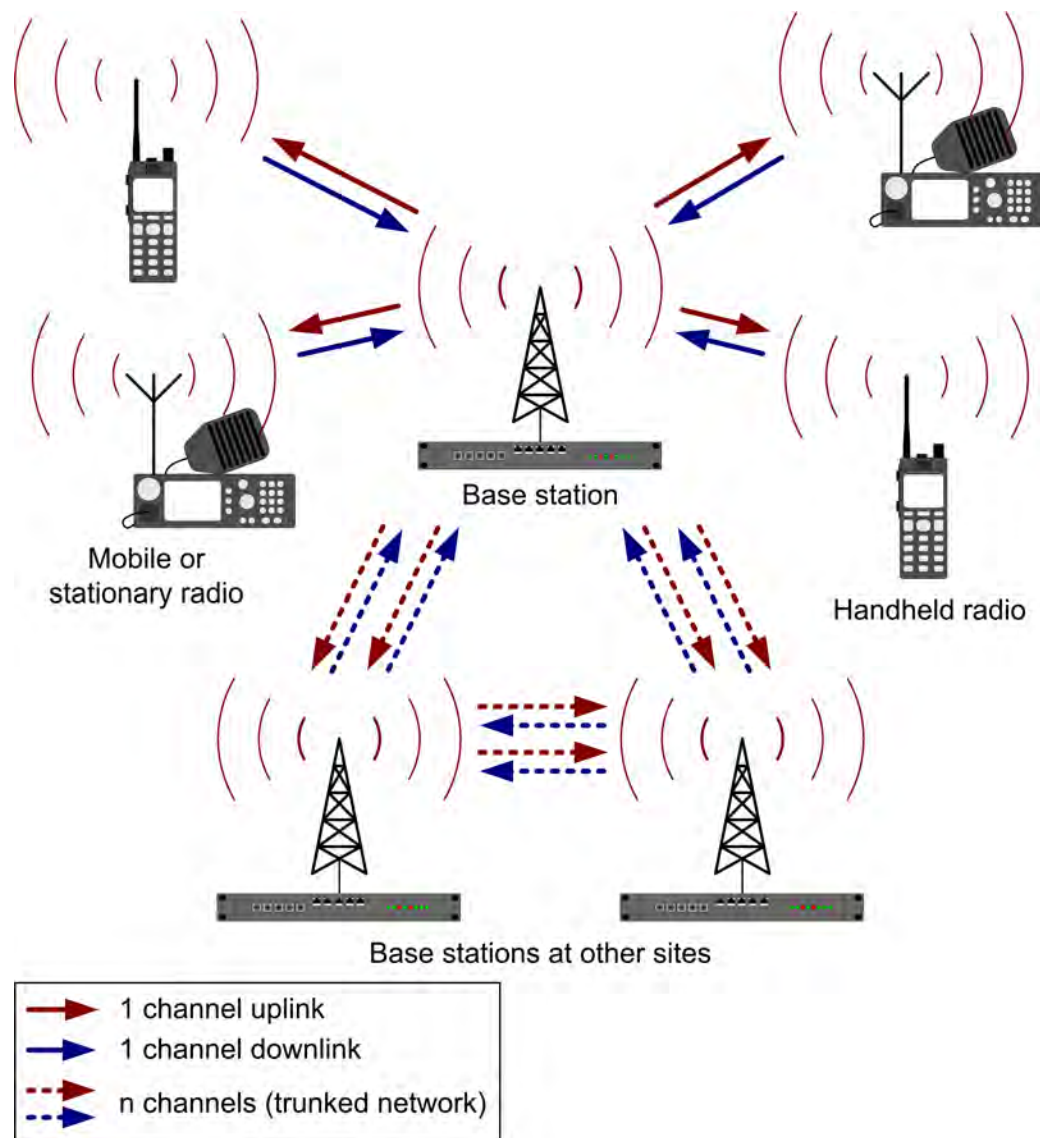


Fig. 3-34: dPMR mode 3 configuration.

Two radios wishing to be connected are authenticated, then linked together by the infrastructure, independent whether both belong to the same or different sites of the complete network. Routing calls alternatively to landlines or even IP addresses is also possible. Priority and emergency calls may be handled, and so are waiting lines for calls not being allocated a frequency channel immediately.

3.37.3.6 Voice Codec

dPMR as a fully digital radio system does not convey analog speech signals (e.g. arising from other networks connected); thus these signals are to be converted to digital domain (and re-converted to analog after transmission). This process is done by the voice codec (vocoder). Due to several realizations of vocoder technologies existing it is essentially important that converting and re-converting vocoders are of the same type.

The vocoder most often used with dPMR is the *AMBE+2*[®] (Advanced Multi Band Excitation), which applies an improved and advanced multiband excitation (MBE) method. It was developed by *Digital Voice Systems, Inc. (DVS)*. See a scope of properties in [chapter 3.70, "NXDN"](#), on page 211 and detailed specifications in *AMBE+2* technical documents by *DVS*.

Some other vocoders have been tested and approved; see details from "dPMR Mou tech.lib-Voc Bits-v1" (dPMR MoU Vocoder Selection, September 16, 2009).

3.37.3.7 Frame Structure

An overview of the frame structure with dPMR is shown in [figure 3-35](#). The most important types of frames are

- Header frame
- Superframe
- Payload frame
- End frame

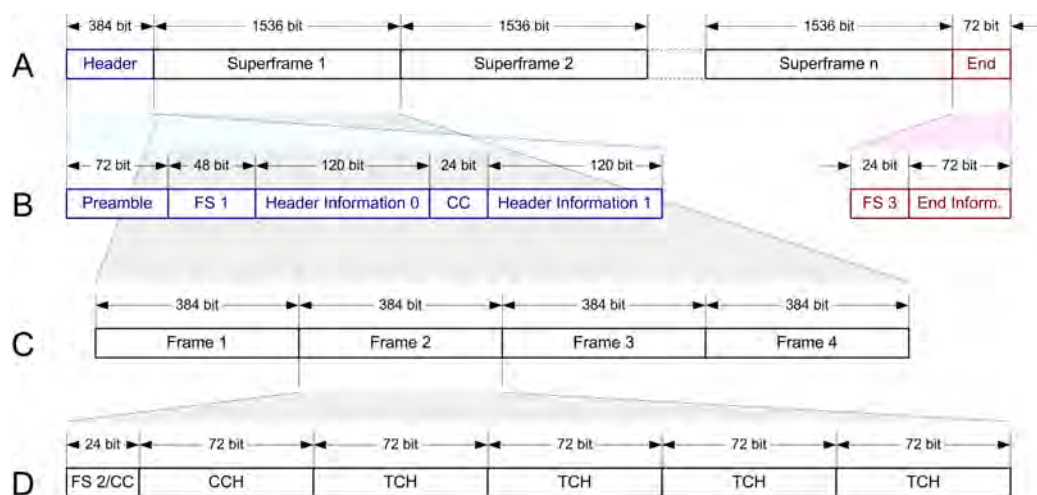


Fig. 3-35: dPMR frame structure.

- A = Transmission sequence
 B = Header (left) and End frame (right)
 C = Superframe
 D = Payload frame
 FS = Frame Sync; FS 1: Header, FS 2: Frame 1 and Frame 3, FS 3: End
 CC = Colour Code: Header, Frame 2 and Frame 4
 CCH = Control Channel
 TCH = Traffic Channel

Transmissions (**A** in [figure 3-35](#)) are always started with a **Header frame** (**B**, left) containing a Preamble (for bit synchronization), a Frame Sync (for frame synchronization), a so-called Colour Code (information of the occupied frequency channel) and two Header Information blocks (header type, station ID etc.). The **End frame** (**B**, right) also has a Frame Sync section and additionally an End information block.

The Header frame is followed by a series of **Superframes** (**C**) that contain both the payload (voice or data) and the information about the call such that receiving stations

can implement late entry. A call always consists of an integral number of Superframes and is terminated by an End frame.

A Superframe itself is made up of always four **payload frames (D)** of 384 bit or 80 ms length each (1536 bit or 320 ms Superframe length). One payload frame contains

- a 24-bit section with
 - Frame Sync (Frame 1 and Frame 3 of the Superframe) or
 - Colour Code (Frame 2 and Frame 4)
- the 72-bit Control Channel (CCH, created by a channel coding process from originally 41 control bits)
- four 72-bit Traffic Channel (TCH) sections (with the actual information to transmit)

More detailed informations of architecture and contents of the frames can be found in technical specification ETSI TS 102 490.

3.37.3.8 Communication Modes and Channel Coding

Several communication modes exist:

- **Voice communication** only (no user data in SLD¹⁾ field)
- **Voice and slow data** (user data in SLD field)

In voice communication modes, a special data protection (channel coding) is not defined in the specification (except for the CCH which is always channel coded as told in 3.37.3.7, "Frame Structure"). The four TCHs, however, commonly are already forward error corrected by the voice codec (in any case by the *AMBE+2*, see 3.37.3.6, "Voice Codec"); in the current process step they are merely appended to the CCH without modification. A final scrambling process is applied only to the CCH.
- **Data communication type 1** (payload is user data without FEC)

As with voice communication, the data communication type 1 also just adds the payload data delivered in packets of 288 bits (representing all 4 TCHs together) without additional treatment; the user has to look after suitable channel coding to his data himself. Final scrambling, however, is extended to a complete frame (but without the FS/CC field).
- **Data communication type 2** (payload is user data with FEC)

Type 2 data communication mode splits the payload data into packets of 40 bits, adds one zero bit and subjects the resulting 41-bit data to the channel coding process also applied to the CCH; 72 bits are delivered. Again, the 360 bits of the complete frame without FS/CC are scrambled.
- **Data communication type 3** (packet data, ARQ method)

Type 3 is the packet data mode, it uses a data structure different from the frame/superframe architecture described above. Data have to be channel coded from outside in advance, but scrambling is now performed for a length of 1 to 4 frames. See the technical specification for more information.
- **Voice and appended data** (type 2).

- ¹⁾ The Communications Mode (M) field in the CCH of each frame tells the communication mode currently active. The Slow Data (SLD) field (also with the CCH) can carry 2 bytes of user data (e.g. in data communication modes indicating the data format, type etc.)

3.37.3.9 Principle of Operation

An example of a conventional payload continuous transmission (voice or data) is shown in figure 3-36.

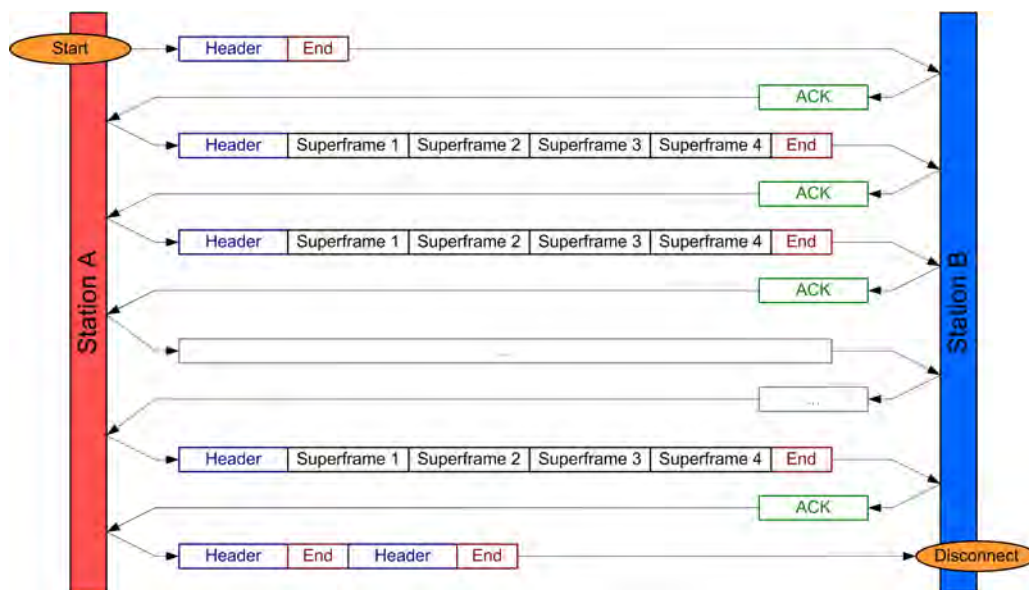


Fig. 3-36: dPMR payload transmission.

The call is set up by emitting a Header/End frame combination by Station A, Station B then confirms with an **ACK** frame (a frame of type Header), after that normal transmission of the payload data in the packets described in 3.37.3.7, "Frame Structure" can begin. Terminating the transmission is done by a Disconnection request: a repeated Header/End pair.

Again, consult ETSI TS 102 490 for more information, also about all aspects of channel coding: **FEC**, interleaving, scrambling.

3.38 DTMF

3.38.1 General

Transmission method	DTMF
Explanation of name	D ual- T one M ulti- F requency Signaling
Other designations	MFV (M ehr F requenz w ahl V erfahren) MFC (M ehr F requenz C ode) Touch Tone MF4 (M ulti- F requency, 4 tones)
Variants existing	
Derived from method	
Typical users	Telecommunication signaling over analog telephone lines in the voice-frequency band between telephone handsets and other communications devices and the switching center Mobile radios supporting selective calling
Kind of data	Sinusoidal two-frequency tones, pulse duration > 40 ms (typically 70 ms), pause 20 ms to 50 ms, frequencies dependent on pressed dial key
Reference to standard	ITU-T Recommendation Q.23 : " <i>Technical Features of Push-Button Telephone Sets</i> "
Frequency band	VHF/UHF (signaling in voice-frequency band), two 4-frequency sets - lower 697 Hz, 770 Hz, 852 Hz, 941 Hz - upper 1209 Hz, 1336 Hz, 1477 Hz, 1633 Hz
Modulation method	Indirect FM
Shift/tone spacing	
Baud rate	
Modulating subcarrier	
Bandwidth	12.5 kHz
Operating method	Simplex
Data protection	
Code table	

3.38.2 History

DTMF as used for push-button telephone tone dialing was known throughout the *Bell System* by the trademark Touch-Tone. This term was first used by *AT&T Inc. (American Telephone & Telegraph Corporation)* in commerce on July 5, 1960 and then was introduced to the public on November 18, 1963. It replaced the pulse dialing in use until then.

3.38.3 Description

The intention to use phones to access computers led to the addition of

- the number sign (#) key
- the asterisk or "star" (*) key
- a group of keys for menu selection: **A**, **B**, **C** and **D**

(Today the lettered keys were dropped from most phones, and it was many years before these keys became widely used for **VSCs** (**V**ertical **S**ervice **C**odes) – such as "*67" in the United States and Canada to suppress caller **ID**.) From this reason, the DTMF keypad is laid out in a 4×4 matrix, with each row representing a low frequency, and each column representing a high frequency ([table 3-13](#)). Pressing a single key (e.g. **1**) will send a sinusoidal tone for each of the two frequencies (e.g. 697 **Hz** and 1209 **Hz**). The original keypads had levers inside, so each button activated two contacts. The multiple tones are the reason for calling the system multifrequency. These tones are then decoded by the switching center to determine which key was pressed.

Table 3-13: Keypad frequencies.

	1209 Hz	1336 Hz	1477 Hz	1633 Hz
697 Hz	1	2	3	A
770 Hz	4	5	6	B
852 Hz	7	8	9	C
941 Hz	*	0	#	D

3.39 DUP-ARQ

3.39.1 General

Transmission method	DUP-ARQ
Explanation of name	DUP lex operation, A utomatic R epeat r e Q uest
Other designations	ARQ DUPLEX ARTRAC 125-ARTRAC
Variants existing	
Derived from method	
Typical users	Diplomatic services
Kind of data	
Reference to standard	
Frequency band	HF

Transmission method	DUP-ARQ
Modulation method	FSK2
Shift/tone spacing	Shift 170 Hz, spacing 400 Hz
Baud rate	125 Bd
Modulating subcarrier	
Bandwidth	375 Hz
Operating method	Half-duplex, synchronous
Data protection	FEC, ARQ
Code table	ITA-2 (table 4-2 in chapter 4.1.2)

3.39.2 Description

DUP-ARQ is a high-sophisticated transmission system using half-duplex operation mode with ARQ and additionally FEC error protection. It is capable to observe the current level of interference as well as to follow the prediction of propagation conditions and to select the optimum conveying channel accordingly. Character error rates achieved this way underrun 10^{-5} (typically 10^{-7}).

DUP-ARQ works with frequency bands allocated in advance (eight maximum), each band consisting of 5 discrete frequencies (channels) spaced at 400 Hz, the shift is always 170 Hz or ± 85 Hz around the channel center frequency. Propagation predictions can be entered, each of them uses ranking-lists for the bands to be used. These ranking lists are kept up-to-date during normal operation, aiming to hit best transmission conditions at any time.

The system is operated (see figure 3-37) in a fixed timing pattern (**A**), formed by a 256 ms (32-bit) transmission sequence (Tx cycle) and an acknowledge sequence (the receiving station confirms correct reception or requests repetition of erroneous data) of equal length, both separated from each other by two pause periods of 96 ms (all together, seen from the transmitting station, is summarized as Rx cycle). In use is the ITA-2 code table (5 bits per character);

- 5 characters make up a frame (**B**) and are completed by
- a single additional bit (bit 16 in the figure, simply the inverted bit 17),
- 5 bit Hamming checksum (bits 1 to 5) and
- a parity bit (bit 0) comprising all other 31 bits (so-called Hamming code with additional parity),

resulting in a length of the entire frame of 32 bit. Before transmission, the whole 32-bit sequence is mirrored, thus reversing the order of the frame (first bit to send is bit 0). The baud rate of 125 Bd (8 ms per bit) leads to the frame duration of 256 ms.

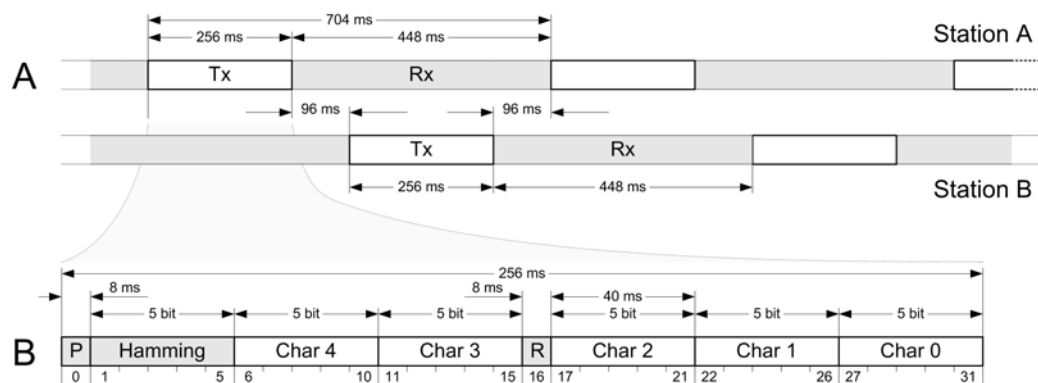


Fig. 3-37: Timing with DUP-ARQ.

A = timing diagram between two stations

B = frame with 32 bit

P = overall parity bit

R = additional bit: inverted bit 17

This code is able to correct 1-bit errors and to recognize 2-bit errors (Hamming distance of 4) or, alternatively, to recognize all errors up to 3 bits. Hence, an ARQ-and-FEC mode or a pure ARQ mode may be used on demand, the former giving a slightly better throughput, the latter an optimum reliable link.

For operation in multistation networks, DUP-ARQ has extensive feasibilities for establishing and maintaining calls, including selective call ([SELCAL](#)) features with the possibility to change SELCAL codes periodically without disclosing to the operating staff, e.g. for security reasons. Calls emitted by a station intending to send consist of special data blocks:

- Call blocks containing the SELCAL code of the addressed station
- Identification blocks containing the identity of the calling station and frequency information of best reception of the calling station
- [RQ](#) (odd or even) blocks for establishing synchronization between the transmit and receive periods of the two stations

After an RQ block, the called station answers with an answer block if there is a suitable channel (the call could be heard) – if not, the calling station tries the next channel of the frequency band and, if necessary, further bands. If establishing of a connection was unsuccessful, some minutes later a new call will be made.

During idle condition, DUP-ARQ performs scanning cycles consisting of

- Searching for possible calls
- Testing (measuring) state of interference, helping to determine the best channel to receive

3.40 DUP-ARQ2

3.40.1 General

Transmission method	DUP-ARQ2
Explanation of name	DUP lex operation, A utomatic R epeat r e Q uest, 2 nd version
Other designations	ARTRAC II 250-ARTRAC
Variants existing	
Derived from method	DUP-ARQ
Typical users	
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	Shift 170 Hz , spacing 400 Hz
Baud rate	250 Bd
Modulating subcarrier	
Bandwidth	520 Hz
Operating method	Synchronous, half-duplex
Data protection	FEC , ARQ
Code table	ITA-2 (table 4-2 in chapter 4.1.2) ITA-5 (ASCII) (table 4-9 and table 4-10 in chapter 4.2)

3.40.2 Description

DUP-ARQ2 is an enhancement of DUP-ARQ ([chapter 3.39, "DUP-ARQ"](#), on page 122). Characteristics of the system are to a large extent congruent, but DUP-ARQ2 operates (see [figure 3-38](#)) with 250 [Bd](#) (twice as much as the 125 [Bd](#) of DUP-ARQ), allowing transmission of 64 bit (2 frames) per [Tx](#) period (**A** and **B** in the figure). Alphabets in use are [ITA-2](#) and also [ITA-5 \(ASCII\)](#); in the [ITA-2](#) case, frame build-up is the same as with DUP-ARQ (case **C**), whereas [ITA-5](#) is covered by conveying three 8-bit characters in one frame (case **D**). Two bits (bit 6 and bit 7) are not needed, they are set to zero (except in Idle state or with other special functions); again, the 5-bit Hamming checksum (bit 1 to bit 5) is calculated, an overall parity bit (bit 0) added and the whole 32-bit sequence mirrored.

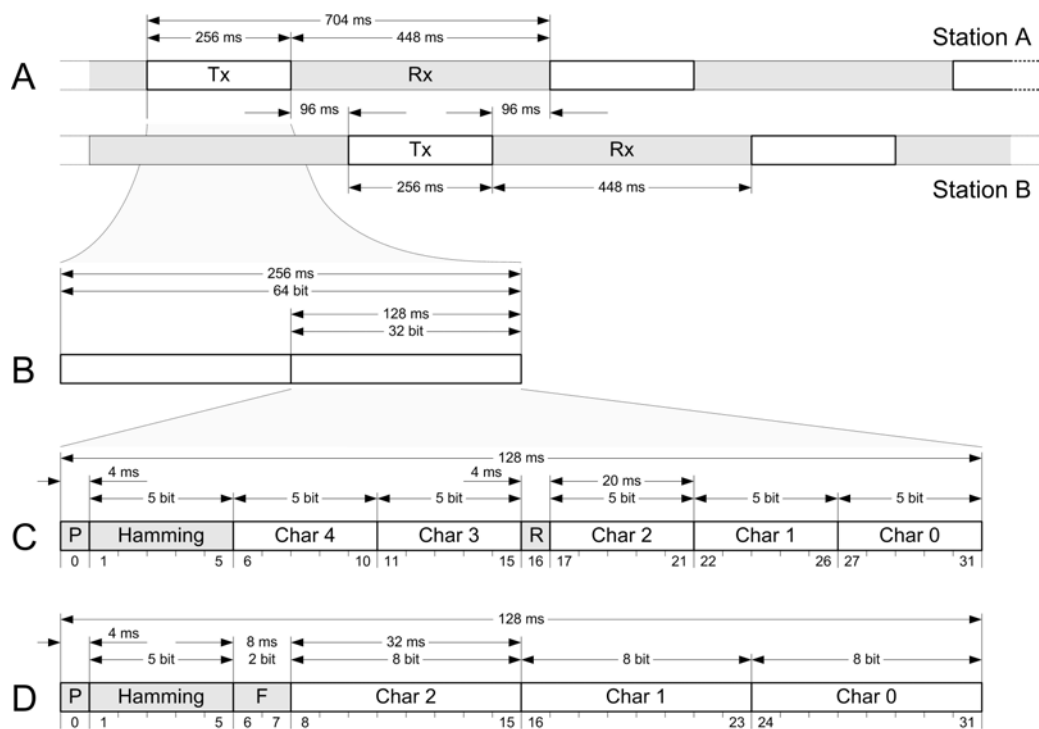


Fig. 3-38: Timing with DUP-ARQ2.

A = timing diagram between two stations
 B = twin frame with 64 bit
 C = 32-bit frame with 5 ITA-2 (5-bit) characters
 D = 32-bit frame with 3 ITA-5 (8-bit) characters
 P = overall parity bit
 R = additional bit: inverted bit 17
 F = always zero

3.41 DUP-FEC2

3.41.1 General

Transmission method	DUP-FEC2
Explanation of name	DUPlex operation, Forward Error Correction, 2nd version
Other designations	DUP-FEC
Variants existing	
Derived from method	DUP-ARQ2
Typical users	
Kind of data	
Reference to standard	

Transmission method	DUP-FEC2
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	Shift 170 Hz, spacing 400 Hz
Baud rate	125 Bd, 250 Bd
Modulating subcarrier	
Bandwidth	1150 Hz
Operating method	Duplex, synchronous
Data protection	FEC, ARQ
Code table	ITA-2 (table 4-2 in chapter 4.1.2) ITA-5 (ASCII) (table 4-9 and table 4-10 in chapter 4.2)

3.41.2 History

DUP-FEC2 is a further development of the DUP-ARQ2 system (chapter 3.40, "DUP-ARQ2", on page 125), and system characteristics are very similar.

3.41.3 Description

DUP-FEC2 is the FEC (broadcast) variant of both DUP-ARQ (chapter 3.39, "DUP-ARQ", on page 122) and DUP-ARQ2, i.e. baud rates supported are both 125 Bd and 250 Bd. The data frame shape (including error protection mechanism) is the same, cf figure 3-37 in chapter 3.39 and figure 3-38 in chapter 3.40, but, due to full-duplex and synchronous operation method, there is no Tx and Rx period any longer, thus frames are transmitted consecutively. A differentiation between 32-bit frames and 64-bit frames (two 32-bit frames concatenated) hence is no longer possible.

Although the name "FEC" might suggest a full error-correcting system (no necessity of ARQ sequences), block repetitions (RQ) can be requested by special sequences, however. In case of 125 Bd, the last two 32-bit blocks are retransmitted, and the last three with 250 Bd. Many special IDLE and RQ blocks are available with DUP-FEC2, as are with DUP-ARQ and DUP-ARQ2.

3.42 F7B

3.42.1 General

Transmission method	F7B
Explanation of name	F : frequency modulation, 7 : multichannel digital signal, B : telegraphy, automatic reception (data elements fixed in quantity and duration), according to ITU recommendation – Frequency-Shift-Keying, automatic telegraphy
Other designations	
Variants existing	
Derived from method	
Typical users	
Kind of data	Teletype
Reference to standard	ITU-R Recommendation SM.1138: " <i>Determination of Necessary Bandwidths including Examples for their Calculation and Associated Examples for the Designation of Emissions</i> "
Frequency band	HF
Modulation method	FSK4 (FSK2 on 2 independent channels)
Shift/tone spacing	100 Hz to 500 Hz
Baud rate	50 Bd to 150 Bd
Modulating subcarrier	
Bandwidth	(Universal method)
Operating method	Simplex, broadcast
Data protection	
Code table	

3.42.2 Description

The F7B method deals with signals consisting of two independent, but synchronous channels carrying teletype signals.

TWINPLEX ([chapter 3.97](#), "[TWINPLEX-BAUDOT](#)", on page 297 and [chapter 3.98](#), "[TWINPLEX-SITOR](#)", on page 298) also uses two channels, but applies fixed frames and does a distribution of the original channel data onto the transmission channels in accordance with laid down rules; thus, an F7B decoder can also be used for TWINPLEX methods.

F7B is closely related to F7W ([chapter 3.43](#), "[F7W](#)", on page 129), with the difference that in F7W the two independent channels need not be synchronous.

3.43 F7W

3.43.1 General

Transmission method	F7W
Explanation of name	F : frequency modulation, 7 : multichannel digital signal, W : mixed information, according to ITU recommendation – Frequency-Shift-Keying, 2 independent channels
Other designations	
Variants existing	
Derived from method	
Typical users	
Kind of data	Morse, Teletype
Reference to standard	ITU-R Recommendation SM.1138: " <i>Determination of Necessary Bandwidths including Examples for their Calculation and Associated Examples for the Designation of Emissions</i> "
Frequency band	HF
Modulation method	FSK4 (FSK2 on 2 independent channels)
Shift/tone spacing	100 Hz to 500 Hz
Baud rate	50 Bd to 150 Bd, in case of Morse signals 4 Bd to 40 Bd
Modulating subcarrier	
Bandwidth	800 Hz
Operating method	Simplex, broadcast
Data protection	
Code table	

3.43.2 Description

The F7W method deals with signals consisting of two independent asynchronous channels carrying either Morse or teletype signals (combination of signals on both channels arbitrary). Recognition of signal type may take place manually or automatically. In case of both channels carrying the same signal type (Morse or teletype) just one of them can be decoded at a time.

3.44 FEC-A

3.44.1 General

Transmission method	FEC-A
Explanation of name	Forward Error Correction
Other designations	FEC-100 FEC-101 FEC-100A
Variants existing	
Derived from method	
Typical users	Press, diplomatic services
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	Variable (usually 400 Hz)
Baud rate	96 Bd, 144 Bd, 192 Bd, 288 Bd or 384 Bd
Modulating subcarrier	
Bandwidth	780 Hz
Operating method	Synchronous, simplex
Data protection	FEC (convolutional code with code rate 1/2)
Code table	ITA-2P (ARQ-1A) (table 4-6 in chapter 4.1.5)

3.44.2 Description

3.44.2.1 Convolutional Codes

A convolutional code is a code that no longer (like as with block codes) is formed blockwise, i.e. a block of information bits is translated to another (commonly longer) block of code bits, but is coded by a coding architecture similar to a digital filter. Hence, bits made use of in the past influence also the code series in the present and future, in other words: coding is performed with "memory". This coding architecture may be recursive (a special bit influences future coding forever, so-called IIR filter structure) or non-recursive (a special bit terminates its influence onto future code after having passed through the complete structure length, so-called FIR structure).

Equivalent descriptions exist using generator polynomials; this is not dealt with here in detail, refer to relevant publications for more information.

In [figure 3-39](#) the scenario for the non-recursive case is explained: A shift register (the simplified – only binary, i.e. modulo 2, multiplying and adding – form of the FIR filter) transforms the information bit series u_i into a code bit series $c_i^{(j)}$.

- Case **A** shows a single branch ($j=1$) of a coding register, i.e. an incoming bit u_i produces just one code bit c_i in clock cycle i . The shift register length is l , so the c_i bit is formed by u_i itself and the last l bits u_{i-1} to u_{i-l} , weighted by the "filter coefficients" (weight factors) g_0 to g_l .
- If an information bit is to produce more than one code bit (if serial transmission is kept up, an according acceleration of clock rate follows), more than one shift register branches ($j>1$) have to be supplied; case **B** shows this for a branch count of $j+1$ (producing code bits $c_i^{(0)}$ to $c_i^{(j)}$).
- Generally shift registers are used with just a few taps after some special positions (all g factors are zero except the ones in question), this case is told in **C** in the figure for an example of a 16-position shift register with tapplings after bit 15, bit 12, bit 10, bit 4 and bit 0 (note that the latter tap is always used because it determines the register length) (upper section, shown in red). Additionally a second branch is available using different tapplings after bit 14, bit 11, bit 9, bit 6 and bit 0 (lower section, shown in blue), the output rotary switch produces the final code to be conveyed. This is a very common and often used architecture.
If, as a special case of **C**, the only tapping would take place before bit 15, i.e. the input bit u_i be unmodifiedly guided to the output (lower section, shown in green), the result would be that the original code is obtained there and the c_i bit(s) produced form an additional [FEC](#) information that can be utilized by setting the output switch accordingly.

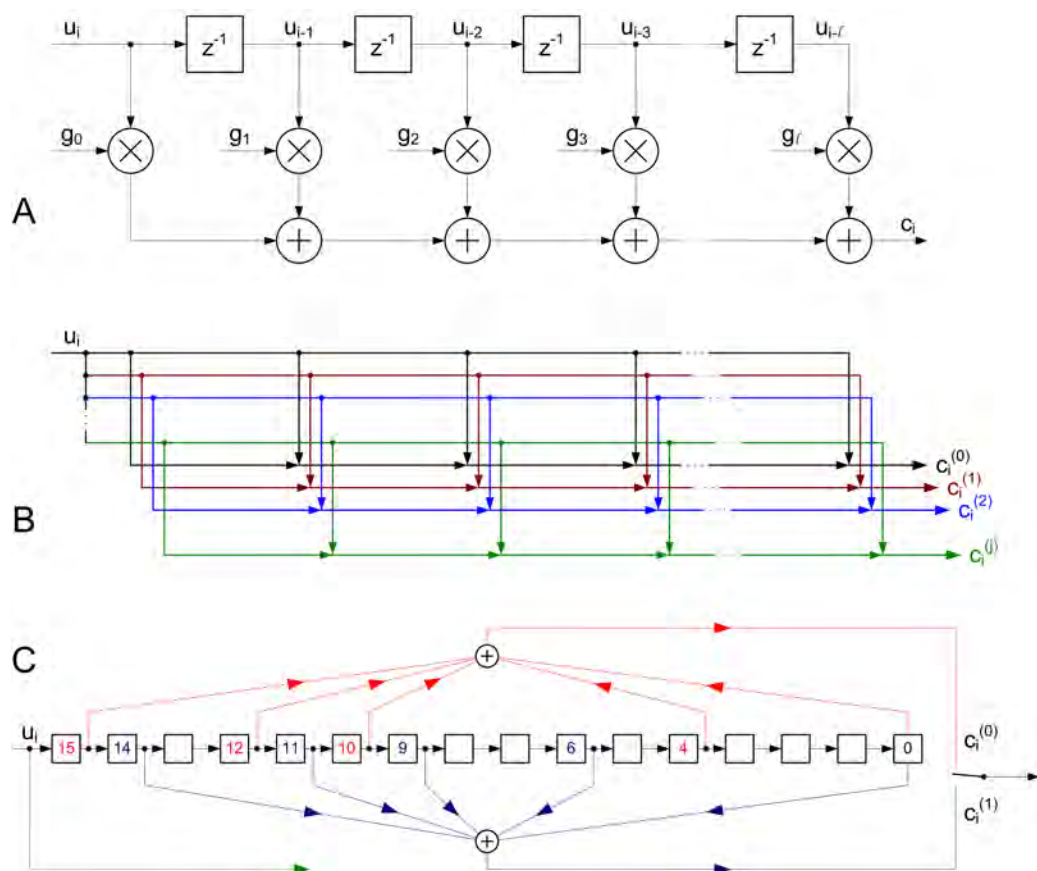


Fig. 3-39: Convolutional coding.

A = Principle: non-recursive shift register, 1 output bit per input bit

B = $j+1$ output bits per input bit

C = Shift register with taps after several positions, additional branch for uncoded input

3.44.2.2 FEC-A Characteristics

FEC-A is a method developed by *Siemens* of Germany. It is a simplex system, i.e. no backward channel is provided, thus the system is preferentially suitable for one-way applications. These can be operated in broadcast mode or also with calling facilities such as individual subscriber station call (up to 17575 stations) or group call (up to 676 groups, each with up to 26 individual stations).

As explained in the previous section, the transmitter derives error correction information from the original message information; a shift register is tapped after some special positions and therefore delivers one FEC bit per information bit (50 % redundancy, thus doubling of the code rate). The unmodified message text and the error correction bits are transmitted in bitwise alternate succession: first the information bit, then the according FEC bit, and so on. On the receiving side, a decoding structure similar to the one encoding may be used to check the incoming data for errors and to correct them if necessary.

Alternative methods operate with probability decoding: the most popular and often used one is Viterbi decoding applying Trellis diagrams, another one Fano decoding.

Complexity required by these methods drops considerably, especially when register lengths in use are not too long. Again, for detailed information refer to relevant publications.

In use is the ITA-2P (or ARQ-1A, [table 4-6](#) in [chapter 4.1.5, "ITA-2P Code Table"](#), on page 330) code table. Its 7-bit characters are formed from the 5-bit ITA-2 characters by prefixing a synchronous bit (always zero except with some special control signs) and affixing a parity bit giving odd parity for the resulting character word. These characters are upgraded by the check bits in the way explained.

The standard shift register lengths that have been observed are 218 bits, 128 bits and 72 bits, the tap positions may vary in the individual systems. This issue is denoted in [figure 3-40](#).

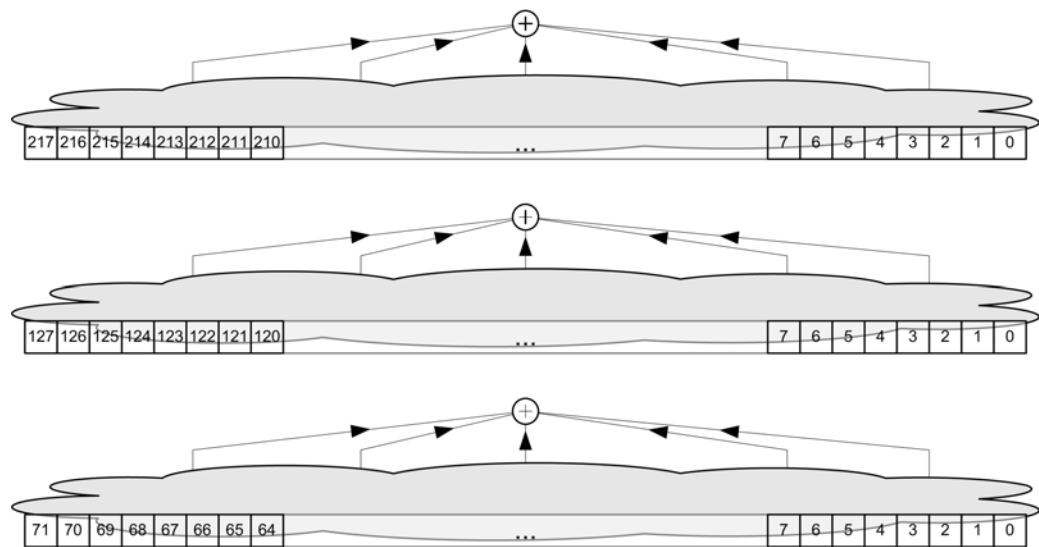


Fig. 3-40: Schematized shift register lengths of 218, 128 and 72 positions with taps after positions not specified explicitly.

These features lead to a correcting capability for error bursts (in case of 50 Bd of the original teleprinter/ITA-2P text) of a burst length of up to 7 s and additionally for single (random) errors, but this is bought by a significant delay in the signal output (also, output is continued for a certain period after the transmitting station has already switched to idle condition).

3.45 FEC-S

3.45.1 General

Transmission method	FEC-S
Explanation of name	Forward Error Correction, Simplex
Other designations	SI-FEC FEC-1000 Simplex FEC-1000S
Variants existing	
Derived from method	
Typical users	Diplomatic services
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	Variable (usually 170 Hz)
Baud rate	96 Bd, 192 Bd, 200 Bd
Modulating subcarrier	
Bandwidth	450 Hz
Operating method	Simplex
Data protection	Mark to space ratio 3 to 4, FEC by character repetition
Code table	ITA-3 (CCIR 342-3) (table 4-5 in chapter 4.1.4)

3.45.2 Description

The FEC-S method originates from the *Siemens* "ARQ 1000 Simplex" data protection device (teleprinting system) that manages ARQ-S (see [chapter 3.15, "ARQ-S"](#), on page 69) as an ARQ system and this method as an FEC system. Hence, for both the same code table ITA-3 is used, obeying to a strict mark to space ratio of 3 to 4 what makes it easy to detect (but not correct) single-bit errors on the transmission path.

Due to the fact that FEC-S is a simplex method (no backward channel available and therefore no repetition request possible), an additional data protection process is applied: each character is conveyed twice – the second time with inverted bit polarity and with a significant delay to the first time of 15 characters (what is equivalent to 105 bits). In [figure 3-41](#) the situation is illustrated; the procedure is exactly the same as with SITOR-B ([chapter 3.88, "SITOR-B"](#), on page 268) with the only exception of the

longer first-to-second-emission delay (the above-mentioned 15 characters instead of only 5 with SITOR-B). From this reason, the error detection scheme given in [table 3-47](#) is also valid here: the supposedly correct character of both received is output or, if none of both is correct or both seem to be, but differ from each other, an error sign.

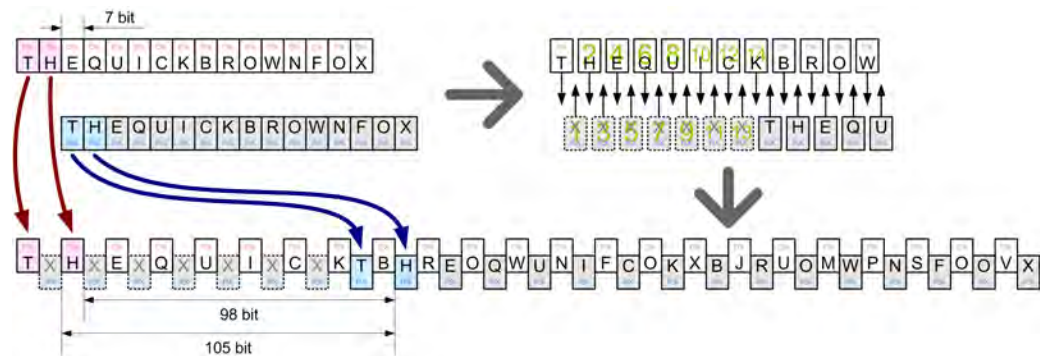


Fig. 3-41: Character repetition and interleaving with FEC-S.

3.46 FLEX

3.46.1 General

Transmission method	FLEX
Explanation of name	FLEX ible wide area paging protocol
Other designations	
Variants existing	
Derived from method	
Typical users	Paging systems Radio amateurs
Kind of data	Short messages
Reference to standard	ITU-R Recommendation M.584-2: "Codes and Formats for Radio Paging"
Frequency band	VHF/UHF
Modulation method	FSK: MSK (FFSK), MSK4; 1600 bit/s, 3200 bit/s, 6400 bit/s
Shift/tone spacing	3.2 kHz: -4800 Hz, -1600 Hz, +1600 Hz, +4800 Hz
Baud rate	1600 Bd, 3200 Bd, 6400 Bd
Modulating subcarrier	
Bandwidth	13 kHz
Operating method	Simplex, synchronous

Transmission method	FLEX
Data protection	BCH Code
Code table	ITA-5 (ASCII) (table 4-9 and table 4-10 in chapter 4.2) BCD

3.46.2 History

Pager services using the POCSAG standard ([chapter 3.80, "POCSAG"](#), on page 249) are introduced by a number of PTT (Post, Telephone and Telegraph) administrations. The POCSAG protocol is standardized in [ITU-R Recommendation M.584-2](#), FLEX was invented by *Motorola* and introduced in 1994. Some service providers offer POCSAG and FLEX services on the same radio frequency. Pagers are one-way devices. A base station controls a large number of receivers sending different kinds of messages to them. A return channel for transmission of reception acknowledgments or text as an answer is not available.

3.46.3 Description

FLEX is another mode for pager transmissions; it is often combined with [POCSAG](#). Four different transmission modes are specified:

- 1. MSK (FFSK) with 1600 Bd (1600 bit/s)
- 2. MSK4 with 1600 Bd (3200 bit/s)
- 3. MSK with 3200 Bd (3200 bit/s)
- 4. MSK4 with 3200 Bd (6400 bit/s)

3.46.4 Source Coding

Two message formats are defined for the text of messages (dependent on transmission mode, see [3.46.3, "Description"](#)): 7-bit ASCII and BCD. In case of ASCII, data is segmented to subsequent code words (20 message bits [see [3.46.5, "Channel Coding/Structure of Data Blocks"](#)] not divisible by 7), i.e. bits are transmitted consecutively regardless of ASCII word borders.

3.46.5 Channel Coding/Structure of Data Blocks

A message starts with a preamble identifying the modulation type, followed by a Frame Information Word (FIW) carrying the cycle and frame number; these two are always modulated as MSK (FFSK) with 1600 Bd. Finally the message is sent; the modulation according to the preamble. The message block contains the information and is composed of 11 blocks, each of which carrying 8 words with 32 bits each. The length of a message block is always constant. With a higher modulation type than the basic MSK, 1600 Bd, it is possible to transmit more than one (up to four) complete and independ-

ent message blocks. To distinguish between the different message blocks, they are called phase A to D.

3.47 FMS-BOS

3.47.1 General

Transmission method	FMS-BOS
Explanation of name	(Germ.) FunkMeldeSystem für Behörden und Organisationen mit Sicherheitsanforderungen (radio messaging system for authorities and organizations with security concerns)
Other designations	
Variants existing	
Derived from method	
Typical users	German authorities and organizations with security concerns (police, fire brigade, customs, ambulances)
Kind of data	Tactical short informations
Reference to standard	"Funkmeldesystem (Juni 1999), Polizeitechnisches Institut bei der Polizeiführungsakademie, Postfach 480353, D-48080 Münster" (Radio Messaging System [June, 1999], Institute for Police Technology in Police University)
Frequency band	VHF: 68 MHz to 87.5 MHz
Modulation method	FSK2, indirect FM
Shift/tone spacing	600 Hz
Baud rate	1200 Bd
Modulating subcarrier	1500 Hz
Bandwidth	12.5 kHz
Operating method	Simplex, duplex
Data protection	Abramson code
Code table	BCD

3.47.2 History

Established since 1980

3.47.3 Description

FMS-BOS is a radio signaling system, which conveys the status of mobile units (e.g. police cars) to the control center. It allows for a considerable reduction in speech message interchange between stations by transmitting abbreviated telegrams digitally.

3.47.4 Channel Coding/Structure of Data Blocks

48-bit blocks, each block carries 40 bits of information sub-divided into 8 parameters:

- BOS ID (4 bits)
- country code (4 bits)
- trunk code (4 bits)
- vehicle ID (4 bits)
- status (4 bits)
- 3 parameters (1 bit, 1 bit and 2 bits) carrying additional information

The 8 additional bits cover redundancy bits (7 bits) and a terminating bit (1 bit). Blocks can be chained together to build larger messages. Before each block 10 '1' bits and the synchronisation sequence 0001 1010₂ (8 bits) are sent.

3.48 GMDSS/DSC-HF

3.48.1 General

Transmission method	GMDSS/DSC-HF
Explanation of name	Global Maritime Distress and Safety System/Digital Selective Calling, HF band
Other designations	GMDSS-HF DSC
Variants existing	
Derived from method	
Typical users	Used worldwide in maritime environment
Kind of data	Maritime Mobile Service Identity (MMSI): series of 9 digits (10 in future) to uniquely identify ship stations, ship earth stations, coast stations, coast earth stations, and group calls; additional information about kind and severity of call
Reference to standard	ITU-R Recommendation M.493-12: "Digital Selective-Calling System for Use in the Maritime Mobile Service"
Frequency band	HF: 2.1875 kHz, 4.2075 kHz, 6.312 kHz, 8.4145 kHz, 12.577 kHz, 16.8045 kHz

Transmission method	GMDSS/DSC-HF
Modulation method	FSK2
Shift/tone spacing	170 Hz
Baud rate	100 Bd
Modulating subcarrier	
Bandwidth	300 Hz
Operating method	Asynchronous, simplex, broadcast
Data protection	FEC
Code table	GMDSS/DSC (table 4-22 in chapter 4.8)

3.48.2 History

In 1979, a group of experts drafted the International Convention on Maritime Search and Rescue (SAR), which called for development of a global search and rescue plan, and passed a resolution calling for development by International Maritime Organization (IMO) of a Global Maritime Distress and Safety System (GMDSS) to provide the communication support needed to implement this plan. This system, which the world's maritime nations are implementing, is based upon a combination of satellite and terrestrial radio services, and has changed international distress communications from being primarily ship-to-ship based to ship-to-shore (RCC/Rescue Coordination Center) based. It spelled the end of the formerly widely-used Morse code communications. The GMDSS provides for automatic distress alerting and locating in cases where a radio operator doesn't have time to send an SOS or MAYDAY call, and, for the first time, requires ships to receive broadcasts of maritime safety information which could prevent a distress from happening in the first place. In 1988, IMO amended the Safety of Life at Sea (SOLAS) convention, requiring ships subject to it to fit GMDSS equipment (NAVTEX and satellite EPIRBs by August 1, 1993, and all other GMDSS equipment by February 1, 1999).

IMO also introduced Digital Selective Calling (DSC) on MF, HF and VHF maritime radios as part of the GMDSS system. DSC is primarily intended to initiate ship-to-ship, ship-to-shore and shore-to-ship radiotelephone and MF/HF radiotelex calls. DSC calls can also be made to individual stations, groups of stations, or "all stations" in one's radio range. Each DSC-equipped ship, shore station and group is assigned a unique 9-digit Maritime Mobile Service Identity (MMSI, see table 3-14; the MID [Maritime Identification Digit] is an identifier unique to each country). These identities can be used by telephone and telex subscribers connected to the general telecommunications network to call ships automatically. The 4 kinds of maritime mobile service identities are: ship station identities, group ship station identities, coast station identities, group coast station identities.

Table 3-14: Maritime Mobile Service Identity (MMSI).

Leading '0's	MID	Identification digits	Meaning
–	3 digits	6 digits	Ship station identities
	211	123456	Example: German ship station
1 digit: 0	3 digits	5 digits	Group ship station identities
0	211	12345	Example: group of German ship stations
2 digits: 00	3 digits	4 digits	Coast station identities and group coast station identities
00	211	1240	Example: MRCC (Maritime Rescue Coordination Centre) Bremen

3.48.3 Description

The code table for GMDSS/DSC can be seen from [table 4-22 \(chapter 4.8, "GMDSS/DSC Code Table"](#), on page 348). 128 characters are used (0 to 127₁₀), the first 100 of which, 0 to 99₁₀, just represent the corresponding two-digit decimal number (cf [table 3-15](#)), whereas characters 100₁₀ to 127₁₀ are control signs (note that only numbers have to be coded, no letters). Each character is constructed from 7 information bits (dual representation of the original two-digit number, but in "LSB first" notation) and 3 control bits (telling, in "MSB first" notation, the dual number of '0's in the 7 information bits).

Table 3-15: Decimal two-digit number, forming (left) and example (right).

Decimal two-digit number		Decimal two-digit number	
10 ¹	10 ⁰	35 ₁₀	
left digit of character (tens)	right digit of character (units)	3 (tens)	5 (units)
Character: first 7 bits = two-digit number (LSB first) second 3 bits = no. of '0's in first 7 bits (MSB first)		1100010 100 ₂	

If numbers of more than two decimal digits have to be formed, they are divided in two-digit groups and then represented by the corresponding two-digit numbers as shown in [table 3-16](#), with an example given in [table 3-17](#). If the original number has an odd count of decimal digits, it is left-expanded by a zero.

Table 3-16: Decimal ten-digit number, forming.

Decimal ten-digit number									
10 ⁹	10 ⁸	10 ⁷	10 ⁶	10 ⁵	10 ⁴	10 ³	10 ²	10 ¹	10 ⁰
Decimal digit of resulting character									
left (10)	right (1)	left (10)	right (1)	left (10)	right (1)	left (10)	right (1)	left (10)	right (1)
Character 5		Character 4		Character 3		Character 2		Character 1	

Table 3-17: Decimal ten-digit number, example.

3 749 268 015 ₁₀									
3	7	4	9	2	6	8	0	1	5
1010010 100 ₂	1000110 100 ₂	0101100 100 ₂	0000101 101 ₂	1111000 011 ₂					

A call sequence for a typical routine message is shown in figure 3-42. The user information (call content) consists of

- a format specifier (describing the type of the call sequence, 2 characters, **A** in the figure)
- the address to call (5, **B**)
- the category (severity of message, 1, **C**)
- the self identification (address calling, 5, **D**)
- a telecommand information (2, **E**)
- a frequency designation (6, **F** and **G**)

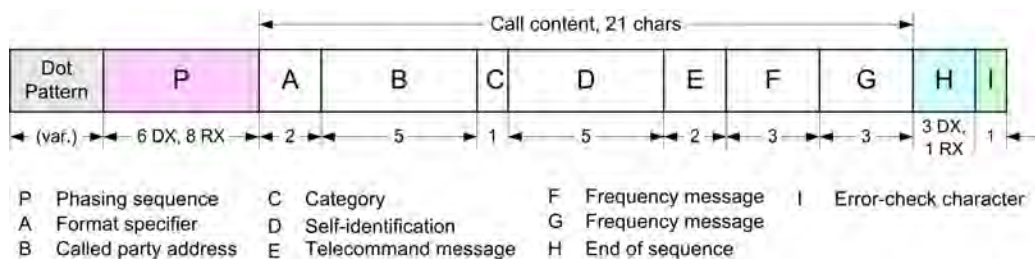


Fig. 3-42: Call sequence format of a typical routine message.

For distress situations, differing call sequence formats and messaging protocols exist not described here in detail. For further informations, also about contents used in the individual data fields, refer to the [ITU-R Recommendation](#).

3.48.4 Channel Coding/Structure of Data Blocks

The overall 21 characters of a routine call sequence (see 3.48.3, "Description") are subjected to a [FEC](#) procedure, i.e. each character in reality is sent twice with a delay of 4 intermediate characters. The method is the same as with SITOR-B, thus, take all details, such as transmitting levels, constructing the data stream from the raw data, etc., from [chapter 3.88, "SITOR-B"](#), on page 268.

The transmission sequence resulting can be seen in [figure 3-43](#):

- The first element ([figure 3-43, A](#)), introducing a call sequence, is a dot pattern of 20 bits or 200 bits (depending on kind of message to be sent) just alternating between 1 and 0. A distinction of **DX** and **RX** transmission levels is not made here.
- The phasing sequence following next is made up of six fixed 125₁₀ characters on DX and the descending series of characters 111₁₀ to 104₁₀ on RX level.
- The 21 characters of the call sequence itself (A to G3) are described in 3.48.3, "Description" ([figure 3-42](#)).

- The EOS (end of sequence, **B**) character of the trailing sequence can be 117₁₀, 122₁₀ or 127₁₀, again depending on kind of message. It is transmitted three times on DX and once on RX.
- The ECC (error check character) which is also part of the trailing sequence is formed from the (modulo-2) sum of the corresponding bits of all information characters (the seven information bits only). It is included once in each level DX and RX.

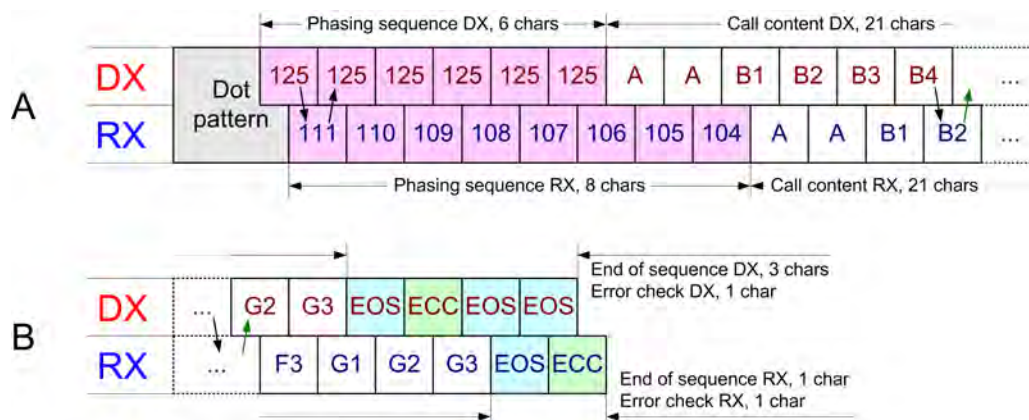


Fig. 3-43: Character repetition for FEC.

A = Start of sequence (dot pattern and phasing)

B = End of sequence (with error check)

Due to the 10-bit length of each character, the overall sequence shown is made up of 640 bits (20-bit dot pattern) or 820 bits (200-bit dot pattern). Therefore, with 100 Bd transmission speed, the forwarding time for a complete call sequence is 6.4 s or 8.2 s, respectively.

3.49 GMDSS/DSC-VHF

3.49.1 General

Transmission method	GMDSS/DSC-VHF
Explanation of name	Global Maritime Distress and Safety System/Digital Selective Calling, VHF band
Other designations	DSC
Variants existing	
Derived from method	GMDSS/DSC-HF
Typical users	Used worldwide in maritime environment
Kind of data	Maritime Mobile Service Identity (MMSI): series of 9 digits (10 in future) to uniquely identify ship stations, ship earth stations, coast stations, coast earth stations, and group calls. Additional information about kind and severity of call

Transmission method	GMDSS/DSC-VHF
Reference to standard	ITU-R Recommendation M.493-12: <i>"Digital Selective-Calling System for Use in the Maritime Mobile Service"</i>
Frequency band	VHF Channel 70: 156.525 MHz
Modulation method	FSK2, indirect FM
Shift/tone spacing	800 Hz
Baud rate	1200 Bd
Modulating subcarrier	1700 Hz
Bandwidth	300 Hz
Operating method	Simplex, broadcast, asynchronous
Data protection	FEC
Code table	GMDSS/DSC (table 4-22 in chapter 4.8)

3.49.2 Description

With the exception of the differing frequency range and the fact that an additional indirect FM is applied, GMDSS/DSC-VHF is identical to GMDSS/DSC-HF. Therefore, for all informations refer to chapter 3.48, "GMDSS/DSC-HF", on page 138.

The dot pattern with GMDSS/DSC-VHF always contains 20 bits, so that, with 1200 Bd transmission speed, a forwarding time for a complete call sequence of 533 ms results.

3.50 G-TOR

3.50.1 General

Transmission method	G-TOR
Explanation of name	Golay Teletype Over Radio (after the Swiss mathematician, physicist, and information theorist Marcel J. E. Golay)
Other designations	
Variants existing	
Derived from method	PACTOR
Typical users	Military Governmental agencies International Committee of the Red Cross (ICRC) Commercial radionets in Africa Radio amateurs

Transmission method	G-TOR
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	200 Hz (mark 1600 Hz, space 1800 Hz) 170 Hz (mark 2125 Hz, space 2295 Hz)
Baud rate	100 Bd, 200 Bd, 300 Bd (adaptive)
Modulating subcarrier	
Bandwidth	340 Hz
Operating method	Half-duplex ("Simplex-ARQ"), synchronous
Data protection	FEC (Golay (24,12)), ARQ
Code table	Huffman (table 4-14 in chapter 4.4) ITA-5 (ASCII) (table 4-9 and table 4-10 in chapter 4.2)

3.50.2 History

G-TOR is a method developed by *Kantronics Company, Inc.*, and introduced in March 1994. It was derived from PACTOR ([chapter 3.74](#), "PACTOR I", on page 227) and introduces new firmware features using existing terminal controllers, thus dramatically increasing throughput, reducing interference and multi-path propagation effects and observing low cost.

3.50.3 Description

3.50.3.1 Overview

G-TOR operates as a synchronous system using FEC and ARQ error protection at a time. As shown in [figure 3-44](#), a strict system cycle of 2.4 s is used, consisting of 1.92 s Tx cycle (data frame duration) and 480 ms Listen cycle during which the 160 ms Acknowledge signal (ACK or NAK) is conveyed.

Several error protection measures are used:

- Golay (24,12) code
- Code table ASCII (8 bits per character fixed) or Huffman (variable bit length from 2 bits for frequently to 14 bits for rarely occurring characters)
- 3 baud rates (100 Bd, 200 Bd, 300 Bd), altering automatically due to current quality of link
- Bitwise interleaving of data prior to transmitting frame
- Overhead in data frames reduced, depending on number of errors detected

- Standard FSK tone pair (mark and space)

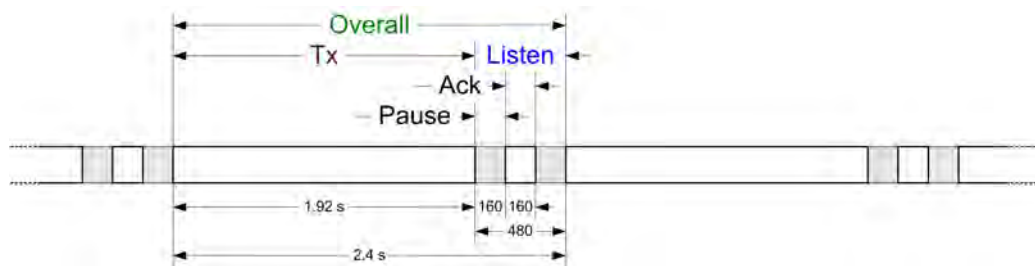


Fig. 3-44: Basic timing with G-TOR (time details in ms unless noted otherwise).

3.50.3.2 Golay coding

The original Golay code has been discovered by *Marcel J. E. Golay*, a Swiss mathematician, physicist, and information theorist, in 1949, and since then was a subject of study by many other coding theorists and mathematicians. It appends to the 12 bits of the information word 11 parity bits, therefore it is also designated as Golay (23,12) code. The minimum code word distance of 7 bits reveals its close relation to the popular Hamming codes and makes it capable of correcting any error pattern of 3 bits or less in the 23-bit code block.

In G-TOR, the so-called extended binary Golay code is used; it is formed by adding one trailing parity bit to the original Golay (23,12) code, thus resulting in the Golay (24,12) code. This code became famous from NASA's Voyager space mission where it was used to transmit the color images of Jupiter and Saturn. One of its outstanding features is the fact that it is invertible, i.e. just as well as the 11 plus 1 parity bits are formed from the 12 information bits, the other way round these information bits can be deduced completely from their parity bits.

The code may be implemented as a block code or as a cyclic code; in G-TOR the block code variant is applied. Decoding of the code is not as simple as coding, and also not as decoding Hamming codes. One algorithm mastering this is the Kasami decoder, another one, but consuming much more memory, is the use of look-up tables.

3.50.3.3 Data Frame Structure

As mentioned in 3.50.3.1, "Overview", G-TOR operates in three rates: 100 Bd, 200 Bd and 300 Bd. Selection is done automatically by the system, depending on the current channel conditions. For initiations of links and for all ACK/NAK transmissions always the lowest speed (100 Bd) is used. Due to the constant frame length of 1.92 s, three different structures of data frames (cf figure 3-44) are formed (figure 3-45; tribble = three nibbles [half-bytes]).

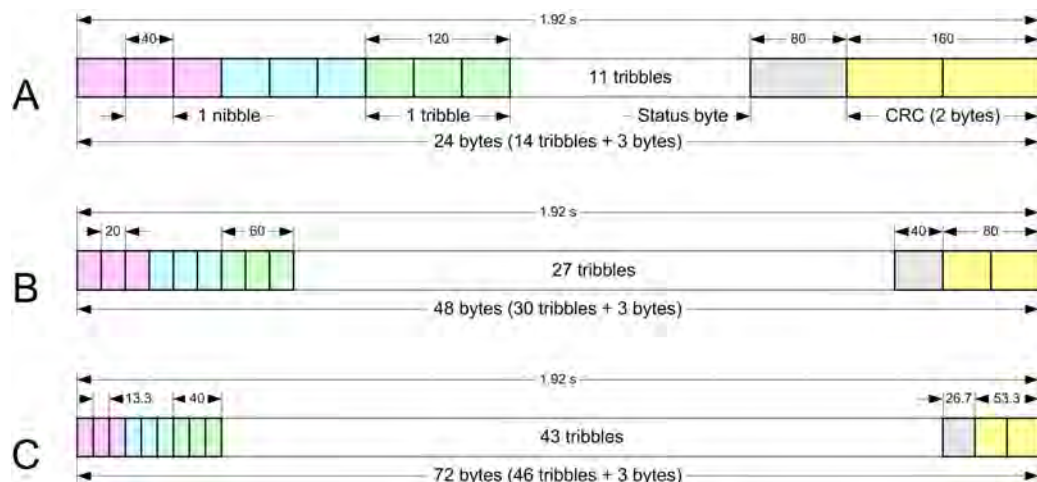


Fig. 3-45: Frame architecture with G-TOR (time details in ms unless noted otherwise).

A = Baud rate 100 Bd: 14 payload tribbles (12 bits or 1.5 bytes each) in 21 bytes (frame length 24 bytes)

B = Baud rate 200 Bd: 30 payload tribbles in 45 bytes (frame length 48 bytes)

C = Baud rate 300 Bd: 46 payload tribbles in 69 bytes (frame length 72 bytes)

Each frame type is terminated by a status byte and two CRC bytes (the checksum being calculated over the complete frame as defined in the X.25 protocol). The status byte structure is given in [table 3-18](#).

Table 3-18: Status byte.

Bits	Meaning	Comment
7 (MSB) to 6	00: data 10: disconnect 01: turnaround request 11: connect	Kind of frame
5 to 4	Reserved	Unused
3 to 2	00: none 10: Huffman-B 01: Huffman-A 11: reserved	Kind of compression
1 to 0 (LSB)		Frame ID number

- 100 Bd: 192 bits or 24 bytes are available, 21 of which give space for 14 tribbles (12-bit units, **A** in the figure)
- 200 Bd: 384 bits or 48 bytes available, 45 offer 30 tribbles (**B**)
- 300 Bd: 576 bits or 72 bytes available, 69 offer 46 tribbles (**C**)

When the complete frame is assembled as explained, it is interleaved bitwise before transmitting as shown in [3.50.3.6, "Interleaving"](#).

3.50.3.4 ACK and Command Frame structure

The ACK (and NAK) frames (cf to [figure 3-44](#)) are always 16 bits long, 15 of which are a single pseudo-random noise (PN) sequence (multiply cycle shifted, thus tolerating up to 3 bit errors in an ACK frame), and the 16th (LSB) is zero for balance purposes.

These frames are never interleaved nor contain parity bits and are always transmitted

in the 100 Bd speed, resulting in the 160 ms time range mentioned in [3.50.3.1, "Overview"](#). Five types are possible:

- Data ACK: frame received without error, next frame may be sent
- Data NAK: frame error detected, send complementary part of frame pair (see [3.50.3.7, "Transmission Protocol"](#))
- Speed-up ACK: accelerate transmission speed
- Speed-down ACK: decelerate transmission speed
- Change-over ACK: exchange **ISS** and **IRS** (IRS wants to send data to ISS)

The Connect and Disconnect procedure and frames and other command frames are not described here. For details, refer to relevant publications.

3.50.3.5 Code Tables ASCII and Huffman

Two code tables are in use with G-TOR:

- During normal text transmission, a data compression code, the Huffman code, is used; depending on frequency of occurrence of a character in a special (linguistic) environment, a differing count of code elements (bits) is spent to code it. Huffman codes commonly are constructed (coded and decoded) by tree structures; for more details, refer to [chapter 4.4, "Huffman Code Table"](#), on page 340 and to relevant publications. In [table 4-14](#), the Huffman code words used with G-TOR are shown in detail.
Additionally, a run-length encoding (**RLE**) structure is implemented, i.e. a 14-bit Huffman word is followed by a 5-bit repetition factor telling how often the word is to be repeated. Again, see relevant publications for details.
- If the text to transmit will not benefit from Huffman coding, the transmitting station will disable the encoding process and switch to a normal 8-bit ASCII coding scheme. The code table can be found in [table 4-9](#) and [table 4-10](#) ([chapter 4.2, "ITA-5 \(ASCII\) Code Table"](#), on page 336).

In [figure 3-46](#), the construction of frames for the ASCII case is shown. The original text (**A**) in its 8-bit representation in a first step is grouped into 12-bit units (i.e. every three characters form two units, also called tribbles, **B1**). In **B2** these units are coded with Golay (24,12) as told in [3.50.3.2, "Golay coding"](#), the upper 12 bits (parity bits) of the resulting code words are presented symbolically. From the resulting **B1** and **B2** bit streams, the G-TOR frames are formed, one for the uncoded data stream, one for the "upper-12-bit" (parity) data stream. The case of 100 Bd operation is shown in **C1** to **D2**: 14 tribbles are amended by the three status and **CRC** bytes. As a last operation before transmission, the whole frame constructed is interleaved bitwise as explained in [3.50.3.6, "Interleaving"](#) (shown in [figure 3-48](#), but not in [figure 3-46](#)).

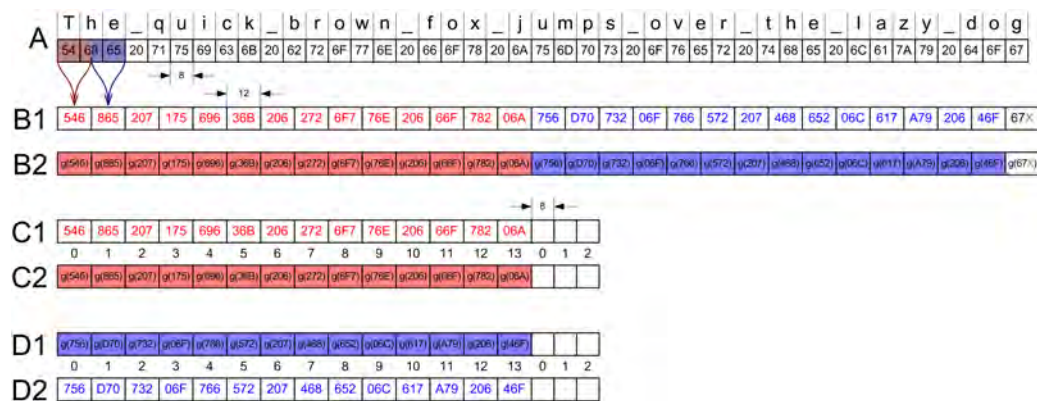


Fig. 3-46: Constructing frames from ASCII characters.

A = Message text and corresponding ASCII characters (hexadecimal notation)

B1 = Hexadecimal characters (half-bytes or nibbles) grouped to triples (tribbles)

B2 = Symbolic Golay code (upper 12 bits or parity fraction) of B1

C1 = First frame constructed from B1: case 100 Bd, i.e. 14 tribbles and 3 bytes; first frame to transmit (interleaving omitted)

C2 = First frame constructed from B2: first frame to keep in ISS

D1 = Second frame constructed from B2: second frame to transmit

D2 = Second frame constructed from B1: second frame to keep in ISS

In contrast, [figure 3-47](#) explains the same situation for the case of Huffman encoding. Again, **A** shows the original message, but now represented by code words of differing lengths (2 bits to 14 bits) and hence represented in dual notation. The tribbles are formed in the known way, every 12 bits form one of them, now regardless of the previous message word borders, and Golay (24,12) coded (**B**); then the frames are constructed (and their bits interleaved) as in the ASCII case (**C1** to **D2**). Note that the case demonstrated suggests a reduction in expense (saving of bits) compared to the ASCII case: Huffman accommodates the message in 19 tribbles and 2 bits, whereas 2 complete frames or 28 tribbles do not suffice in ASCII.



Fig. 3-47: Constructing frames from Huffman characters.

A = Message text and corresponding Huffman characters (dual notation)

B1 = Dual characters (bits) grouped 12-bitwise (tribbles, dual and hexadecimal notation)

B2 = Symbolic Golay code (upper 12 bits or parity fraction) of B1

C1 = First frame constructed from B1: case 100 Bd, i.e. 14 tribbles and 3 bytes; first frame to transmit (interleaving omitted)

C2 = First frame constructed from B2: first frame to keep in ISS

D1 = Second frame constructed from B2: second frame to transmit

D2 = Second frame constructed from B1: second frame to keep in ISS

3.50.3.6 Interleaving

Any pure data frame in G-TOR is subjected to a bitwise interleaving process in order to spread eventually occurring burst errors over the entire frame, thus increasing probability to have such errors corrected by the Golay (24,12) code. This process can be seen from [figure 3-48](#); the *n* parameter (register length) represents the number of tribbles (including the three control/CRC bytes equating two tribbles) of the respective Baud rate.

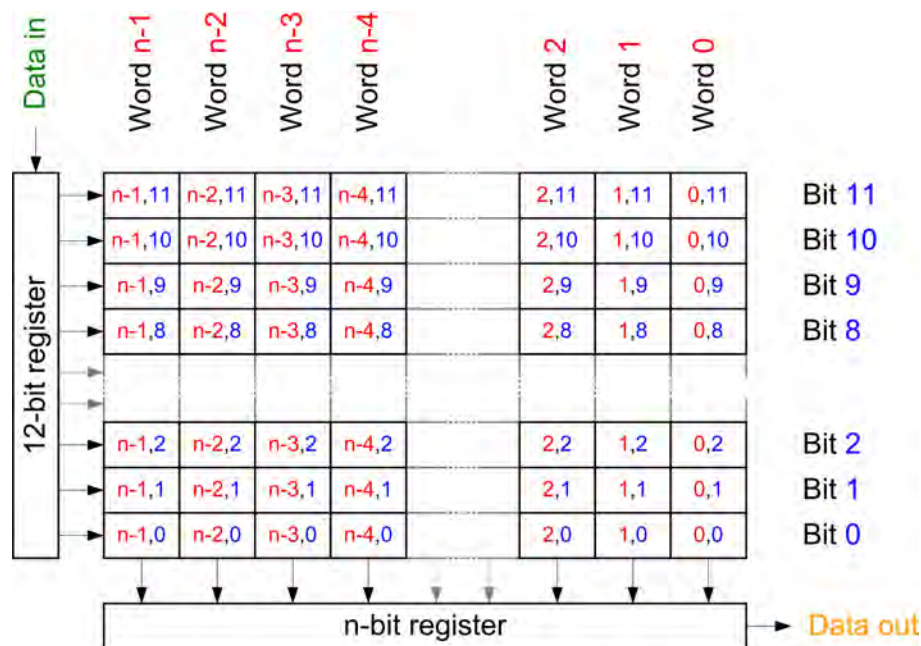


Fig. 3-48: Frame interleaving; speed 100 Bd: register length $n = 16$, 200 Bd: $n = 32$, 300 Bd: $n = 48$.

3.50.3.7 Transmission Protocol

The basic timing of G-TOR has been illustrated in [figure 3-44](#). The key point causing the large improvement of throughput, however, is the concept of the so-called hybrid ARQ, two types of which are distinguished:

- Type I: Due to combination of an FEC and ARQ concept, after checking a frame received and determining it to be in error, first an attempt to correct the error(s) is made and, if this was not successful, second a retransmission is requested. The advantage of this concept (compared with plain ARQ) is the fact that not in any case of error a retransmission has to be asked, but the disadvantages are the significantly higher amount of parity check bits to transmit, thus reducing throughput, and the risk to have the errors "corrected" to a wrong (admissible, but representing another character than the one sent originally) bit pattern.
- Type II: This is the concept applied in G-TOR. The complete FEC process is only performed if it is really needed, thus lessening to a large amount the number of parity bits to convey. This method is described subsequently.

The Golay (24,12) code is a very powerful (3 bits corrigible), but also very intricate code (1 parity bit per information bit), so it would seem excessive to use it at any time, i.e. also under good link conditions – throughput would decrease to 50 %. Thus the strategy pursued is as follows (remember that, due to the code being an invertible one, the original information bits can be recovered completely from the parity bits):

- Two frames are constructed by the ISS separately from the 12 original information bits and from the 12 parity bits as explained in [3.50.3.5, "Code Tables ASCII and Huffman"](#) ([figure 3-46](#) and [figure 3-47](#)).

- One of the two frames (alternating from cycle to cycle) is (interleaved and) transmitted to the IRS, the other one stored in the ISS.
- The IRS (after de-interleaving) checks the received frame by means of the 16 CRC bits whether it is to be considered correct or erroneous.
- In the error case, a NAK signal instead of the ordinary ACK is returned, causing the ISS to additionally transmit the other member of the frame pair (parity to information or information to parity).
- This frame is also checked for errors in the way told, if none are present, the information bits are used (if it was an information frame) or recovered from the parity bits and then used (if it was a parity frame).
- In case of errors also in the complementary part of the frame pair (i.e. in both frames), the complete Golay characters received are combined and Golay error correction is performed as scheduled, the corrected information then can be used.

From this approach, two transmission operations deliver three opportunities to have the errors corrected and therefore to obtain an error-free block of data.

3.51 GW-FSK

3.51.1 General

Transmission method	GW-FSK
Explanation of name	Globe Wireless-Frequency Shift Keying
Other designations	
Variants existing	
Derived from method	
Typical users	International ship traffic
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	200 Hz
Baud rate	200 Bd
Modulating subcarrier	
Bandwidth	440 Hz
Operating method	Half-duplex ("Simplex-ARQ")

Transmission method	GW-FSK
Data protection	CRC
Code table	ITA-5 (ASCII) (table 4-9 and table 4-10 in chapter 4.2)

3.51.2 History

Globe Wireless is a company with headquarters in the U.S.A., offering a worldwide communication network to international ship traffic. Transmission capacities exist in (digital) HF range as well as via satellite. The methods of transmission, however, vary according to the medium and its conditions of propagation; both self-developed methods and publicly accessible ones are used. Transmitting stations are spread all over the world.

3.51.3 Description

The GW-FSK transmission method operates in two modes, one at 200 Bd and the other one at 100 Bd. The former will be described here in more detail; it is used exclusively for data transmission, e.g. traffic and GPS position messages (whereas the latter serves for signalization purposes like "station idle", "start of communication", etc., as well as for normal transition in case of less favorable propagation conditions).

Additionally, GW-FSK always opens a HF connection sequence, even though, for the actual communication following, switching to GW-PSK or to another digital transmission mode might be done.

The GW-FSK frame is divided into an introducing section, a data field and a trailing checksum part. Duration of one frame is 735 ms for the 200 Bd case (900 ms for 100 Bd).

When a shore station is idle, "station idle" and ID signals are transmitted frequently.

3.51.4 Channel Coding/Structure of Data Blocks

The first part of a frame in GW-FSK (200 Bd) is the frame start section. It is 16 bits long, the first 7 bits of which are a fixed preamble, the other 9 bits represent the unit identifier (UI).

The data section following has 112 bits (14 bytes); the format used is ITA-5 (ASCII) alphabet, but in a masked manner. Empty or even partly used frames are filled with the constant ASCII character "<".

The concluding 16 bit form the CRC checksum.

3.52 GW-PSK

3.52.1 General

Transmission method	GW-PSK
Explanation of name	Globe Wireless-Phase Shift Keying
Other designations	
Variants existing	
Derived from method	
Typical users	International ship traffic
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	PSK4
Shift/tone spacing	
Baud rate	200 Bd
Modulating subcarrier	
Bandwidth	250 Hz
Operating method	Half-duplex ("Simplex-ARQ")
Data protection	CRC
Code table	ITA-5 (ASCII) (table 4-9 and table 4-10 in chapter 4.2)

3.52.2 History

(See GW-FSK, [chapter 3.51](#), "GW-FSK", on page 151, [3.51.2](#), "History".)

3.52.3 Description

As already described with GW-FSK ([chapter 3.51](#)), any transmissions on GW-PSK are introduced by a GW-FSK interval for signalization purposes.

The GW-PSK section itself consists of 280 bits (35 bytes), resulting, with PSK4 (i.e. 2 bits forming a symbol) and the baud rate of 200 Bd (bit rate 400 bit/s), in a burst duration of 700 ms.

3.52.4 Channel Coding/Structure of Data Blocks

The start section of a GW-PSK signal ([PSK4](#) case) consists of 32 2-bit symbols (64 bits or 8 bytes).

- The 23 symbols introducing the section (this is, the entire frame) are constant, i.e. in modulated state, represent just the carrier frequency).
- 9 symbols follow and establish a preamble common to each frame.

The data content of the frame is represented by the next 25 bytes (100 symbols), the alphabet used is [ITA-5 \(ASCII\)](#). "U" or "<" characters serve for filling frames not completely in use.

Like with GW-FSK (see [3.51.4, "Channel Coding/Structure of Data Blocks"](#) in [chapter 3.51](#)), a 16 bit (2 byte or 8 symbol) [CRC](#) checksum concludes the frame.

3.53 HC-ARQ

3.53.1 General

Transmission method	HC-ARQ
Explanation of name	H agelin C ryptos A utomatic R epeat r e Q uest, after the founder of Crypto AG, Boris Hagelin
Other designations	Hagelin Crypto ARQ
Variants existing	
Derived from method	
Typical users	At first designed for data transmission via telephone lines, but now also used in HF environment Red Cross Organization Diplomatic stations
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	180 Hz
Baud rate	240 Bd
Modulating subcarrier	
Bandwidth	460 Hz
Operating method	Simplex, asynchronous

Transmission method	HC-ARQ
Data protection	ARQ
Code table	ITA-2 (table 4-2 in chapter 4.1.2)

3.53.2 Description

The HC-ARQ teleprinter is a simplex system without a defined timing. The ITA-2 teleprinter alphabet and a telegraph speed of 240 Bd are used. Transmission happens in data blocks of 30, 60 (default) or 180 characters, the length of which has to be agreed before transmission is initiated, that is, the system is not adaptive. The final blocks are formed by adding a synchronization sequence, some leading control and some trailing check bits.

3.53.3 Channel Coding/Structure of Data Blocks

Each block to be sent is introduced by a fixed

- synchronization sequence 1000 1011 1010 0010₂, followed by
- 16 control bits and the
- data block of 150, 300 or 900 data bits (30, 60 or 180 characters, respectively).
- 32 check bits

represent the end of the transmitted block. The desired block length must be known in advance.

3.54 HELLSCHREIBER AM

3.54.1 General

Transmission method	HELLSCHREIBER AM
Explanation of name	Hell writer, after the German inventor <i>Rudolf Hell</i> , AM
Other designations	HELLSCHREIBER FELDHELL HELL
Variants existing	
Derived from method	
Typical users	Internal Press up until about 1993 Radio amateurs

Transmission method	HELLSCHREIBER AM
Kind of data	Teletype characters: a virtual matrix is laid down on the character to be transmitted, then the pixels of the matrix are sent, scanning it from the bottom of the left column to the top of the right column, so covering 7 columns of 14 lines each
Reference to standard	
Frequency band	HF
Modulation method	ASK2 (on = "black", off = "white")
Shift/tone spacing	
Baud rate	122.5 Bd
Modulating subcarrier	
Bandwidth	1000 Hz
Operating method	Simplex, asynchronous
Data protection	
Code table	

3.54.2 History

The Hellschreiber AM or Feldhellschreiber was a facsimile-based teleprinter invented by the German inventor *Rudolf Hell*. It has since been emulated on computer sound cards by amateur radio operators; the resulting mode is referred to as Hellschreiber, Feld-Hell, or simply Hell. It was developed at the end of the 1920s, and has the advantage of being capable of providing intelligible communication even over very poor quality radio or cable links. During World War 2 it was sometimes used by the German military in conjunction with the Enigma encryption system.

3.54.3 Description

Hellschreiber AM transmits text by dividing each column into 7 pixels, and transmitting them sequentially, starting at the lowest pixel. A black pixel is transmitted as a signal, and a white pixel is transmitted as silence. This takes place at a rate of 122.5 Bd. Since the text was printed on continuous rolls, the number of columns is indefinite. Any on-signal could in any case last no shorter than 8 ms, however, both because of having to restrict the occupied bandwidth on the radio, but also for reasons having to do with the mechanical makeup of the receiving machinery.

3.55 HELLSCHREIBER FM

3.55.1 General

Transmission method	HELLSCHREIBER FM
Explanation of name	Hell writer, after the German inventor <i>Rudolf Hell</i> , FM
Other designations	FMHELL
Variants existing	
Derived from method	HELLSCHREIBER AM
Typical users	Internal Press up until about 1993 Radio amateurs
Kind of data	Teletype characters: a virtual matrix is laid down on the character to be transmitted, then the pixels of the matrix are sent, scanning it from the bottom of the left column to the top of the right column, so covering 7 columns of 14 lines each
Reference to standard	
Frequency band	HF
Modulation method	FSK2 (980 Hz = "black", 1125 Hz = "white")
Shift/tone spacing	145 Hz
Baud rate	122.5 Bd
Modulating subcarrier	
Bandwidth	150 Hz
Operating method	Simplex, asynchronous
Data protection	
Code table	

3.55.2 Description

Hellschreiber FM is the same transmitting method as Hellschreiber AM (see [chapter 3.54, "HELLSCHREIBER AM"](#), on page 155), except that an [FM](#) instead of [AM](#) is used.

3.56 HF-FAX (AM)

3.56.1 General

Transmission method	HF-FAX (AM)
Explanation of name	FAX is an abbreviation for (Latin) "fac simile": "make it alike", HF frequency range
Other designations	
Variants existing	WEATHER-FAX (only black and white) PRESS-FAX (with 8 shades of grey)
Derived from method	
Typical users	
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	AM (0 dB = white, 20 dB = black, for quasi-analog facsimile 8 levels from 0 dB to 20 dB)
Shift/tone spacing	
Baud rate	2400 Bd , 4800 Bd , 7200 Bd ; for "rate" definition see chapter 3.57
Modulating subcarrier	1800 Hz for 60, 90, 120 rpm (rotations or lines per minute), 260 Hz for 240 rpm
Bandwidth	6 kHz
Operating method	Broadcast
Data protection	
Code table	

3.56.2 Description

HF-FAX (AM) works exactly as HF-FAX (FM) ([chapter 3.57, "HF-FAX \(FM\)"](#), on page 159), but with amplitude instead of frequency modulation. It is found rather seldomly due to the poor reliability of the **HF** band especially concerning level (i.e.: amplitude) considerations; it is rather conceivable with wired communications. All definitions given in [chapter 3.57](#) apply also here – instead of into modulation frequencies, the modulation range is divided into modulation levels: 0 **dB** for "white" state and 20 **dB** for "black" state; if shades of grey are in use ("quasi-analog" variant), subdivision is done as follows:

20 dB	13 dB	9 dB	6.3 dB	4.2 dB	2.6 dB	1.2 dB	0 dB
black							white

3.57 HF-FAX (FM)

3.57.1 General

Transmission method	HF-FAX (FM)
Explanation of name	FAX is an abbreviation for (Latin) "fac simile": "make it alike", HF frequency range
Other designations	
Variants existing	WEATHER-FAX (only black and white) PRESS-FAX (with 8 shades of grey)
Derived from method	
Typical users	WEATHER-FAX: DWD (D eutscher W etter D ienst/German Weather Service)
Kind of data	Weather maps and data from satellite (but transmitted terrestrially)
Reference to standard	
Frequency band	HF
Modulation method	FM (1500 Hz = black, 2300 Hz = white, for analog facsimile 8 instantaneous frequencies from 1500 Hz to 2300 Hz)
Shift/tone spacing	800 Hz (also emissions with 850 Hz observed)
Baud rate	2400 Bd , 4800 Bd, 7200 Bd (occasionally 9600 Bd); for "rate" definition see 3.57.2, "Description"
Modulating subcarrier	1900 Hz
Bandwidth	2.1 kHz
Operating method	Broadcast
Data protection	
Code table	

3.57.2 Description

A number of stations worldwide transmit weather charts on a regular schedule. Most transmissions work with a wide shift of 800 [Hz](#); weather charts are transmitted almost exclusively with speeds of 60 [rpm](#) (rotations per minute) (1 per second), 90 rpm (1.5 per second) or 120 rpm (2 per second).

Equipment on both transmitting (broadcasting) and receiving end are to be appointed in advance, concerning scanning line length (if equipment with flat-bed scanning) or drum diameter (if with drum scanning). Additionally, a so-called index of cooperation (IOC) is defined and transmitted as the start of every emission:

$$IOC = (\text{scanning line length}) * (\text{number of lines per unit length}) / \pi,$$

informing the receiver about the selected line density of the subsequent emission. Together with the IOC, a phasing signal is conveyed giving the number of lines (or drum rotations) per minute of the emission. These two signals also serve for synchronization of the receiving end to the emission; if reception is started after these start signals or if they are not decoded because the signal is too weak, phase of the image has to be synchronized manually.

In reality, only some particular values for the IOC are in use: an ITU-T recommendation mentions merely 288 (resulting in a line density of 3.79 lines per mm) and 576 (1.89 lines per mm); in table 3-19, the recommended combinations are compiled. Be aware that a baud rate, data rate or bit rate in the original meaning is not defined because the system is an analog system and just transmits black-white transitions. The "rate" only corresponds to the horizontal resolution given.

Table 3-19: ITU-T recommendations for HF-FAX.

IOC	288			576		
Scanning frequency [lines/min]	60	120	240	60	120	240
Horizontal resolution [pixels/line]	2400	1200	1200	2400	2400	1800
Data rate [bit/s]	2400	2400	4800	2400	4800	7200

Other IOCs are observed occasionally (like as 264 or 352), as are lines per minute (e.g. 45, 48 or 90).

Two variants of HF-FAX are possible: a strict black/white representation with only two levels (AM) or frequencies (FM), respectively, ("WEATHER-FAX" variant for just geometric weather charts) or a "quasi-analog" mode with eight levels/frequencies, i.e. intermediate shades of grey ("PRESS-FAX" variant for black-and-white photos).

With FM, the frequency of 1500 Hz is defined the representation for "black" and the frequency of 2300 Hz for "white", thus, the center frequency is 1900 Hz and the shift 800 Hz. If shades of grey are to be accommodated, this range is divided linearly to the frequencies

1500 Hz	1614 Hz	1729 Hz	1843 Hz	1957 Hz	2071 Hz	2186 Hz	2300 Hz
black							white

Especially with the latter (shades of grey) variant, also a shift of 850 Hz has been observed.

3.58 HNG-FEC

3.58.1 General

Transmission method	HNG-FEC
Explanation of name	Hu NGary-Forward E rror C orrection
Other designations	
Variants existing	
Derived from method	
Typical users	Hungarian diplomatic services
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	400 Hz
Baud rate	100.05 Bd
Modulating subcarrier	
Bandwidth	600 Hz
Operating method	Simplex, broadcast
Data protection	FEC , interleaving
Code table	HNG-FEC (table 4-20 in chapter 4.6)

3.58.2 History

HNG-FEC is a teleprinter system invented in Hungary and used by Hungarian diplomatic services.

3.58.3 Description

The system uses a standard speed of 100.05 [Bd](#) with a shift of 400 [Hz](#).

The code table used can be seen in [table 4-20](#) ([chapter 4.6](#), "[HNG-FEC Code Table](#)", on page 345). It consists of the 32 characters of the [ITA-2](#) code table with two codes for "IDLE" and "UT" (unperforated tape) added. Each character is 15 bits long: the first 5 bits correspond to the original ITA-2 character, but with its respective first and last bit ([MSB](#) and [LSB](#)) inverted, the remaining 10 bits are used for error detection and correction ([FEC](#)), they can be divided in two 5-bit groups (also see [chapter 4.6](#) for details).

Due to the minimum Hamming distance of 7 arising, up to 3 bit errors can be corrected. Thus, burst errors (errors concerning consecutive bits) are tried to be anticipated by an interleaving strategy shown in detail in [figure 3-49](#) (original bits entered vertically, bits to transmit taken out horizontally line by line): The spread (bit distance after interleaving between two consecutive bits of the original bit stream) is 64 bits, and additionally a new character only begins at each 15th bit throughout the complete interleaving block (64 columns, 15 lines). This is, in the figure, characters start at each bit with a number divisible by 15, and it also is evident that after start of a new emission, a bit stream containing only payload bits (bits from the original bitstream without gaps) is obtained only after having waited for "nearly" a complete interleaving block (the last line of a block is the first with no more vacant positions). A more schematized illustration of the situation with the starting and terminating bits of each character marked separately is shown in [figure 3-50](#); it can be followed how the transmitted bits are filled with payload bits by and by. The first block shows the starting (filling), the center block the operating (busy) and the last block the terminating (emptying) phase of the interleaving process.



Fig. 3-49: Interleaving with HNG-FEC.

A = first characters starting in interleaving block

B = last character starting in interleaving block

C = interleaving block with characters entered

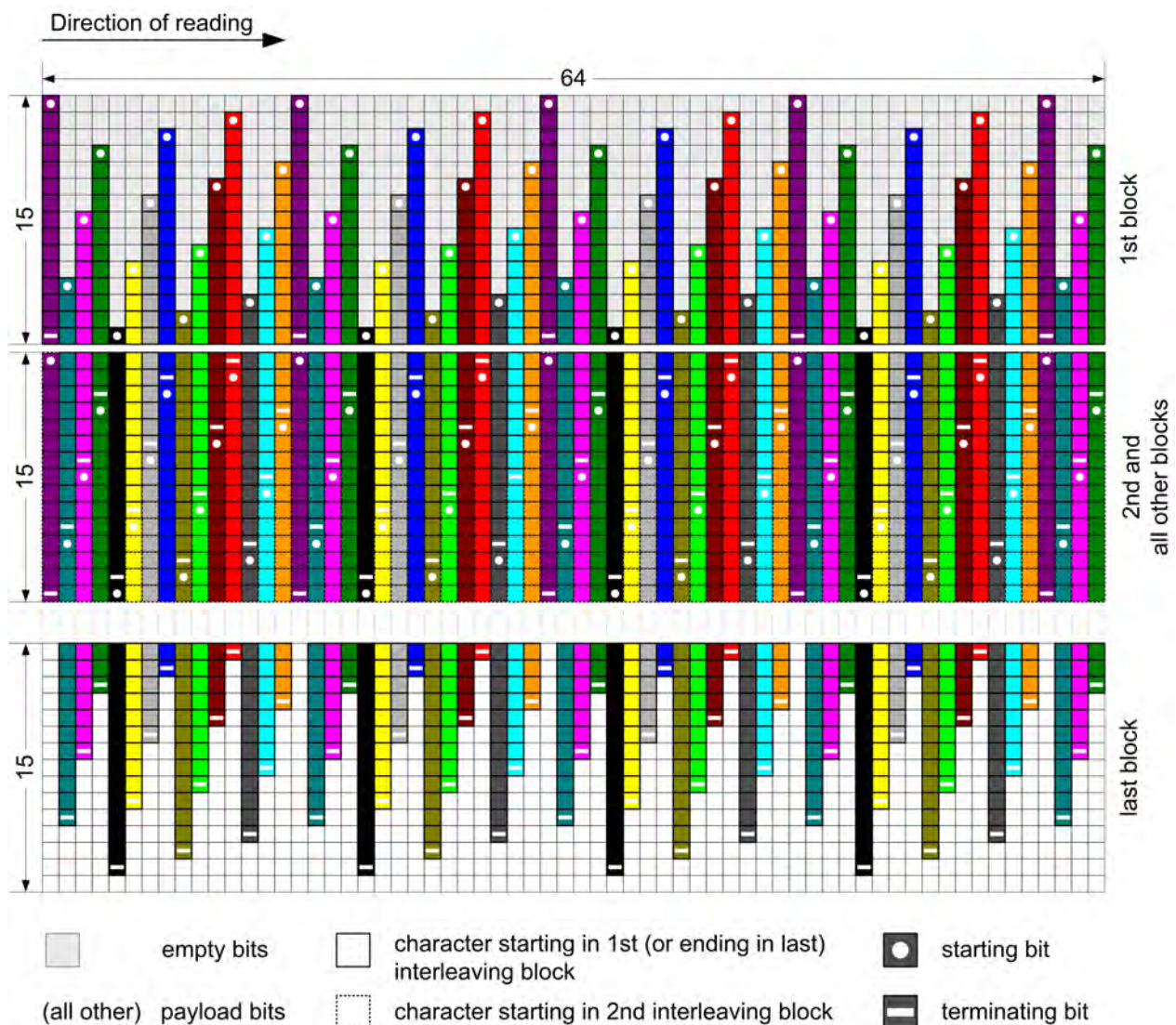


Fig. 3-50: Simplified interleaving scheme.

Bit inversion of a valid character code results in another valid character code, therefore, there is no possibility for an automatic polarity detection. From that, the decoder delivers both possible results (for normal and inverse polarity) separately in two channels, and the user has to decide which one is correct.

3.59 ICAO-SELCAL

3.59.1 General

Transmission method	ICAO-SELCAL
Explanation of name	International Civil Aviation Organization- SE lective CA lling
Other designations	ARINC ANNEX 10 SELCAL (A eronautical R adio, INC orporated)
Variants existing	Quik-Call I (Trademark of <i>Motorola</i>)
Derived from method	
Typical users	Aircraft controllers to aircraft on trans-oceanic routes
Kind of data	Two sinusoidal two-frequency tones sent sequentially
Reference to standard	ICAO Annex 10 Volume II: " <i>Communication Procedures Including those with PANS Status</i> ", Section 5.2.4: " <i>SELCAL procedures</i> "
Frequency band	HF, VHF/UHF
Modulation method	AM (USB)
Shift/tone spacing	16 tones from 312.6 Hz to 1479.1 Hz, non-constant spacing
Baud rate	
Modulating subcarrier	
Bandwidth	3 kHz
Operating method	Simplex
Data protection	
Code table	

3.59.2 History

The International Civil Aviation Organization (ICAO), a United Nations (UN) specialized agency, is the global forum for civil aviation. ICAO works to achieve its vision of a safe, secure, and sustainable development of civil aviation through cooperation through its member states. ICAO is responsible for defining air navigation policies and procedures for the civil aviation industry. Annex 10 of ICAO contains procedures for air navigation services that apply to the operation of a SELCAL system.

ICAO selective calling was initially defined in 1985 using 12 tones (frequencies, denominated tone "A" to tone "M", but without tone "I", see [table 3-20](#)). In 1994 the ICAO calling system, also known as Annex 10, was extended with the additional tones "P", "Q", "R" and "S" and thus now operates with 16 tones.

The allocation of selective call addresses had exclusively been managed by ARINC (*Aeronautical Radio, Inc.*) (ICAO Designator Selcal Registry); but on January 1, 2006,

Aviation Spectrum Resources, Inc. (ASRI) was organized. A separate ASRI Board of Directors consisting of airline management staff was formed to provide guidance and oversight to the new company; ICAO-SELCAL address allocation passed to ASRI then.

3.59.3 Description

ICAO-SELCAL is used to ring down airborne aircraft on [HF](#) and [VHF/UHF](#) single-side-band systems over trans-oceanic routes. Each aircraft equipped with the system is permanently assigned a four-letter code (address unique to that aircraft). At the beginning of a trans-oceanic flight, the pilots and controller test the system (the controller sends the aircraft a SelCal call to check its operation).

Thereafter, if instructions need to be given, the controller rings down the aircraft with the transmission of coded tones to the aircraft over the voice communications channel. The system is one-way, only allowing the controller to signal the aircraft, not vice-versa.

Each address consists, as mentioned, of four letters and thus of four tones grouped in a sequence of two pairs of tones, e.g. "AC-BD". The 16 tone frequencies defined at the moment are shown, together with their assigned letters (letters "I", "N", "O" and "T" to "Z" omitted/not used), in [table 3-20](#).

Table 3-20: Tone allocation.

Letter	"A"	"B"	"C"	"D"	"E"	"F"	"G"	"H"
Frequency [Hz]	312.6	346.7	384.6	426.6	473.2	524.8	582.1	645.7
Letter	"J"	"K"	"L"	"M"	"P"	"Q"	"R"	"S"
Frequency [Hz]	716.1	794.3	881.0	977.2	1083.9	1202.3	1333.5	1479.1

The two sinusoidal two-frequency tones are sent sequentially, the pulse duration is $1000 \text{ ms} \pm 250 \text{ ms}$, with a pause between them of $200 \text{ ms} \pm 100 \text{ ms}$. Each frequency represents one letter of the 16-letter set. The 4-letter code emitted this way forms the aircraft address (unique to each aircraft); see [figure 3-51](#) for the address example "AC-BD".

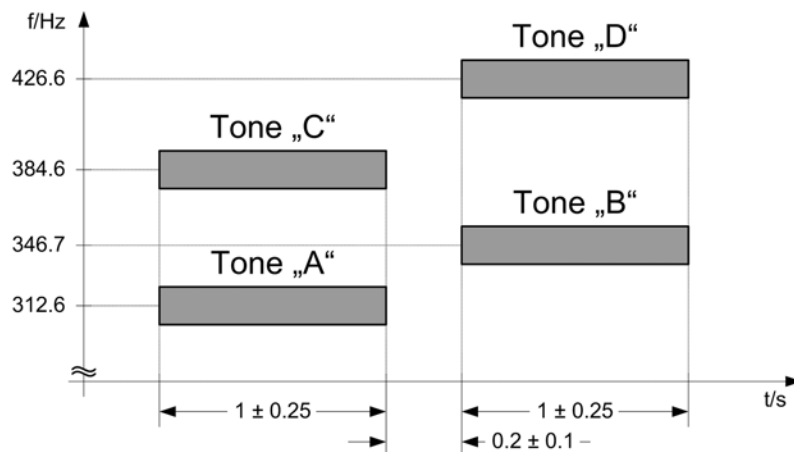


Fig. 3-51: Two-tone ICAO-SELCAL signal.

3.60 LTE

3.60.1 General

Transmission method	LTE
Explanation of name	Long Term Evolution
Other designations	E-UTRAN (Evolved Universal [or UMTS] Terrestrial Radio Access Network)
Variants existing	Open standard, subject to regular enhancement work
Derived from method	So-called 3rd generation (designations may vary) standard for mobile telecommunications, thus derived from 2nd generation predecessors such as GSM and from other 3rd generation predecessors such as UMTS
Typical users	
Kind of data	
Reference to standard	Plenty of separate standards; examples for getting started: 3GPP TS (Technical Specification) 36.211: "3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation" 3GPP TS 36.212: "3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding" 3GPP TS 36.300: "3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description"
Frequency band	UHF : 700 MHz to 2.7 GHz

Transmission method	LTE
Modulation method	PSK4, QAM16, QAM64
Shift/tone spacing	
Baud rate	100 Mbit/s (downlink), 50 Mbit/s (uplink)
Modulating subcarrier	12 per physical resource block (PRB), 15 kHz distance
Bandwidth	1.25 MHz, 1.6 MHz, 2.5 MHz, 5 MHz, 10 MHz, 15 MHz, 20 MHz; 15 kHz per subcarrier
Operating method	TDMA, FDMA, OFDM
Data protection	Convolutional coding for control channels (exclusively PSK4 modulation), turbo codes with code rate 1/3 for data channels
Code table	

3.60.2 History

LTE can be considered an evolution of the GSM and UMTS (cf [chapter 3.99, "UMTS"](#), on page 302) standards. The goal was to especially increase capacity and speed of wireless data communication, this means: to achieve considerably higher data rates than them possible so far. Also the network architecture was to be simplified by a redesign to an IP-based concept inducing a reduced transfer latency in comparison to the previous 3G solutions. Due to the LTE wireless interface being incompatible to 3G (and to 2G), it has to be operated on an own frequency range.

In 2007 the LTE/SAE Trial Initiative (LSTI) alliance was founded by vendors and operators all over the world in order to introduce the new technology as soon as possible. The LTE standard was concluded in December 2008, and the first publicly available LTE service was offered in Oslo and Stockholm in 2009.

3.60.3 Description

3.60.3.1 Single Carrier vs. Multicarrier

Until the emergence of LTE, cellular networks almost exclusively used single carrier transmission. The most obvious approach to increase data rate therefore is to modulate the single carrier with the faster data rate. Due to multipath propagation being present in virtually every environment, but especially in urban surroundings that also are the main playground for mobile communications, several "copies" of the very same signal, but with different time delays, will arrive at the receiver, what in the frequency domain is equivalent to phase shifts. This phenomenon leads to overlappings of the individual data symbols and thus to intersymbol interference or, in the frequency domain, to partial amplification or weakening (depending on the extent of the phase difference) of spectral components; all this together is also called fading. Methods to compensate for fading of course exist, but become rather complex with increasing data rates.

Therefore, with LTE a different approach has been pursued: **OFDM**, the Orthogonal Frequency Division Multiplex. The available bandwidth is split into many small subcarriers and the data stream to transmit into many parallel, slower individual data streams. Each of the subcarriers is then modulated by one of the data streams, the modulation method to currently be applied is thereby determined from continuously a-priori measuring the signal quality. Methods to select from are **PSK4**, **QAM16**, QAM64 or even higher orders.

OFDM is the superordinate principle of the LTE architecture of transmission; find more information about basic operation in relevant publications. With LTE, for downlink (base station to user) and uplink communication (user to base station) two different modes of OFDM are applied: OFDMA (Orthogonal Frequency Division Multiple Access) for downlink and SC-FDMA (Single Carrier Frequency Division Multiple Access) for uplink. An overview of both is given in the subsequent sections.

3.60.3.2 OFDMA in Downlink

In [figure 3-52](#) the nature of both OFDM and OFDMA used in downlink direction is told: whereas the term OFDM just describes the use of different orthogonal carriers (that do not interfere to each other in the ideal, i.e. undisturbed case) that are allocated to the individual users and remain allocated as long as each user is present, OFDMA is a scheme of access that distributes carriers to the users anew from symbol to symbol to transmit, following the amount of traffic caused/needed by each user at the moment.

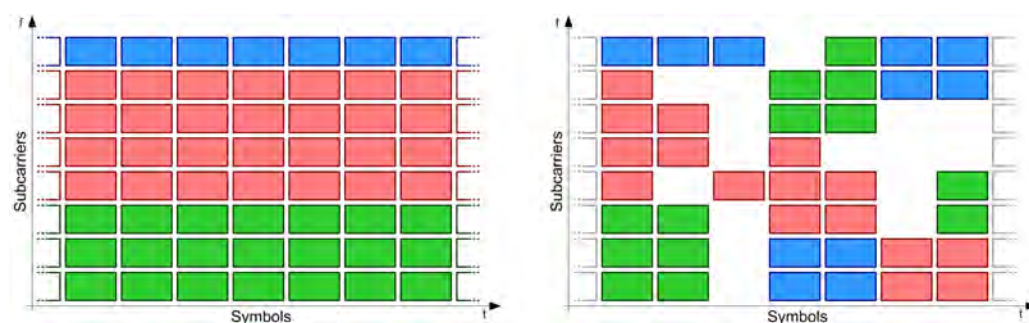


Fig. 3-52: Subcarrier and symbol allocation in OFDM (left) and OFDMA (right).

blue = User 1
 red = User 2
 green = User 3
 white (missing) = temporarily not used

The figure is just a basic illustration of the situation; the portions that time and frequency dimension are divided into (called physical resource blocks, PRB) are explained in more detail in [3.60.3.4, "Frame Structure"](#).

Due to some disadvantages of pure OFDM(A) like sensitivity to Doppler shift and the emergence of signals with a high peak-to-average ratio, the latter of which is unsuitable for handheld phones, a modified technique is used for the uplink direction; see [3.60.3.3, "SC-FDMA in Uplink"](#).

3.60.3.3 SC-FDMA in Uplink

SC-FDMA combines the low peak-to-average ratio of single carrier transmission (as known from [GSM](#) or [CDMA](#)) with multipath resistance and flexible frequency allocation of OFDMA, so it has been selected for use in the uplink direction. Find a brief comparison of both principles in [figure 3-53](#).

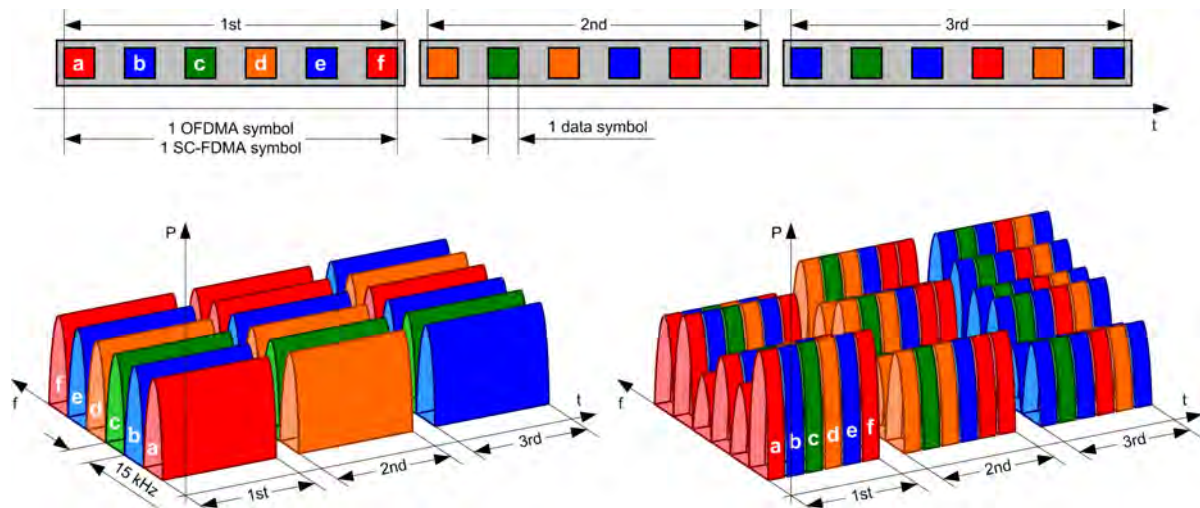


Fig. 3-53: Transmission of data symbols with OFDM in LTE.

top = series of data symbols (quaternary, i.e. 4 different available; e.g. PSK4)
 left = OFDMA
 right = SC-FDMA
 color = type of data symbol (state in constellation)
 a to f = ordinal letter of symbol

Let the 18 symbols shown at the top be the data to transmit. All symbols are considered quaternary, this means: house two information bits each and therefore offer four different states; PSK4 could have been the modulation method to have created them. 6 symbols form one OFDMA or SC-FDMA symbol, respectively.

In OFDMA (left in the figure) each symbol just modulates one of the 6 subcarriers; the period this state is held for is the symbol duration. The next set of 6 symbols and the one after next are treated the same way. Mind that due to the PSK4 modulation assumed no change at all can be observed in amplitude but only in phase (not to be seen in the figure).

In SC-FDMA (right), in contrast, no direct modulation of the subcarriers takes place, but the 6 symbols are mapped into the constellation of the PSK4 scheme serially in time, thus creating a complex signal in time domain consisting of the *I* and *Q* components as usual. Only now a 6-point DFT transforms this time signal into frequency domain, resulting in a spectrum (of also 6 spectral lines) like the one shown as an example in the figure. Be aware that, strictly speaking, painting 6 individual spectra "serially" in time as done in the figure is not correct, but the spectrum all over the entire symbol duration contains the complete information of all 6 data symbols and therefore is constant during this duration.

A procedure can be defined from this scheme viewing the OFDMA as its core part and the SC-FDMA as an additive surrounding this core:

Procedure only for SC-FDMA (*all printed in italics meaning the given example of figure 3-53*)

1. Fetch K data bits ($K = 24$),
2. Map data bits into constellation diagram (*quaternary, thus 6 symbols*),
3. Construct complex time domain signal, i.e. I and Q component signals,
4. Transform to frequency domain via M-point DFT ($M = 6$),

Procedure in common for SC-FDMA and OFDMA

1. Map the M symbols to M subcarriers ($M = 6$), map additional symbols (of other channels) to additional (adjacent) subcarriers,
2. Transform to time domain via N-point IDFT ($N > M$),
3. Upconvert to transmission frequency, convert to analog domain, transmit.

Of course the opposite actions have to be taken on the Rx end of the transmission path to recover the original data bits.

3.60.3.4 Frame Structure

A comparison of some scenarios showing intersymbol interference (ISI) is given in figure 3-54. All diagrams show a time signal received on three different paths due to reflections (multipath propagation), this is: received with delays individual to each path (and also possibly changing over time). What finally arrives is the linear combination of all these signals; a receiver commonly will be capable to eliminate these delays (or distortions if observing the frequency domain) once the overall impulse response of the channel is known (as is by calculating it by periodic transmission of reference signals). But this is only the case if the symbol does not spill over into a neighboring symbol; thus, the two actions to take are

- to keep the delays as small as possible – what of course is much easier with longer symbols as existing with multicarrier systems than with decreasing more and more the symbol duration as with a single carrier system – and
- to introduce a guard period that contains no payload information but only is used to compensate the delays told.

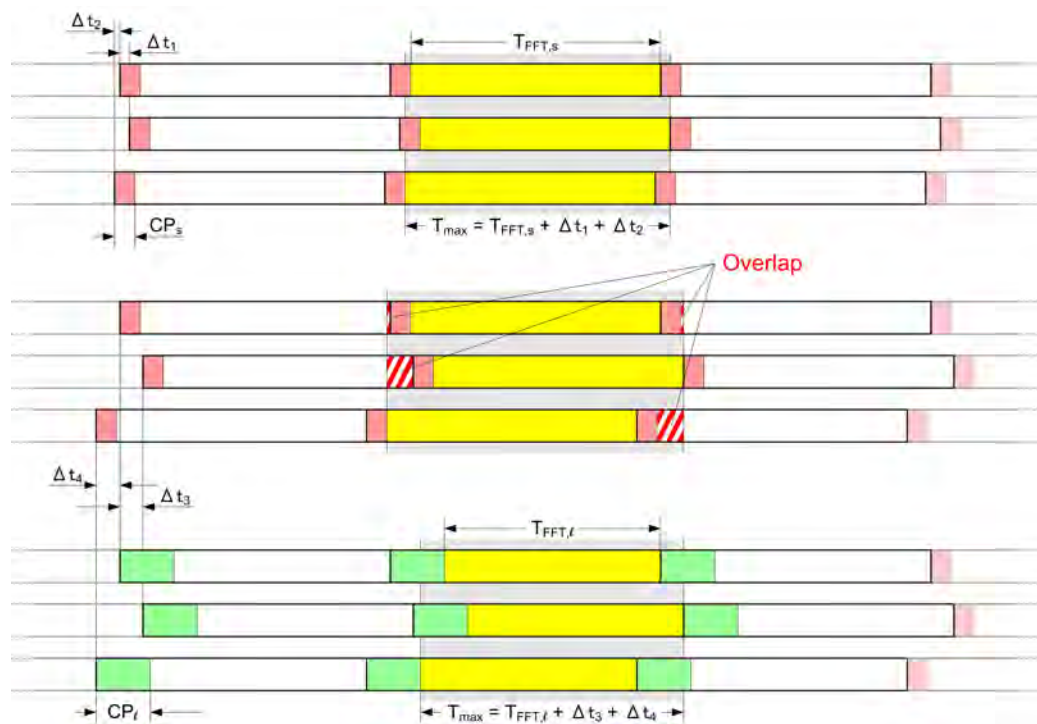


Fig. 3-54: Intersymbol interference.

top = Small time delays (Δt_1 positive, Δt_2 negative related to uppermost signal)
 center = Large time delays Δt_3 and Δt_4 : FFT range overlaps the one of neighbor symbol
 bottom = Large time delays: smaller FFT range and larger CP, no overlapping
 yellow = FFT range
 red, green = Cyclic Prefix (CP)

So, the first diagram in the figure shows a situation of "moderate" delays, the upper one of the signals with a "positive", Δt_1 , and the lower one with a "negative" delay, Δt_2 , versus the "reference" signal. The guard period, called "Cyclic Prefix" (CP) and shown in red, inhibits an intermixing of the interesting FFT periods (yellow), length $T_{FFT,s}$ ("short delay"), to the ones of adjacent symbols – the maximum time occupied by all delayed FFT periods is T_{max} .

The larger delays Δt_3 and Δt_4 in the second diagram now would cause such an intermixing and therefore overlaps (hatched); the only possible way out would be to provide longer CPs as depicted in the third diagram: then, again, an intermixing is inhibited, but at the cost of (assumed a constant overall symbol duration) less space (i.e. time: $T_{FFT,l}$ for "long delay") to accommodate payload data.

How frames are organized with LTE can be seen in [figure 3-55](#): The basic frame has a duration of 10 ms and is divided into 10 subframes of 1 ms each; a further dividing of the subframes is done into two slots therefore lasting 500 μs each. A slot contains the OFDM symbols consisting of the guard period (CP) and the payload data occupying the FFT period as told above. The continuous monitoring of the channels in question being performed leads to a higher (in case of little disturbance) or lower order (for "bad" channels) of modulation on the one hand and to a shorter or longer CP between the payload data on the other hand.

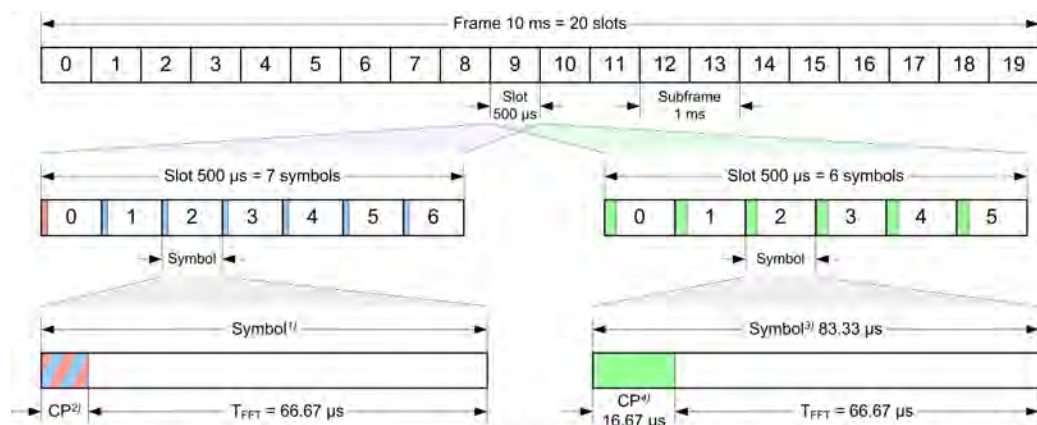


Fig. 3-55: Frame structure.

CP = Cyclic Prefix

- ¹⁾ = Symbol length: 71.875 μs (Symbol 0), 71.354 μs (Symbol 1 to 6), 71.429 μs (average)
- ²⁾ = CP length (count of samples given for FFT size 128): 5.208 μs = 10 samples (Symbol 0), 4.688 μs = 9 samples (Symbol 1 to 6), 4.761 μs = 9.143 samples (average)
- ³⁾ = Symbol length: 83.333 μs (Symbol 0 to 5)
- ⁴⁾ = CP length (count of samples given for FFT size 128): 16.667 μs = 32 samples (Symbol 0 to 5)

Thus, the left part of the figure tells the scenario with the shorter CPs and the right part with the longer ones. The fact that more time is consumed in the latter case for the CP, but the FFT period is of unalterable length results in a reduced count of OFDM symbols: only six (Symbol 0 to 5) instead of seven (Symbol 0 to 6) in the former case. Be also aware in this context that the fixed slot duration induces a varying CP length with the short CPs: the CP in Symbol 0 is slightly longer than the CPs in all other symbols. All relevant timing information for some transmission bandwidths currently defined can be taken from [table 3-21](#).

Table 3-21: Characteristics of LTE bandwidths.

Transmission bandwidth [MHz]	1.25	1.6	2.5	5	10	15	20
Subcarrier bandwidth [kHz]	15						
Sampling frequency [MHz]	1.92		3.84	7.68	15.36	23.04	30.72
Sample duration [ns]	520.8		260.4	130.2	65.1	43.4	32.6
FFT size	128		256	512	1024	1536 (DFT)	2048
CP length [μs]	Short	Symbol 0	5.208				
		Symbol 1 to 6	4.668				
	Long		16.667				
CP length [samples]	Short	Symbol 0	10	20	40	80	120
		Symbol 1 to 6	9	18	36	72	108
	Long		32	64	128	256	384
PRB bandwidth [kHz]	180						
Number of PRBs	6		12	25	50	75	100

As shown in the table, bandwidth of the subcarriers is fixed to 15 kHz with LTE, whereas overall transmission bandwidths can be selected in a flexible way; the subcarrier concept implies that even an individual transmission bandwidth can be split into several frequency bands. However, the transparent allocation with OFDMA (see [figure 3-52](#)) is not done on a basis of single subcarriers (in frequency domain) or single OFDMA symbols (in time domain), but the smallest information unit to dispose is the physical resource block (PRB). As can be seen from [figure 3-56](#), a PRB consists of one slot (6 or 7 symbols) in time and 12 subcarriers in frequency dimension. 1 subcarrier during 1 symbol is called a resource element.

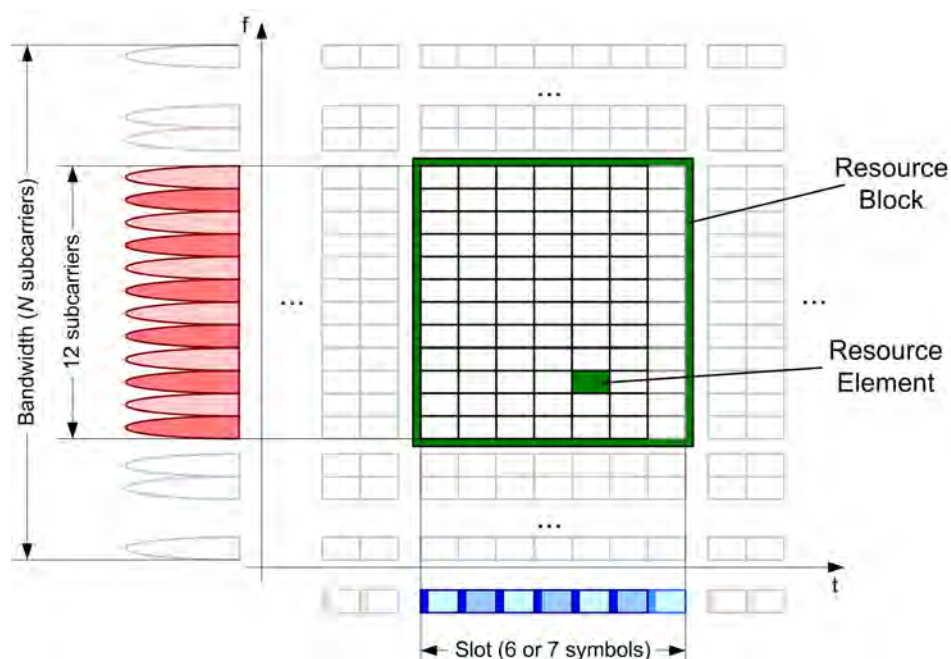


Fig. 3-56: Physical resource block (PRB) and resource element.

Details about physical and logical channels (control channels, transport channels etc.) as well as about types and architecture of the frames in use with them are not given in this short overview. If in need of more specific information, refer to relevant documentation, e.g. the basic [standards](#).

3.60.3.5 Frequency Band

Instead of a detailed presentation of the frequency bands in use in different countries of the world (the situation is rather difficult to grasp and also on the move, thus use relevant publications for more detailed information), [table 3-22](#) comprises the bands defined so far with the standard. Also told is the ordinal number (the "name") of each individual band; a claim to completeness of whatever kind is not implied on that.

Table 3-22: LTE frequency bands (FDD only).

No. of band	Range [MHz]	Frequencies [MHz]		Bandwidths [kHz]	Region
		Downlink	Uplink		
1	2100	2110 to 2170	1920 to 1980	5, 10, 15, 20	Europe, Asia
2	1900	1850 to 1910	1930 to 1990	1.4, 3, 5, 10, 15, 20	Asia, U.S.
3	1800	1710 to 1785	1805 to 1880	1.4, 3, 5, 10, 15, 20	EU, Asia, U.S.
4	1700	1710 to 1755	2110 to 2155	1.4, 3, 5, 10, 15, 20	U.S.
5	850	824 to 849	869 to 894	1.4, 3, 5, 10	U.S., South Korea, Israel
7	2600	2500 to 2570	2620 to 2690	5, 10, 15, 20	Europe, Asia, Canada
8	900	880 to 915	925 to 960	1.4, 3, 5, 10	Europe, Japan
12	700	699 to 716	729 to 746	1.4, 3, 5, 10	U.S.
13	700	777 to 787	746 to 756	5, 10	U.S.
14	700	788 to 798	758 to 768	5, 10	U.S.
17	700	788 to 798	734 to 746	5, 10	U.S.
19	850	830 to 845	875 to 890	5, 10, 15	Japan
20	800	832 to 862	791 to 821	5, 10, 15, 20	Europe
22	3500	3410 to 3490	3510 to 3590	5, 10, 15, 20	not yet known to be used
25	1900	1850 to 1915	1930 to 1995	1.4, 3, 5, 10, 15, 20	U.S.
26	850	814 to 849	859 to 894	1.4, 3, 5, 10, 15	U.S.

3.60.3.6 Operating Modes and Features

As with UMTS, the operating modes Frequency Division Duplex (FDD) and Time Division Duplex (TDD) also exist with LTE. Find an overview about this subject in [chapter 3.99, "UMTS"](#), on page 302 and more specific information in the basic [standard](#) and in relevant literature.

Also not described here is the core network related to LTE. LTE has its own access network consisting of a network of base stations, here called Evolved Node B (eNB), forming a flat architecture without a central intelligent controller in order to speed up the connection set-up and reduce the time required for a handover (handover time is essential for real-time services where end-users tend to end calls if the handover takes too long).

Another features found in LTE are

- **MIMO** (Multiple Input Multiple Output) data transmission using more than one antenna both on UE and on base station to increase system data rates and
- **MRC** (Maximal Ratio Combining) to enhance link reliability in challenging propagating conditions (multipath).

Consult relevant documentation, e.g. the basic [standards](#), if in need of more detailed information.

3.61 METEOSAT-WEFAX

3.61.1 General

Transmission method	METEOSAT-WEFAX
Explanation of name	METE Orological SAT ellite WE ather FAC Simile
Other designations	METEOSAT WEFAX
Variants existing	
Derived from method	
Typical users	
Kind of data	Weather maps and data from satellite
Reference to standard	
Frequency band	VHF/UHF
Modulation method	Indirect FM, AM
Shift/tone spacing	
Baud rate	(240 rpm [Rotations Per Minute], IOC 288 [Index Of Cooperation])
Modulating subcarrier	
Bandwidth	40 kHz
Operating method	Broadcast
Data protection	
Code table	

3.61.2 History

The [Meteosat](#) (Meteorological Satellite) series of satellites are geostationary meteorological satellites operated by [EUMETSAT](#) (**EU**ropean Organisation for the Exploitation of **METE**orological **SAT**ellites). The first generation of Meteosat satellites, Meteosat-1 to Meteosat-7, provide continuous and reliable meteorological observations from space to a large user community. At the end of June 2007 Meteosat-6, -7, -8 and -9 were all operational. Meteosat-6 and -7 are stationed over the Indian Ocean. Meteosat-8 and -9 are both located over Africa with various differences in operational configuration.

3.61.3 Description

In addition to the provision of images of the Earth and its atmosphere every half-hour, a range of processed meteorological products is produced. Meteosat also supports the

retransmission of data from data collection platforms in remote locations, at sea and on board aircraft, as well as the dissemination of meteorological information in graphical and text formats. The METEOSAT method is specifically tailored to the transmissions of the meteorological satellites parked in geostationary orbit at 0.2 degrees East and transmitting on 1691.0 MHz (the international standard broadcast frequency for WEFAX transmissions is 1691.0 MHz, but some systems, such as EUMETSAT's Meteosat, also transmit WEFAX on 1694.5 MHz). In contrast to HF-FAX/PRESSFAX/WEATHER-FAX (see [chapter 3.57, "HF-FAX \(FM\)"](#), on page 159), operation is on VHF/UHF, and 256 shades of grey are used.

3.62 MIL-STD-188-110A

3.62.1 General

Transmission method	MIL-STD-188-110A¹⁾
Explanation of name	MIL itary STanDard 188 (series related to telecommunications)
Other designations	MIL-STD-188-110A serial STANAG 4415 (STAN dardization AG reement) (in case of 75 bit/s)
Variants existing	
Derived from method	
Typical users	All departments and agencies of the U.S. Department of Defense Embassies of numerous states (e.g. in case of failure of conventional telephone network or satellite link)
Kind of data	(Universal data)
Reference to standard	MIL-STD-188-110A ¹⁾ : Military Standard " <i>Interoperability and Performance Standards for Data Modems</i> " (U.S. Department of Defense [DoD], Sept. 30, 1991), Chapter 5.3: " <i>HF Data Modems</i> "
Frequency band	HF
Modulation method	PSK8
Shift/tone spacing	
Baud rate	2400 Bd User data rates: • 75 bit/s, 150 bit/s, 300 bit/s, 600 bit/s, 1200 bit/s, 2400 bit/s, 4800 bit/s
Modulating subcarrier	1800 Hz
Bandwidth	3 kHz
Operating method	Simplex, Broadcast
Data protection	FEC or (4800 bit/s only) uncoded, interleaving
Code table	Bit transparent (no limitation to special kind of data)

¹⁾ *supersedes MIL-STD-188-110 of Nov. 15, 1980*

3.62.2 Description

3.62.2.1 Scope

MIL-STD-188-110A is one of the most popular modes in HF data modems. It employs PSK8 on a single carrier frequency of 1800 Hz as the fixed modulation technique for the data transmission. The constant baud rate is 2400 Bd whereas the actual user data rate can vary from 75 bit/s to 4800 bit/s. FEC coding is performed with rates from 1/2 to 1/8, depending on the user data rate, and interleaving is available in a "none" (0 s), a short (0.6 s) and a long version (4.8 s). No FEC coding and also no interleaving is done with 4800 bit/s.

Each transmission starts with a synchronisation preamble, followed by the data section of unlimited (indefinite) length. This data is organized into pairs of user data (called "unknown data") and channel probes (called "known data"), the length in symbols of which is also changing with the data rate active. A fixed EOM sequence terminates the transmission.

3.62.2.2 Modulation

Modulation used with MIL-STD-188-110A is PSK8, the constellation diagram can be seen in figure 3-57. Also given are numbering of the tribits from 0 to 7 and bit combinations allocated to each phase state. Mind that the count of bits taken from the incoming data bit stream to form a channel symbol varies from 3 bits to 1 bit, depending on the original user data rate (all cases are shown in table 3-25); in other words, with only 1 bit or only 2 bits used instead of the permissible 3 bits, in reality the situation of a PSK4 or PSK2 exists, respectively. A PSK8 is the result anyhow, because output of the allocation process is always a tribit (only tribit 0 and tribit 4 possible with 1 bit/symbol, and only tribits 0, 2, 4 and 6 with 2 bits/symbol), and before yielding the obtained tribits to the modulator, a scrambling process (3.62.2.4, "Framing") is performed delivering a "real" PSK8.



Fig. 3-57: Modulation constellation diagram and bit numbering.

3.62.2.3 Coding, Interleaving

The user data being arbitrary in principle ([standard](#) open to any kind of user data) are first FEC coded. In use is a convolutional encoder with a constraint length of 7 and a code rate of 1/2. The generator polynomials are

$$g(x) = x^6 + x^4 + x^3 + x + 1$$

$$g(x) = x^6 + x^5 + x^4 + x^3 + 1$$

The user data rates of 2400 bit/s, 1200 bit/s and 600 bit/s generate coded bit rates of 4800 bit/s, 2400 bit/s and 1200 bit/s, respectively. For 300 bit/s data rate the output bits are repeated twice and for 150 bit/s four times in order to achieve a 1200 bit/s rate, too. At 75 bit/s data rate a completely different transmit format (see [3.62.2.4, "Framing"](#)) is used; the coded bit rate produced by only the FEC encoder is 150 bit/s.

The next operation to perform is an interleaving process of three interleaver lengths: 0 s (no interleaving at all), 0.6 s (short interleaver setting) and 4.8 s (long interleaver setting), these lengths being constant, i.e. independent of the user data rate currently active. Therefore, the length of the interleaver matrix varies with the individual user data rate; see details about interleaving in the [standard](#).

In all cases where two (data rates 75 bit/s and 1200 bit/s) or three (2400 bit/s and 4800 bit/s) bits form a channel symbol, a code translation is done to the two- or three-bit words, respectively, with the objective to obtain, if single-bit errors happen, an adjacent symbol and not a distant one, i.e. to minimize the impact of the bit error to the overall error. This approach is used with the known Gray code, thus this code translation is called Modified Gray Decoding (MGD); [table 3-23](#) and [table 3-24](#) show the translation.

Table 3-23: Modified Gray Decoding, two-bit words.

Symbol	0	1	2	3
Dibit	00	01	10	11
MGD Dibit	00	01	11	10

Table 3-24: Modified Gray Decoding, three-bit words.

Symbol	0	1	2	3	4	5	6	7
Tribit	000	001	010	011	100	101	110	111
MGD Tribit	000	001	011	010	111	110	100	101

3.62.2.4 Framing

Data Phase

The "central" part of a transmission is the *data phase*; to the coded and interleaved data (the *message section*, see 3.62.2.3, "Coding, Interleaving"), synchronization information is added, i.e. training bits (also called *channel probes*) to enable the receiver to determine correct bit layout. Due to the user data being arbitrary, they in the following are called **unknown data**, whereas the synchronization bits are called **known data**. The length ratio of known vs. unknown data (or channel probe section length vs. message section length) again varies with the user data rate; the situation can be seen from table 3-25. Again, be aware that with the 75 bit/s user data rate a different transmit format described below is in use.

Table 3-25: Waveform parameters forming baud rate.

User data rate [bit/s]		4800	2400	1200	600	300	150	75
Code rate		1	1/2	1/2	1/2	1/4	1/8	1/2
Bit sequence	Unknown data	32	32	20	20	20	20	All
	Known data	16	16	20	20	20	20	None
Bits/symbol		3	3	2	1	1	1	2

From all parameters of influence explained so far, the baud rate resulting can be calculated as

$$\text{Baud rate} = \frac{\text{User data rate}}{\text{Code rate}} \cdot \frac{\text{bits}U + \text{bits}K}{\text{bits}U} \cdot \frac{1}{\text{Bits/sym}} \quad (3 - 1)$$

with

Code rate (see table 3-25)

bitsU unknown bits (bits in message section)

bitsK known bits (bits in channel probe section)

Bits/sym (see [table 3-25](#))

As told above ([3.62.2.1, "Scope"](#)), the baud rate is always 2400 Bd.

Data rate 75 bit/s

In the 75 bit/s user data rate case, two (not only one) bits are taken to form a channel symbol; unlike all other data rates, no channel probes are sent and no repeated coding is in progress. Instead, the tribit numbers 0 and 4 (see [figure 3-57](#)) are used to form four different sequences of four consecutive symbols each, each of which is repeated eight times (leading to a 32-tribit sequence) corresponding to the two-bit combination to be mapped. 2 bits/symbol, code rate 1/2, no known bits (*bitsK* = 0) together with the 32-times sequence (32-times repetition) again result ([equation 3-1](#)) in a baud rate of 2400 Bd.

The mapping can be taken from [table 3-26](#); alternative mappings (for details consult the [standard](#)) exist for exceptional cases.

Table 3-26: Channel symbol mapping for 75 bit/s (tribit sequences to repeat 8 times).

Channel symbol	Tribit sequence	Channel symbol	Tribit sequence
00	0 0 0 0	10	0 0 4 4
01	0 4 0 4	11	0 4 4 0

Scrambling

After having decided the channel symbols, a scrambling process is performed to them (more precisely: to the bit stream made of three bit elements at the output of the symbol formation) with pseudo-random three bit numbers, so that the waveform after that appears as "real" 8-ary tribit numbers (resulting in a "real" PSK8) regardless of the current user data rate. Find more details about scrambling and later-on descrambling in the [standard](#).

Synchronization Preamble

Any message is initiated by a synchronization preamble (it immediately precedes the data phase); its length is 0.6 s for the no interleaving and short interleaving cases and 4.8 s for the long interleaving case, i.e. either 3 or 24 segments of 200 ms duration. Each of these 200-ms segments consists of a fixed sequence of three-bit channel symbols (cf [figure 3-57](#)), this sequence is

0 1 3 0 1 3 1 2 0 *D1 D2 C1 C2 C3* 0

where *D1* and *D2* represent the data rate and interleaver setting currently active, see [table 3-27](#), and *C1*, *C2* and *C3* are used to count the 200 ms segments mentioned (starting at 2 or 23, respectively, and counting down to 0). Representation is just a six-bit word, formed from three two-bit words, *C1* being the most significant word. Extension from the two-bit original to the three-bit result requested is performed by just adding a leading '1' (what of course is equivalent to just adding 4 to the two-bit value).

Example:

Value: $19_{10} = 01\ 00\ 11_2$ (just write number in binary form)
Representation: $1\ 01_2, 1\ 00_2, 1\ 11_2$ (add a leading '1' to each two-bit group)
Channel symbols: $C1 = 5_{10}, C2 = 4_{10}, C3 = 7_{10}$ (write resulting three-bit groups in decimal form)

Table 3-27: Preamble symbols D1 and D2.

Bit rate [bit/s]		4800	2400	1200	600	300	150	75
Short interleave	D1	7	6	6	6	6	7	7
	D2	6	4	5	6	7	4	5
Long interleave	D1	—	4	4	4	4	5	5
	D2	—	4	5	6	7	4	5

Converting of the 75 Bd baud rate that would result from this process (5 segments per second containing 15 symbols each) to the mandatory 2400 Bd is done a similar way as described in [table 3-26](#); the difference is that not four-tribit sequences are repeated eight times but eight-tribit sequences four times. See [table 3-28](#) for the complete mapping and the [standard](#) for more detailed information.

Table 3-28: Channel symbol mapping for synchronization preamble (tribit sequences to repeat 4 times).

Channel symbol	Tribit sequence	Channel symbol	Tribit sequence
000	0 0 0 0 0 0 0 0	100	0 0 0 0 4 4 4 4
001	0 4 0 4 0 4 0 4	101	0 4 0 4 4 0 4 0
010	0 0 4 4 0 0 4 4	110	0 0 4 4 4 4 0 0
011	0 4 4 0 0 4 4 0	111	0 4 4 0 4 0 0 4

EOM Phase

When the end of the message is reached (no additional data to transmit), a fixed EOM (End Of Message) pattern (4 byte or 32 bit) is sent as the termination sequence. This constant pattern is

$4B65\ A5B2_{16}$ (hex.) = $0100\ 1011\ 0110\ 0101\ 1010\ 0101\ 1011\ 0010_2$ (binary)

The FEC encoder and the interleaver (if in use) are to be flushed (cleared) then, this is described in detail in the [standard](#).

3.63 MIL-STD-188-110A (Appendix A)

3.63.1 General

Transmission method	MIL-STD-188-110A¹⁾ (Appendix A)²⁾
Explanation of name	MIL itary STanDard 188 (series related to telecommunications)
Other designations	MIL-STD-188-110A Parallel Tone MIL-STD-188-110 16 Tone
Variants existing	
Derived from method	
Typical users	All departments and agencies of the U.S. Department of Defense (DoD)
Kind of data	(Universal data)
Reference to standard	MIL-STD-188-110A ¹⁾ : Military Standard " <i>Interoperability and Performance Standards for Data Modems</i> " (U.S. Department of Defense [DoD], Sept. 30, 1991), Appendix A (non-mandatory part): " <i>16-Tone Differential Phase-Shift Keying (DPSK) Mode</i> "
Frequency band	HF
Modulation method	16-tone DPSK (PSK2 and PSK4): • frequencies from 935 Hz to 2585 Hz • 1 Doppler tone at 605 Hz • 1 synchronization tone at 825 Hz
Shift/tone spacing	110 Hz
Baud rate	75 Bd User data rates: • 75 bit/s, 150 bit/s, 300 bit/s, 600 bit/s (PSK2) • 1200 bit/s, 2400 bit/s (PSK4)
Modulating subcarrier	1760 Hz
Bandwidth	
Operating method	Simplex, broadcast
Data protection	In-band diversity combining ³⁾ : • 75 bit/s to 1200 bit/s
Code table	

¹⁾ *supersedes MIL-STD-188-110 of Nov. 15, 1980*

²⁾ *also Appendix A to MIL-STD-188-110B (of April 27, 2000, superseding MIL-STD-188-110A)*

³⁾ *A combining of two or more signals which uses frequencies within the bandwidth of the information channel and carries the same information received with the objective of providing a single resultant signal that is superior in quality to any of the contributing signals*

3.63.2 Description

In MIL-STD-188-110A (Appendix A) an **OFDM** (Orthogonal Frequency Division Multiplex) modulation technique is used: 16 orthogonal subcarriers in the frequency range of 935 Hz to 2585 Hz are **PSK** modulated the way that a fixed baud rate of 75 Bd arises in any case. This is obtained by – if the user data speed is higher than 75 bit/s (only power-of-two multiples of the baud rate permitted) – "spreading" the bit stream to more than one carrier (tone). In [table 3-29](#) the details are given: all 16 data tones are always in use, if less would essentially be needed, several tones (order in a cyclic manner) convey the same information (called in-band diversity combining).

Table 3-29: Tone frequencies and modulating bits.

Data rate [bit/s]		2400	1200	600	300	150	75			2400	1200	600	300	150	75
Bits/symbol		32	16	8	4	2	1			32	16	8	4	2	1
Modulation		PSK4		PSK2						PSK4		PSK2			
f [Hz]	Tn.	Bit position						f [Hz]	Tn.	Bit position					
935	1	1, 2	1, 2	1	1	1	1	1815	9	17, 18	1, 2	1	1	1	1
1045	2	3, 4	3, 4	2	2	2	1	1925	10	19, 20	3, 4	2	2	2	1
1155	3	5, 6	5, 6	3	3	1	1	2035	11	21, 22	5, 6	3	3	1	1
1265	4	7, 8	7, 8	4	4	2	1	2145	12	23, 24	7, 8	4	4	2	1
1375	5	9, 10	9, 10	5	1	1	1	2255	13	25, 26	9, 10	5	1	1	1
1485	6	11, 12	11, 12	6	2	2	1	2365	14	27, 28	11, 12	6	2	2	1
1595	7	13, 14	13, 14	7	3	1	1	2475	15	29, 30	13, 14	7	3	1	1
1705	8	15, 16	15, 16	8	4	2	1	2585	16	31, 32	15, 16	8	4	2	1
605	Pilot/Doppler						825	Synchronization							

The modulation method applied is either PSK2 (DBPSK, data rates 75 bit/s to 600 bit/s) or PSK4 (DQPSK, 1200 bit/s and 2400 bit/s); each bit (PSK2) or two bits (PSK4) raise(s) a phase change of the tone relative to the phase state of the immediately preceding signal element. The phase diagram can be seen in [figure 3-58](#).

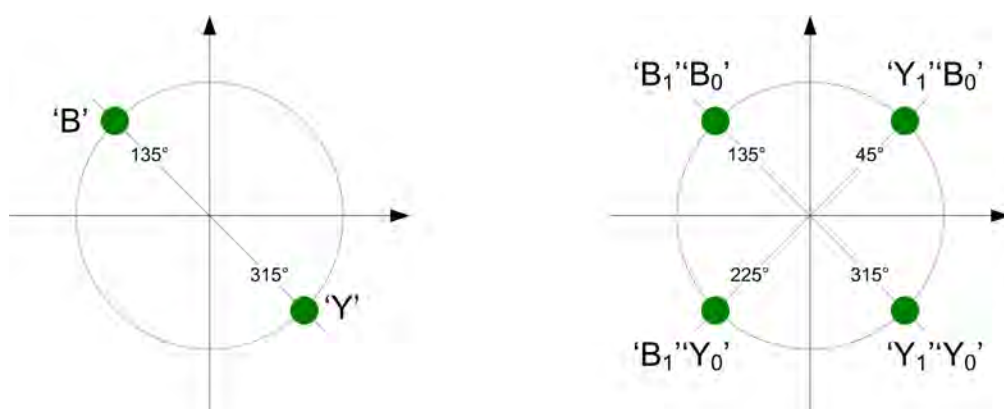


Fig. 3-58: Phase diagram for PSK2 (left) and PSK4 (right) with 16-tone modem.

Y = mark
 B = space
 1 = first (left) bit
 0 = second (right) bit

See [chapter 2.3, "PSKn"](#), on page 14 for details about PSK2 and PSK4; but mind that the mapping between modulating bits and phase changes here is different from the one told there.

For more clearness, [figure 3-59](#) and [figure 3-60](#) again show the situation: In [figure 3-59](#) the tone frequencies are given in a spectral representation using different colors, whereas [figure 3-60](#) tells assigning of the individual bits of the bit stream to these frequencies. From 32 bits (2400 bit/s, **A** in the figure) down to just 1 bit (75 bit/s, **F**) are extracted from the original bit stream to transmit for modulating the current symbol due to the data rate in operation.



Fig. 3-59: Tone frequencies in spectral representation.

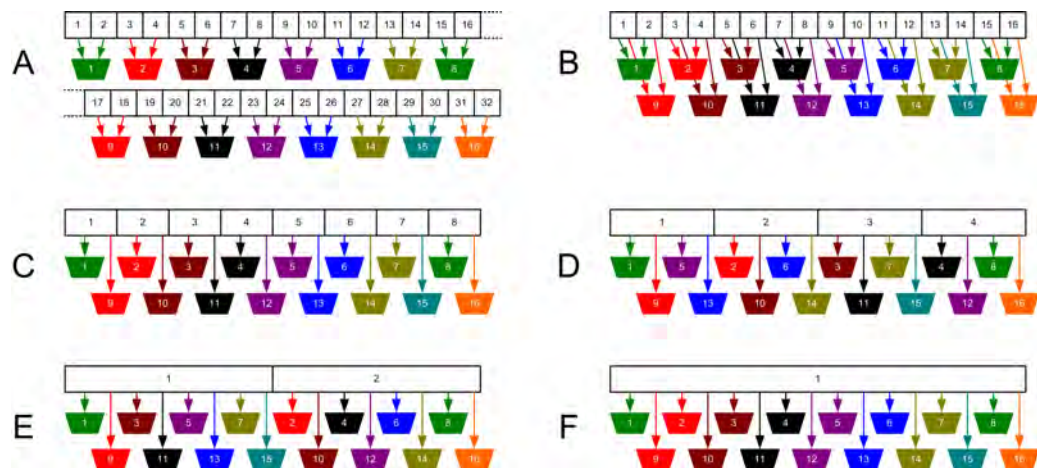


Fig. 3-60: Assigning bits to frequencies.

top = bit sequence to accommodate in 1 symbol

bottom = tone frequencies, cf [figure 3-59](#)

A = 2400 bit/s, PSK4: 2 bits per tone, 32 bits per symbol

B = 1200 bit/s, PSK4: 2 bits per tone, 16 bits per symbol

C = 600 bit/s, PSK2: 1 bit per tone, 8 bits per symbol

D = 300 bit/s, PSK2: 1 bit per tone, 4 bits per symbol

E = 150 bit/s, PSK2: 1 bit per tone, 2 bits per symbol

F = 75 bit/s, PSK2: 1 bit per tone, 1 bit per symbol

As an example, with a data rate of 300 bit/s (4 times the target baud rate, **D** in the figure), groups of 4 bits each are formed, the 1st (leftmost) bits of which are allocated to the 1st tone (and also the 5th, 9th and 13th), the 2nd, 3rd and 4th bits are treated correspondingly (2nd/6th/10th/14th tone for the 2nd bit and so on). Each tone is then modulated with PSK2 as told before. With, as another example, 1200 bit/s data rate and therefore PSK4 to be used, two bits are collected a time (**B**); the 1st and 2nd bit modulate the 1st (and the 9th) tone, the 3rd and 4th bit the 2nd (and 10th) tone and so on. In the 2400 bit/s case, all 16 tones are needed for the 32 bits to accommodate, so no redundancy is left.

Upon receipt of a transmit command, a synchronization process is initiated. As a preamble, the two tones 605 Hz and 1705 Hz are activated for a minimum duration of 66.67 ms (5 data tone elements/modulation steps), maximum 426.67 ms (32 data tone elements). During this period, the 1705 Hz tone is phase shifted by 180° for each tone element (13.33 ms), this sequence is to be used for proper modem synchronization, whereas the 605 Hz tone (can be considered a pilot tone) remains unmodulated and can help establishing or maintaining Doppler correction if needed. At the completion of the preamble, all data tones are transmitted for the duration of one signal element prior to the transmission of data to establish a phase reference.

During transmission, synchronization can be maintained via the 825 Hz tone by sampling its signal energy. Therefore, conveying a signal carrying other information in this synchronization slot is not permitted.

As told above, the tone at the frequency of 605 Hz serves as a means to perform Doppler correction; its level surpasses the level of any other carrier by 7 dB.

3.64 MIL-STD-188-110A (Appendix B)

3.64.1 General

Transmission method	MIL-STD-188-110A¹⁾ (Appendix B)²⁾
Explanation of name	MIL itary STanDard 188 (series related to telecommunications)
Other designations	MIL-STD-188-110A Parallel Tone MIL-STD-188-110 39 Tone
Variants existing	
Derived from method	
Typical users	All departments and agencies of the U.S. Department of Defense (DoD)
Kind of data	(Universal data)
Reference to standard	MIL-STD-188-110A ¹⁾ : Military Standard " <i>Interoperability and Performance Standards for Data Modems</i> " (U.S. Department of Defense [DoD], Sept. 30, 1991), Appendix B (non-mandatory part): " <i>39-Tone Parallel Mode</i> "
Frequency band	HF
Modulation method	39-tone DPSK (PSK4) : - frequencies from 675 Hz to 2812.5 Hz 1 Doppler tone at 393.75 Hz
Shift/tone spacing	56.25 Hz
Baud rate	44.44 Bd User data rates: 75 bit/s, 150 bit/s, 300 bit/s, 600 bit/s, 1200 bit/s, 2400 bit/s
Modulating subcarrier	1800 Hz
Bandwidth	
Operating method	Simplex, broadcast
Data protection	FEC In-band diversity combining ³⁾ : 75 bit/s to 600 bit/s 1200 bit/s (partially)
Code table	Bit-transparent (no limitation to special kind of data)

¹⁾ *supersedes MIL-STD-188-110 of Nov. 15, 1980*

²⁾ *also Appendix B to MIL-STD-188-110B (of April 27, 2000, superseding MIL-STD-188-110A)*

³⁾ *A combining of two or more signals which uses frequencies within the bandwidth of the information channel and carries the same information received with the objective of providing a single resultant signal that is superior in quality to any of the contributing signals*

3.64.2 Description

3.64.2.1 Synchronous Mode

In MIL-STD-188-110A (Appendix B) an **OFDM** (Orthogonal Frequency Division Multiplex) modulation technique is used. 39 orthogonal subcarriers in the frequency range of 675 Hz to 2812.5 Hz are **PSK4** modulated the way that, although data rates can vary from 75 bit/s to 2400 bit/s, a fixed baud rate of 44.44 Bd arises in any case. This is obtained by "spreading" the bit stream to more than one carrier (tone). In [table 3-30](#) the details are given: all 39 data tones are always in use, if less would essentially be needed, several tones (order in a cyclic manner) convey the same information (called in-band diversity combining). Additionally, a distinction is done between only frequency diversity or both frequency and time diversity at a time, see below.

Table 3-30: Tone frequencies and modulating bits.

Data rate [bit/s]		2400	1200	600	300	150	75
Bits per symbol		32	16	8	4	2	1
f [Hz]	Function of tone	Bit sequence position/data word ¹⁾ of bits modulating carrier					
393.75	Pilot/Doppler						
675.00	1	1, 2	1, 2	1, 2	1, 2	1, 2	1, 2
731.25	2	3, 4	3, 4	3, 4	3, 4	3, 4	3, 4
787.50	3	5, 6	5, 6	5, 6	5, 6	5, 6	5, 6
843.75	4	7, 8	7, 8	7, 8	7, 8	7, 8	7, 8
900.00	5	9, 10	9, 10	9, 10	9, 10	9, 10	9, 10
956.25	6	11, 12	11, 12	11, 12	11, 12	11, 12	11, 12
1012.50	7	13, 14	13, 14	13, 14	13, 14	13, 14	13, 14
1068.75	8	15, 16	15, 16	15, 16	15, 16	15, 16	15, 16
1125.00	9	17, 18	17, 18	17, 18	17, 18	17, 18	17, 18
1181.25	10	19, 20	19, 20	19, 20	19, 20	19, 20	19, 20
1237.50	11	21, 22	21, 22	21, 22	21, 22	21, 22	21, 22
1293.75	12	23, 24	23, 24	23, 24	23, 24	23, 24	23, 24
1350.00	13	25, 26	25, 26	25, 26	25, 26	25, 26	25, 26
1406.25	14	27, 28	27, 28	27, 28	27, 28	27, 28	27, 28
1462.50	15	29, 30	29, 30	29, 30	29, 30	29, 30	29, 30
1518.75	16	31, 32	31, 32	31, 32	31, 32	31, 32	31, 32
1575.00	17	33, 34	33, 34	33, 34	33, 34	33, 34	33, 34
1631.25	18	35, 36	35, 36	35, 36	35, 36	35, 36	35, 36
1687.50	19	37, 38	37, 38	37, 38	37, 38	37, 38	37, 38
1743.75	20	39, 40	39, 40	39, 40	39, 40	39, 40	39, 40

Data rate [bit/s]		2400	1200	600	300	150	75
Bits per symbol		32	16	8	4	2	1
f [Hz]	Function of tone	Bit sequence position/data word ¹⁾ of bits modulating carrier					
1800.00	21	41, 42	41, 42	9, 10	9, 10	1, 2	1, 2
1856.25	22	43, 44	43, 44	11, 12	11, 12	3, 4	3, 4
1912.50	23	45, 46	45, 46	13, 14	13, 14	5, 6	1, 2
1968.75	24	47, 48	47, 48	15, 16	15, 16	7, 8	3, 4
2025.00	25	49, 50	49, 50	17, 18	1, 2	1, 2	1, 2
2081.25	26	51, 52	51, 52	19, 20	3, 4	3, 4	3, 4
2137.50	27	53, 54	53, 54	21, 22	5, 6	5, 6	1, 2
2193.75	28	55, 56	55, 56	23, 24	7, 8	7, 8	3, 4
2250.00	29	57, 58	57, 58	25, 26	9, 10	1, 2	1, 2
2306.25	30	59, 60	59, 60	27, 28	11, 12	3, 4	3, 4
2362.50	31	61, 62	61, 62	29, 30	13, 14	5, 6	1, 2
2418.75	32	63, 64	63, 64	31, 32	15, 16	7, 8	3, 4
2475.00	33	65, 66	1, 2	1, 2	1, 2	1, 2	1, 2
2531.25	34	67, 68	3, 4	3, 4	3, 4	3, 4	3, 4
2587.50	35	69, 70	5, 6	5, 6	5, 6	5, 6	1, 2
2643.75	36	71, 72	7, 8	7, 8	7, 8	7, 8	3, 4
2700.00	37	73, 74	9, 10	9, 10	9, 10	1, 2	1, 2
2756.25	38	75, 76	11, 12	11, 12	11, 12	3, 4	3, 4
2812.50	39	77, 78	13, 14	13, 14	13, 14	5, 6	1, 2

¹⁾ Only for "Both time and frequency diversity" variant

A 40th (unmodulated) tone of 393.75 Hz serves for Doppler correction.

The modulation method applied is PSK4 (DQPSK); each two bits raise a phase change of the tone relative to the phase state of the immediately preceding signal element. The phase diagram can be seen in [figure 3-58 \(chapter 3.63, "MIL-STD-188-110A \(Appendix A\)", on page 182\)](#).

The bits to be transmitted are grouped into sections of $64/d$ bits – hereby introducing $d = 1200/(\text{data rate})$. Thus with 1200 bit/s the first 32 tones carry the 64 bits to be conveyed per symbol, the remaining 7 repeat the first 14 of them. Correspondingly, with the lower data rates, more repetitions of the fewer bits necessary can be done along the tone series. With 2400 bit/s the composed blocks are 78 bits long and so fill up all 39 tones. Two modes are defined for spreading the user data bits to the tone frequencies:

- **Frequency-only diversity:**

This method is intended for backward compatibility with older modems and effects just a dispensing of the bits to the tones as explained above.

- **Both time and frequency diversity:**

In this case instead of a simple repetition an additional distribution of the data groups to the individual symbols is performed as shown in the table.

User data are arbitrary in principle and come with data rates from 75 bit/s to 2400 bit/s (power-of-two multiples). An FEC is done to them via a shortened Reed-Solomon (15,11) block code with the generator polynomial

$$g(x) = x^4 + a^{13}x^3 + a^6x^2 + a^3x + a^{10} ;$$

the code is shortened to (14/10) in the 2400 bit/s case and to (7/3) for all other data rates. An interleaving is then processed to the resulting data stream with several (selectable) interleaving degrees (eight degrees for 2400 bit/s and four degrees for all other data rates). A set of interleaved code is called a super block (cf [figure 3-61](#), **A** and **C**), thus the interleaving degree is defined as the number of data blocks forming a super block.

A demodulator determines the boundaries of super blocks by a framing information, i.e. block sync sequences. These sequences are known pseudo-random sequences occurring in the unknown data stream. The primitive polynomial

$$f(x) = x^9 + x^7 + x^6 + x^4 + 1$$

defines the sequence. Insertion happens at regular time intervals, the length of which as well as the length of the sequence itself vary with data rate and interleaving degree (the reason is that the resulting baud rate of 44.444 Bd has to be obtained); [table 3-31](#) shows all cases.

Table 3-31: Insertion of framing sequence.

Data rate [bit/s]	Data block	Length [bits, unless noted otherwise] of				
		Interleaving degree	Super block	Insertion interval		Sequence
75	28	1	28	567	15876	252
		4	112	234	26208	416
		12	336	75	25200	400
		36	1008	16	16128	256
150		1	28	576	16128	256
		9	252	100	25200	400
		25	700	36	25200	400
		81	2268	8	18144	288
300		1	28	567	15876	252
		17	476	54	25704	408
		47	1316	18	23688	376

Data rate [bit/s]	Data block	Length [bits, unless noted otherwise] of				
		Interleaving degree	Super block	[super blocks]	Insertion interval	Sequence
600		153	4284	4	17136	272
		1	28	567	15876	252
		33	924	30	27720	440
		99	2772	10	27720	440
		297	8316	2	16632	264
1200		1	28	567	15876	252
		63	1764	14	24696	392
		189	5292	6	31752	504
		567	15876	1	15876	252
2400	56	1	56	144	8064	256
		9	504	16	8064	256
		18	1008	12	12096	384
		27	1512	9	13608	432
		36	2016	7	14112	448
		72	4032	3	12096	384
		144	8064	1	8064	256
		288	16128	1	16128	512

Including these influences, the resulting baud rate (being constant as 44.444 Bd) is calculated as follows:

$$\text{Baud rate} = \frac{\text{User data rate}}{\text{Code rate}} \cdot \frac{\text{Bits in insertion interval} + \text{Bits in block sync}}{\text{Bits in insertion interval}} \cdot \frac{1}{\text{Bits/sym}}$$

with

Code rate 10/14 for 2400 bit/s and 3/7 for all other user data rates

Bits in insertion interval count of bits after which a block sync sequence is to be inserted

Bits in block sync length of block sync sequence in bits

Bits/sym count of bits conveyed in one symbol.

Two examples, one for 300 bit/s with interleaving degree 47:

$$\frac{300 \text{ bit/s}}{3/7} \cdot \frac{23688 + 376}{23688} \cdot \frac{1}{16} = 44.444 \text{ Bd}$$

and one for 2400 bit/s with 36:

$$\frac{2400 \text{ bit/s}}{10/14} \cdot \frac{14112 + 448}{14112} \cdot \frac{1}{78} = 44.444 \text{ Bd}$$

illustrate the situation. Of course, in reality the *Bits in block sync* value is calculated the way that the compulsory baud rate arises.

Prior to the transmission of data, a *three-part* preamble (figure 3-61, **A** and **B**) is transmitted:

- The *first part* lasts for 14 signal element periods (315 ms) and consists of unmodulated data tone 3 (787.5 Hz), tone 15 (1462.5 Hz), tone 27 (2137.5 Hz) and tone 39 (2812.5 Hz) with equal amplitude each.
- The *second part* lasts for 8 signal element periods (180 ms) and consists of modulated data tone 9 (1125.0 Hz), tone 21 (1800.0 Hz) and tone 33 (2475.0 Hz) with equal amplitude each, but advanced in phase by 180° at the boundary of each data signal element.
- The *third part* lasts for 1 signal element period (22.5 ms) and consists of all 39 data tones plus the Doppler correction tone (393.75 Hz).

Additionally, for improving synchronization probability and signal detection in situations of low SNR, an extended preamble can be selected, lasting 97 signal element periods (58 for the first part, 27 for the second and 12 for the third).

A schematic of timing is shown in figure 3-61, details about signal levels, initial phases and additional aspects of constructing the preamble can be found in the [standard](#).

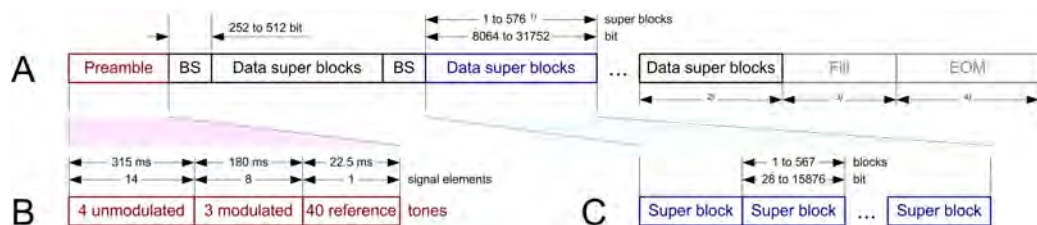


Fig. 3-61: Transmission sequence.

A = complete sequence

B = preamble

C = super blocks section

BS = Block Sync

1) = 1 to 594 with asynchronous mode (3.64.2.2)

2) = length unpredictable, sequence ends when all data transmitted

3) = EOM characters to fill last super block (at least 10, asynchronous mode only)

4) = additional EOM characters to fill minimum count of 10 (asynchronous mode only)

3.64.2.2 Asynchronous Mode

An asynchronous operation mode (accepting data with start and stop characters added) is also recommended in the [standard](#); it is not described here in detail. EOM (End Of Message) characters serve for indicating the end of a data sequence to the receiver; see figure 3-61.

3.65 MIL-STD-188-110B (Appendix C)

3.65.1 General

Transmission method	MIL-STD-188-110B¹⁾ (Appendix C)
Explanation of name	MIL itary ST andard 188 (series related to telecommunications)
Other designations	STANAG 4539 (ST andardization AG reement)
Variants existing	
Derived from method	
Typical users	All departments and agencies of the U.S. Department of Defense (DoD)
Kind of data	(Universal data)
Reference to standard	MIL-STD-188-110B ¹⁾ : Military Standard " <i>Interoperability and Performance Standards for Data Modems</i> " (U.S. Department of Defense [DoD], April 27, 2000), Appendix C (non-mandatory part): " <i>HF Data Modem Waveforms for Data Rates above 2400 bps</i> "
Frequency band	HF
Modulation method	• PSK: PSK4 ("4PSK"), PSK8 ("8PSK") • QAM: QAM16 ("16QAM"), QAM32 ("32QAM") and QAM64 ("64QAM")
Shift/tone spacing	
Baud rate	2400 Bd User data rates: • 3200 bit/s, 4800 bit/s, 6400 bit/s, 8000 bit/s, 9600 bit/s (all FEC coded) • 12800 bit/s (not FEC coded)
Modulating subcarrier	1800 Hz
Bandwidth	3 kHz
Operating method	Simplex, broadcast
Data protection	FEC or (12800 bit/s only) uncoded, interleaving
Code table	Bit-transparent (no limitation to special kind of data)

¹⁾ *supersedes MIL-STD-188-110A of Sept. 30, 1991, thus*

- *for Appendix A see [chapter 3.63](#), "[MIL-STD-188-110A \(Appendix A\)](#)", on page 182*
- *for Appendix B see [chapter 3.64](#), "[MIL-STD-188-110A \(Appendix B\)](#)", on page 186*

3.65.2 Description

3.65.2.1 Scope

MIL-STD-188-110B (Appendix C) covers specifications for modems of data rates above 2400 bit/s, i.e. the data rates from 3200 bit/s to 12800 bit/s. The baud rate used is constantly 2400 Bd, the modulation method is PSK or QAM (non-rectangular), depending on intended user data rate, to a single tone of 1800 Hz. Data rates, modulation methods and number of bits per symbol are given in [table 3-32](#).

Table 3-32: Modulation method for each user data rate.

Data rate [bit/s]	3200	4800	6400	8000	9600	12800
Modulation	PSK4 (QPSK)	PSK8	QAM16	QAM32	QAM64	QAM64 ¹⁾
Bits/symbol	2	3	4	5	6	6

¹⁾ no FEC coding

3.65.2.2 Coding, Interleaving

The arbitrary user data appearing with the data rates told in [table 3-32](#) are first subjected to a convolutional FEC coding (constraint length $l = 7$, code rate $r = 1/2$, punctured to $3/4$); but no FEC coding at all happens with the 12800 bit/s data rate. As the next step in protecting the data against corruption, a block interleaving process is applied: 6 different interleaving lengths result in interleaver block lengths of 120 ms to 8.64 s (find more detailed information about interleaving in the [standard](#)). The later-on accommodation of the obtained bit stream in the frame structure (see below) is done the way that interleaver blocks correspond to frame lengths.

3.65.2.3 Modulation

Modulation charts (constellation diagrams) are shown in [figure 3-62](#) for PSK4, PSK8 and QAM16 and in [figure 3-63](#) for QAM32 and QAM64. It can be seen that the arrangements for the QAM modes (non-rectangular QAM) differ completely from the traditional simple square shapes (rectangular QAM) found frequently with other transmission methods; sometimes arrangements like the ones on hand are rather called n-ary PSK/ASK.

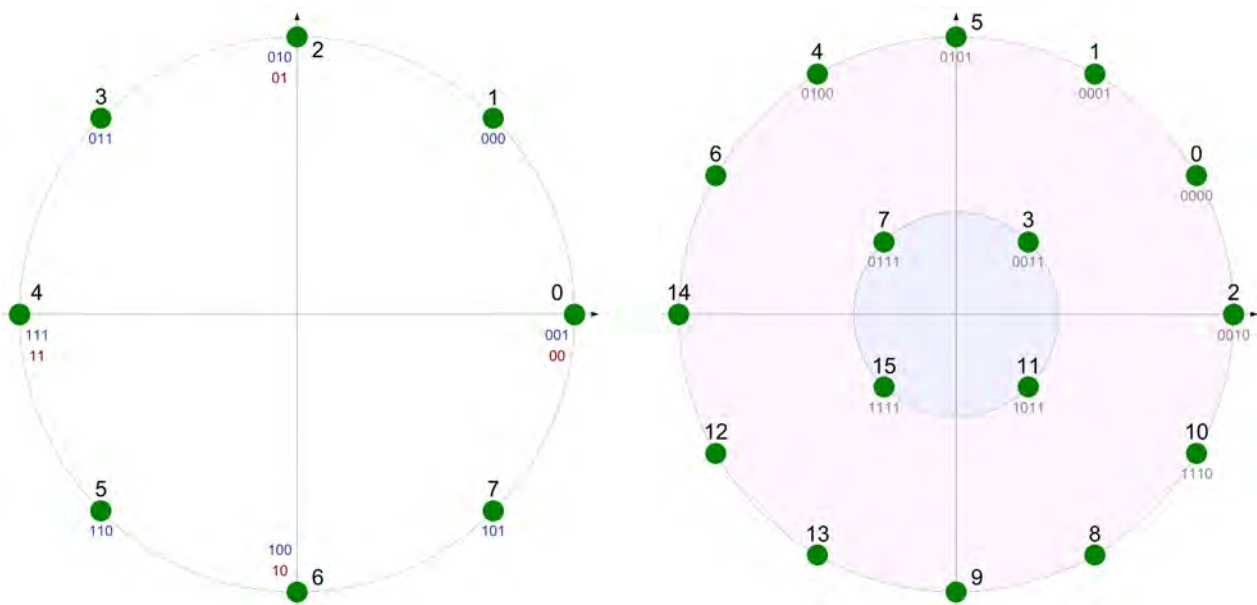


Fig. 3-62: Modulation constellation diagram with PSK8 (bit assignment shown in blue) and PSK4 (red) (left) and QAM16 (right).

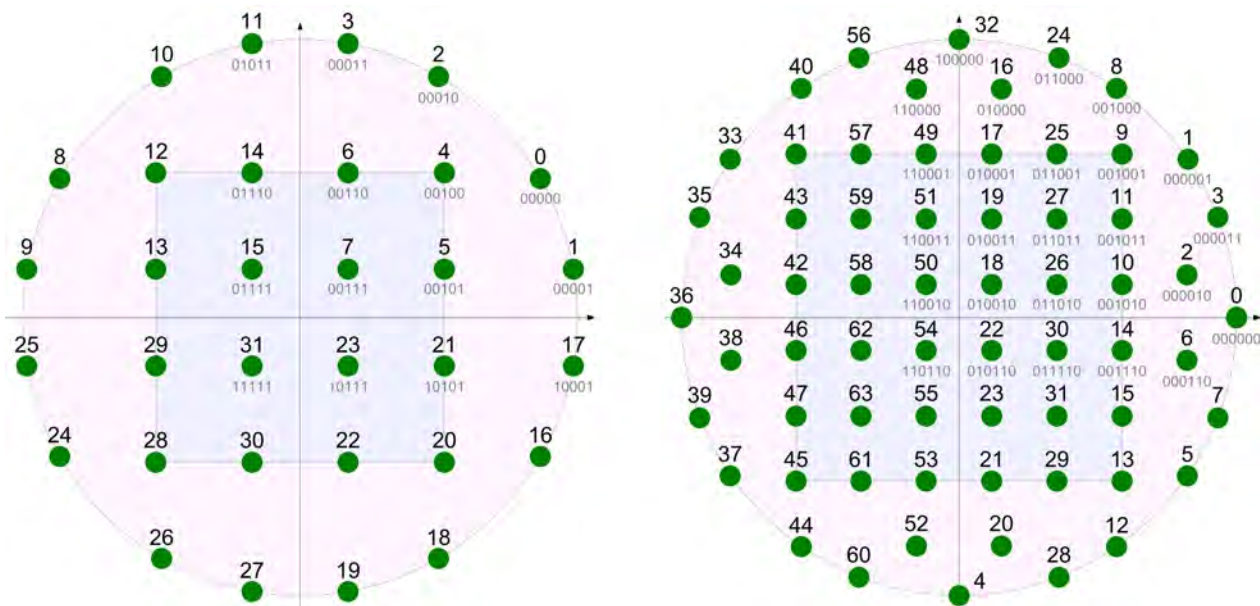


Fig. 3-63: Modulation constellation diagram with QAM32 (left) and QAM64 (right).

Numbering of the phase states for PSK (figure 3-62, left) is done simply counter-clockwise, but assignment of the bits (two for PSK4, three for PSK8) is not obtained from only writing the number binarily; with PSK4, only the phase states 0, 2, 4 and 6 apply. A scrambling procedure, however, is then performed in a "PSK8 manner", meaning that both PSK4 and PSK8 appear as PSK8 after that.

With QAM modes (figure 3-62, right, and figure 3-63), no distinction is made any longer between symbol number and the number formed by the data bits; the selected mapping arises from the intention to minimize bit errors between adjacent phase states (only 1 bit changing from a state to an adjacent one); some, but not all, binary repre-

sentations are given in the figure for visualization. Scrambling is also done with QAM; details can be found in the [standard](#).

3.65.2.4 Frames

Arrangement of the coded symbols in frames is shown in [figure 3-64](#).

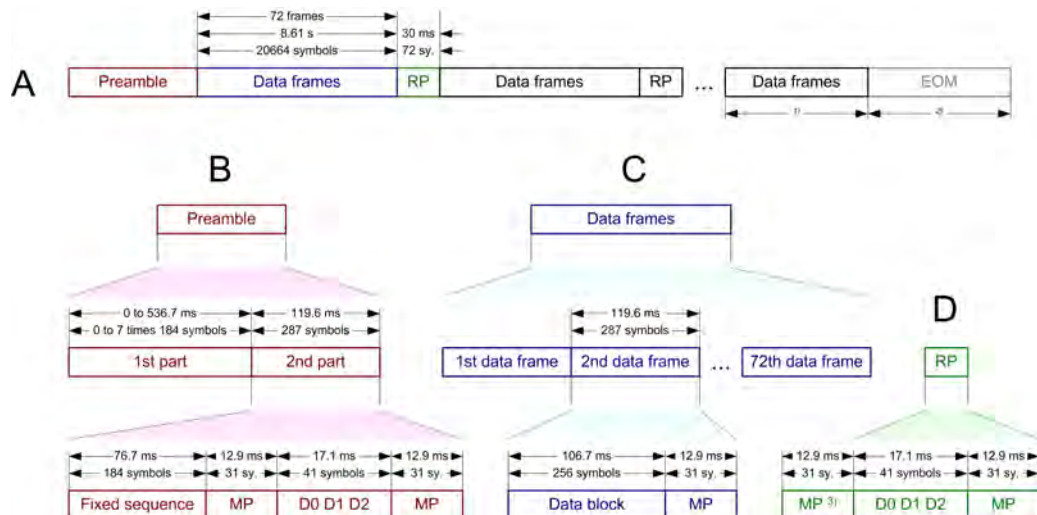


Fig. 3-64: Transmission sequence.

- A = complete sequence
- B = synchronization preamble
- C = data frames section
- D = reinsered preamble
- RP = reinsered preamble
- MP = mini-probe
- D0 D1 D2 = "data symbols": section carrying data rate and interleaver length information
- ³⁾ = mini-probe of 72th data block, not part of reinsered preamble in reality, but considered to be

Mind that all symbols except the data block itself, thus: all signalization symbols, come in PSK8 modulation, regardless of the kind of modulation currently used for the data to transmit.

Synchronization Preamble

Each transmission (**A** in the figure) is preceded by a synchronization preamble (**B**), consisting of two parts, the first of which repeats a definite number of times a fixed symbol sequence (184 symbols, repeated 0 times, meaning that this first part is dropped entirely, to 7 times). The second part is composed of the same fixed sequence (184 symbols, but the one of the first part being the conjugate complex of the one of the second) and a 103-symbol section common with the reinsered preamble, see below.

Data Frames Section

The user data (more precisely: symbols) to be transmitted themselves are grouped into data frames sections of 72 frames each (frame length 287 symbols, **C**). An individual frame consists of 256 symbols of user data and a so-called "mini-probe", again com-

prising just a fixed sequence of symbols. This sequence, however, may appear in "regular" orientation or in phase inverted orientation; varying combinations of these orientations is used to convey information about current data rate and interleaver setting.

Reinserted Preamble

After each data frames section, a so-called "reinserted preamble" (72 symbols) appears; it is considered to also comprise the mini-probe of the last (72th) data frame and in this 103-symbol shape is common to the final 103 symbols of the synchronization preamble.

Calculation of Rates

Considering all these added bits/symbols, the user data rate can be calculated from the (fixed) baud rate of 2400 Bd as

$$User\ data\ rate = Baud\ rate \cdot Code\ rate \cdot \frac{frameF \cdot symF}{frameF(symF + symM) + symR} \cdot Bits/sym$$

with

<i>Code rate</i>	3/4 for 3200 bit/s to 9600 bit/s, 1 (uncoded) for 12800 bit/s
<i>frameF</i>	Frames in data frames sequence: 72
<i>symF</i>	Symbols per frame (data block): 256
<i>symM</i>	Symbols per mini-probe: 31
<i>symR</i>	Symbols per reinserted preamble: 72
<i>Bits/sym</i>	• 2 with PSK4 • 3 with PSK8 • 4 with QAM16 • 5 with QAM32 • 6 with QAM64

Two examples illustrate the situation, the first one (code rate 3/4) describing all data rates except for 12800 bit/s:

$$\begin{aligned}
 User\ data\ rate &= 2400\ Bd \cdot 3/4 \cdot \frac{72 \cdot 256}{72 \cdot (256 + 31) + 72} \cdot Bits/sym \\
 &= 2400\ Bd \cdot 2/3 \cdot Bits/sym
 \end{aligned}$$

and the second one (code rate 1, i.e. no FEC coding) only the latter rate:

$$\begin{aligned}
 User\ data\ rate &= 2400\ Bd \cdot 1 \cdot \frac{72 \cdot 256}{72 \cdot (256 + 31) + 72} \cdot Bits/sym \\
 &= 2400\ Bd \cdot 8/9 \cdot Bits/sym
 \end{aligned}$$

Whereas the two mini-probes surrounding it consist only of constant symbols, the "D0 D1 D2" section of the synchronization (B in [figure 3-64](#)) and reinserted (D) preambles comprise three 13-symbol sequences (the first 13 being symbol D₀, the second D₁

and the third D_2) (plus 2 constant symbols). The combination of the three symbols, $D_0 D_1 D_2$, can assume one of 30 sets of three values (each individual one out of four possible values); the information conveyed therein tells the user data rate and interleaver length currently active. Again, see the [standard](#) for more details about coding the information.

Mini-Probes

The 73 mini-probes (MPs) of a data frames section (i.e. the section between two preambles, whether synchronization or reinserted, C in [figure 3-64](#)) are moreover numerated from 0 to 72 and arranged in four plus one sets as shown in [figure 3-65](#) (mini-probe 0 is part of the reinserted preamble itself). The symbol sequence in a mini-probe is always constant (based on the repeated Frank-Heimiller sequence), but can be conveyed in a "regular"-phase or a phase-inverted (180°) orientation; presence of the one or the other orientation can be used for carrying additional information: it is again the indication of data rate and interleaver length (and additionally the mini-probe set self-identification information, i.e. indication which mini-probe set is currently present).

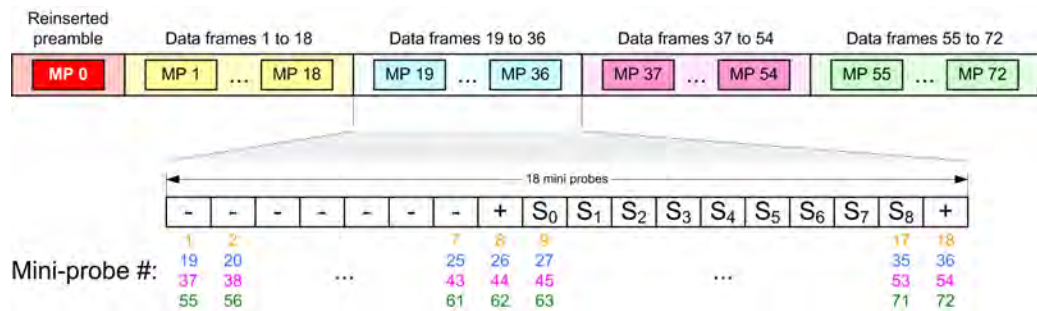


Fig. 3-65: Mini-probe use.

top = mini-probes 0 to 72, divided in 4 + 1 sets

bottom = agreeing use of each set

MP = mini-probe

S_0 to S_8 = "sign values": section carrying data rate, interleaver length and mini-probe set self-identification information

In [figure 3-65](#) the way to realize this is given: each of the four sets carry the same information; if a "+" sign denominates a regular-phase and a "-" sign a phase-inverted appearance, the first seven MPs come constantly the "-" and the eighth the "+" position, followed by the next nine MPs (called S_0 to S_8) containing the data rate and interleaver length information told (S_0 to S_5) or the self-identification (count: 1 to 18, 19 to 36, 37 to 54 or 55 to 72) of the current mini-probe set (S_6 to S_8). The eighteenth MP again is constantly "+"; MP 0 is always "-".

Any detailed information about coding, mapping and other additional aspects of this information transmission can be taken from the [standard](#).

End of message

Sending a unique bit pattern ($4B65 \ A5B2_{16}$ in hexadecimal notation) for marking the end of message (EOM) can be configured, followed by flush bits, for flushing the FEC coder and for the complete transmission of the remainder of the interleaver data block. If no EOM is to be sent, an input data block is filled up with zero bits anyhow.

3.66 MIL-STD-188-141A

3.66.1 General

Transmission method	MIL-STD-188-141A¹⁾
Explanation of name	MIL itary STanDard 188 (series related to telecommunications)
Other designations	ALE (A utomatic L ink E stablishment) 2G ALE or ALE 2G (2nd Generation ALE) FED-STD 1045A MFSK188 (M ulti- F requency S hift K eying, MIL-STD series 188) MIL 188 (MIL -STD series 188) NATO MIL188 MIL-STD-188-141 (ALE) or MIL-188-141 ALE or MIL-STD-188-141A/ALE
Variants existing	
Derived from method	
Typical users	Users all over the world including Europe, Africa, Asia, Middle East and China
Kind of data	
Reference to standard	MIL-STD-188-141A ¹⁾ : " <i>Interoperability and Performance Standards for Medium and High Frequency Radio Equipment</i> " (U.S. Department of Defense [DoD], September 15, 1988) ITU-R Recommendation F.1110-3: " <i>Adaptive radio systems for frequencies below about 30 MHz</i> ", Annex 8: " <i>System for HF radio automatic link establishment</i> "
Frequency band	HF
Modulation method	FSK8
Shift/tone spacing	250 Hz
Baud rate	125 Bd (tone duration 8 ms)
Modulating subcarrier	
Bandwidth	1990 Hz
Operating method	Simplex, Broadcast
Data protection	FEC (Golay (24,12))
Code table	ITA-5 (ASCII) (table 4-9 and table 4-10 in chapter 4.2)

¹⁾ supersedes MIL-STD-188-141 of Mar. 28, 1966

3.66.2 History

ALE (Automatic Link Establishment) evolved from older HF radio selective calling technology. It combined existing channel-scanning selective calling concepts with micro-processors (enabling FEC decoding and quality scoring decisions), burst transmissions (minimizing co-channel interference), and transponding (allowing unattended operation and incoming-call signaling). Early (first generation) ALE systems were developed in the late 1970s and early 1980s by several radio manufacturers, but various methods and proprietary digital signaling protocols were used, leading to incompatibility. Later, a cooperative effort among manufacturers and the U.S. government resulted in a second generation of ALE that included the features of first generation systems, while improving performance. The second generation ALE system (2G ALE) standard in 1986 was adopted in FED-STD-1045 for U.S. federal entities. In the 1980s, military and other entities of the U.S. government began installing early ALE units, using ALE controller products built primarily by U.S. companies. The primary application during the first 10 years of ALE use was government and military radio systems, and the limited customer base combined with the necessity to adhere to MILSPEC standards kept prices extremely high. As the standards were adopted by other governments worldwide, more manufacturers produced competitively priced HF radios to meet this demand. The need to interoperate with government organizations prompted many NGOs to at least partially adopt ALE standards for communication. As non-military experience spread and prices came down, other civilian entities started using 2G ALE. By the year 2000, there were enough civilian and government organizations worldwide using ALE that it became a de facto HF interoperability standard for situations where a priori channel and address coordination is possible.

In the late 1990s, a third generation ALE (3G ALE) with significantly improved capability and performance was included in MIL-STD-188-141B (see [chapter 3.67, "MIL-STD-188-141B \(Appendix C\)"](#), on page 206), retaining backward compatibility with 2G ALE, and was adopted in NATO STANAG 4538. Civilian and non-government adoption rates are much lower than 2G ALE due to the extreme cost as compared to surplus or entry-level 2G gear as well as the significantly increased system and planning complexity necessary to realize the benefits inherent in the 3G specification. For many militaries, whose needs for maximized intra-organizational capability and capacity always strain existing systems, the additional cost and complexity of 3G is far more compelling.

3.66.3 Description

3.66.3.1 Scope

ALE (MIL-STD-188-141A) is a robust, adaptive HF radio method for automatically establishing communications over HF SSB links. Using ALE, an operator or computer-initiated control signal can automatically initiate point-to-point or point-to-multipoint calls. The ALE controller can be programmed to scan one or more frequencies, pick the best frequency for operation, and switch to voice or data operation upon link establishment. The ALE system initiates calls on selected channels, which are rank ordered through an internally programmed link quality analysis (LQA) algorithm. This permits

the link establishment process to have the most likely chance of success on its initial trial using previously measured LQA numerical channel scores that are stored in the system's memory. The identities of the calling and called stations are exchanged between stations, along with call sign designators to distinguish the calling from the called station.

Optional features include linking protection, which employs security methods to prevent unauthorized network entry, transmission and reception of user data, and over-the-air reprogramming (OTAR).

The ALE link establishment and link management functions are performed by reliably conveying the ALE link information over HF channels between station pairs. This high reliability is obtained by triple redundancy transmission of the ALE data, interleaving, and forward error correction.

An adaptive HF radio system consists of the HF SSB transceiver/antenna, the ALE controller and eventually a data modem for serial tone, FSK etc., the ALE controller providing the automation of the linking process. ALE networking functions and linking protection functions can also be incorporated into the ALE controller. After the link is established, data or voice communications can be initiated by switching the high speed data modem into the circuit.

3.66.3.2 Tone (Frequency) Structure

ALE is designed to be modular in nature, and uses audio tones and serial data signals to interface the ALE controller with HF-SSB radios.

The ALE waveform is designed to pass through the audio passband of conventional SSB radio equipment. The waveform is an 8-ary FSK modulation with eight orthogonal tones (see [table 3-33](#)), i.e. the tone frequency distance is equal to the intended baud rate (or, of course, a multiple of it). Each tone emission is 8 ms in duration and ranges in frequency from 750 Hz to 2500 Hz with 250 Hz separation between adjacent tones. Each tone represents 3 bits (1 tritbit) of data coded in Gray code, resulting in an over-the-air data rate of 375 bit/s.

Table 3-33: Tone (frequency) assignment to tritbits (Gray coded).

Tone number	1	2	3	4	5	6	7	8
Frequency [Hz]	750	1000	1250	1500	1750	2000	2250	2500
Tritbit	000	001	011	010	110	111	101	100

3.66.3.3 Word Structure and Channel Coding

The ALE standard word ([figure 3-66](#), **A** – not to be confused with the superior "frame" formed by one or more words, cf [figure 3-67](#)) consists of 24 bits which are separated into a 3-bit preamble field followed by three 7-bit ASCII character fields (all coded in MSB first). The function (type) of each transmitted ALE word, as designated by the preamble code, is related to the basic ALE capabilities. There are eight word types ([table 3-34](#)): TO, THIS IS, THIS WAS, DATA, REPEAT, THRU, COMMAND, and FROM. Each 7-bit ASCII character field is used to specify an individual address character or as ASCII text, depending on the preamble.

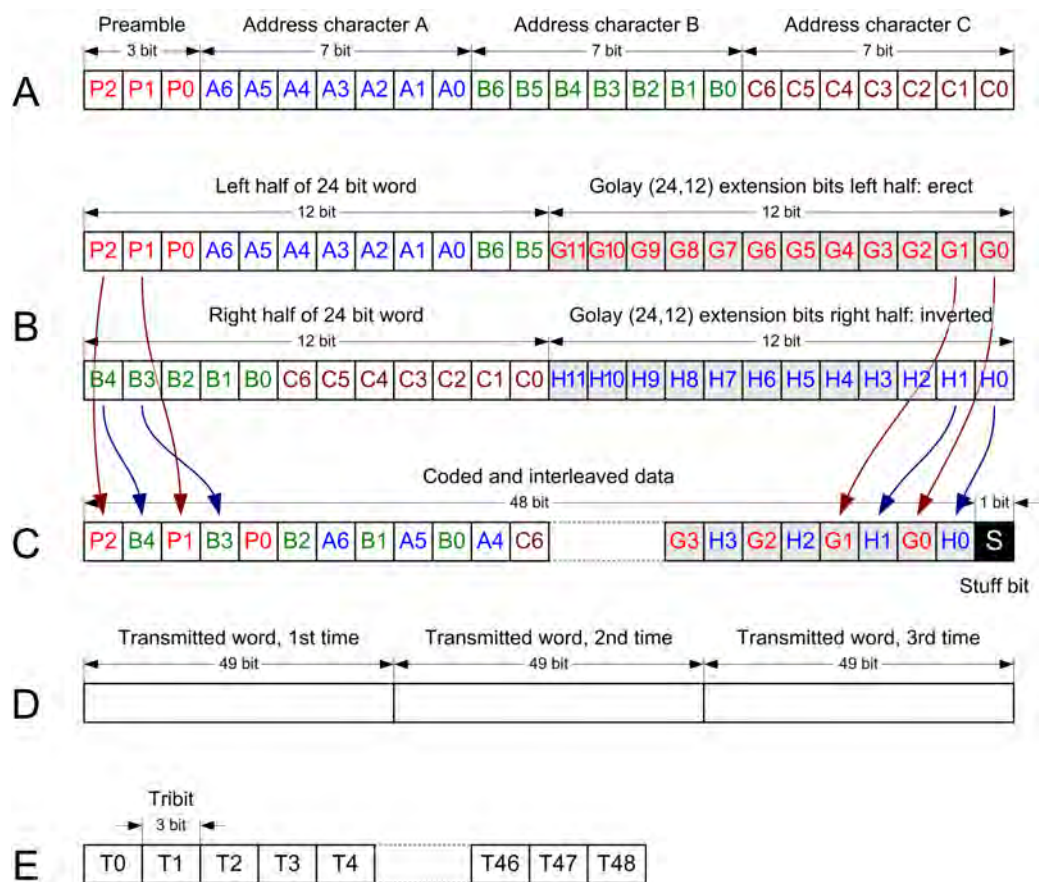


Fig. 3-66: Generation of addressing word.

A = basic word: original 24-bit word with preamble and 3-character address

B = word divided in two halves, converted to Golay (24,12) code each

C = transmitted word: both parts interleaved, single stuff bit amended to form 49-bit word ready to transmit

D = triple redundant word: transmitted word concatenated 3 times to transmit consecutively

E = bits converted to tribits for FSK8 transmission

For a maximum protection against transmission errors, i.e. optimum reliability of the link establishment process, a channel coding procedure is applied before transmitting the word(s).

- First, the 24-bit word is broken into two halves;
- each one of them is then transformed into a Golay (24,12) code word (see [chapter 3.50, "G-TOR"](#), on page 143 for informations about Golay coding),
- the 12 bits additionally created by this process are appended to the left half in erect, to the right half in inverted polarity, respectively ([figure 3-66, B](#)).
- Both 24-bit words arisen are then interleaved and
- a single stuff bit (value 0) is added, resulting in a final 49-bit Transmitted word ([figure 3-66, C](#)).
- This Transmitted word is transmitted three times consecutively ([figure 3-66, D](#)) in the FSK8 tribit form mentioned above ([figure 3-66, E](#)).

On reception, if not all three Transmitted words received are congruent, a majority evaluation of the concerned bits is applied: the bit value obtained more often (twice) is

considered to be correct, the other one (obtained only once) is discarded. The ratio unanimous votes to majority votes is used to determine channel quality later-on.

Table 3-34: Word types (identified by preamble).

Word type	Code bits	Functions	Significance
TO	010	direct routing	present direct destination for individual and net calls
THIS IS	101	terminator and identification, continuing	identification of present transmitter, signal terminations, protocol continuation
THIS WAS	011	terminator and identification, quitting	identification of present transmitter, signal and protocol termination
DATA	000	extension and information	extension of data field of the previous ALE word, or information defined by the previous COMMAND
REPEAT	111	duplication and information	duplication of the previous preamble, with new data field, or information defined by the previous COMMAND
THRU	001	multiple (and indirect) routing	present multiple direct destinations for group calls
COMMAND	110	orderwire control and status	ALE system-wide station (and operator) orderwire for coordination, control, status, and special functions
FROM	100	identification (and indirect routing)	identification of present transmitter without termination

3.66.3.4 Operation

Transmitted messages of the ALE system serve for some dedicated purposes:

- Individual calling
- Multiple station calling
- Sounding
- Orderwire messaging

A station, when operational but not otherwise committed, continually scans a preselected set of channels, the "scan set", listening for calls and ready to respond. ALE receivers scan channels at either 2 or 5 channels/s, resulting in a dwell time of 500 ms or 200 ms, and the channels in the scan set are repeatedly scanned in the same order. When a transmitter wishes to "capture" a scanning receiver, it will transmit a "Scanning call", the duration of which must be sufficient to ensure that the receiver (if it is indeed scanning for calls) will land on the channel carrying the call before the transmitter ceases emitting (cf [chapter 3.4, "ALIS"](#), on page 38).

Selective calling: Selective calling in an ALE system involves the exchange of ALE frames among stations. This selective calling capability supports all higher-level ALE functions, including link establishment and data transfer. The general structure of an ALE frame consists of one or more destination addresses, an optional message section, and a frame conclusion which contains the address of the station sending the frame. The fundamental ALE operation of establishing a link between two stations proceeds as follows:

- The calling station addresses and sends a call frame to the called station.

- If the called station "hears" the call, it sends a response frame addressed to the calling station.
- If the calling station receives the response, it now "knows" that a bilateral link has been established with the called station. However, the called station does not yet know this, so the calling station sends an acknowledgment frame addressed to the called station. At the conclusion of this three-way handshake, a link has been established, and the stations may commence voice or data communications, or drop the link.

Architecture (duration) of the Transmit and Listen periods are to be defined in advance for a given HF network; limitations are given in the relevant [standards](#).

Call types are:

- Single station call
- Net call
- Group call

A **single station call** is a link request to only one individual station as described with "selective calling". A **net call** is addressed to a single address that implicitly names all members of a prearranged collection of stations (a "net"). All stations belonging to the net that hear the net call send their response frames in prearranged timeslots. The calling station then completes the handshake by sending an acknowledgment frame as usual. A **group call** works similarly, except that an arbitrary collection of stations (a "group", i.e. not defined as a "net") is named in the call. Because no prearranged net address has been set up, each station must be individually named. Called stations respond in slots, determining their slot positions by reversing the order that stations were named in the call. Again, the calling station sends an acknowledgment as usual.

Sounding: A sound is a unidirectional broadcast of ALE signaling by a station to assist other stations in measuring channel quality. The broadcast is not addressed to any station or collection of stations, but merely carries the identification of the station sending the sound.

Orderwire messages: In addition to automatically establishing links, ALE stations have the capability to transfer information within the orderwire (message) section of the frame. These functions enable stations to communicate short orderwire messages or prearranged codes to any selected station(s). This permits station operators to send and receive simple ASCII text messages by using only the ALE station equipment.

3.66.3.5 Addressing

Character sets: For the different types of addressing, ALE defines 3 sets (hierarchically organized) of characters based on the 7-bit basic ASCII set ([chapter 4.2, "ITA-5 \(ASCII\) Code Table"](#), on page 336), they are shown and explained in [table 3-35](#).

Table 3-35: Character sets with ALE¹⁾.

Full-128 ASCII set							
		Expanded-64 ASCII subset					
NUL	DLE	SPC	0	@	P	`	p
SOH	DC1	!	1	A	Q	a	q
STX	DC2	"	2	B	R	b	r
ETX	DC3	#	3	C	S	c	s
EOT	DC4	\$	4	D	T	d	t
ENQ	NAK	%	5	E	U	e	u
ACK	SYN	&	6	F	V	f	v
BEL	ETB	'	7	G	W	g	w
BS	CAN	(	8	H	X	h	x
HT	EM	)	9	I	Y	i	y
LF	SUB	*	:	J	Z	j	z
VT	ESC	+	;	K	[	k	{
FF	FS	,	<	L	\	l	
CR	GS	-	=	M	]	m	}
SO	RS	.	>	N	^	n	~
SI	US	/	?	O	_	o	DEL

¹⁾ Shown in bold: Basic-38 ASCII subset

Central 4 columns of table: Expanded-64 ASCII subset

Complete table: Full-128 (7-bit) ASCII set

Individual station addresses: The fundamental address element in the ALE system is the single routing word (figure 3-66, A). An address which is assigned to a single station ("individual" address) commonly consists of 3 characters or less ("basic" size). These 3 characters use only the 36 alphanumeric codes of the Basic-38 set and thus provide an address capacity of $36^3 = 46\,656$. "Extended" size addresses have more than 3 characters, up to a maximum system limit of 15 (enabling ISDN address capability).

Multiple station addresses: A common requirement in HF networks is to simultaneously (or nearly simultaneously) address and interoperate with multiple stations. Hence, the basic address word may be extended to multiple words for increased address capacity and flexibility for Internet and general use. A prearranged collection of stations is termed a **Net** (with a common "net address"), whereas a non-prearranged collection (lacking a prearranged common address) is termed a **Group**.

The net address structure is identical to that of individual station addresses, basic or extended as necessary. At a net member's station, each assigned net address is asso-

ciated with a response slot identifier to allow each station to respond to the net controller in a systematic manner.

The purpose of a group call is to establish contact with multiple non-prearranged stations rapidly and efficiently by the use of a compact combination of their own individual addresses. A group address is formed from a sequence of the actual individual addresses of the called stations, in the manner directed by the specific standard protocol.

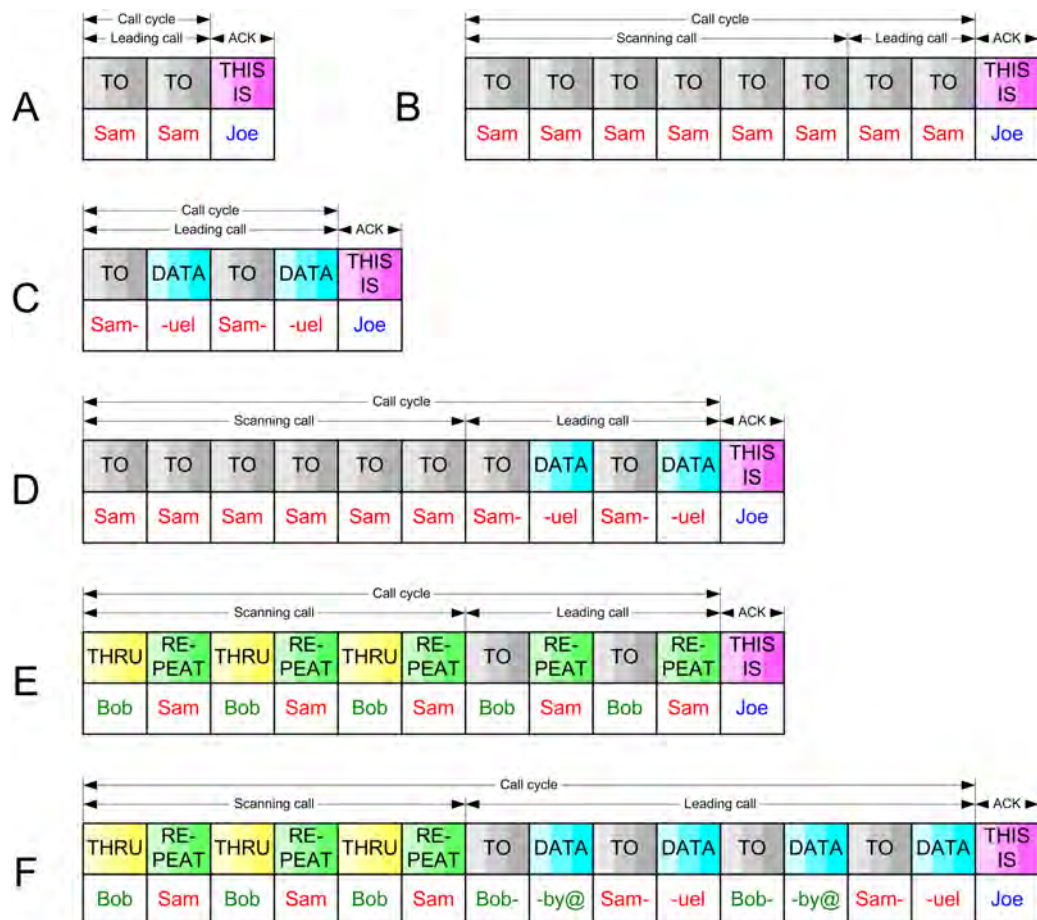


Fig. 3-67: Basic frame structure examples.

A = 1-channel non-scan, 1-word addressing, direct, individual or net call

B = n-channel scanning

C = 1-channel non-scan, 2-word addressing

D = n-channel scanning

E = n-channel scanning, 1-word addressing, direct, group call

F = 2-word addressing

For a basic understanding of the different addressing methods together with the types of ALE words (represented in their preamble, see [table 3-34](#)), in [figure 3-67](#) some examples are shown. Common to all is the fact that in the Leading call section the address word(s) is (are) sent twice to avoid loss of the leading words. As explained above ([figure 3-66, A](#)), the payload of each word shown is made up of the 3-bit preamble and the 3 7-bit characters.

- **A:** Only one frequency (channel) is available, thus no scanning by the later called station is performed; the calling station calls and is acknowledged on first attempt. The address used (whether individual or net) is 3-bit, hence a single calling word of type TO is sufficient; after being answered, the calling station identifies itself by its own 3-bit address in a single THIS IS word.
- **B:** More than one frequency (channel) has been appointed to call on, the calling station has to call long enough to enable the called station to receive the call on the frequency it is emitted on.
- **C:** In contrast to **A**, the address of the called station is 6-bit, so for a correct addressing a second word of type DATA (alternatively REPEAT) has to follow the initial TO word.
- **D:** The Scanning call is done with just the first 3 bits of the complete address; in the Leading call period the complete address is transmitted to identify the called station unanimously.
- **E:** A group call has to emit more than one single address; the THRU word type signals this in the Scanning call section, followed by a REPEAT (or another THRU) word. In the Leading call, however, the TO word type is used.
- **F:** Again, two addresses of a station group are called only with the first 3 of their now more than 3 address bits during the Scanning call section, whereas the Leading call has to convey the complete addresses. Due to the fact that the one address has only 5 characters, the 6th character (3rd of the 2nd 3-character word) has to be stuffed by the "@" character.

3.66.3.6 More information

For all informations in more detail, e.g. the remaining word types not explained here, timing diagrams, flow charts of the different call types, use of wild card characters etc., refer to the underlying [standards](#) (told in 3.66.1, "General").

3.67 MIL-STD-188-141B (Appendix C)

3.67.1 General

Transmission method	MIL-STD-188-141B ⁷⁾ (Appendix C)
Explanation of name	MIL itary STan Dard 188 (series related to telecommunications)
Other designations	ALE 3G (A utomatic Link E stablishment, 3rd G eneration) STANAG 4538 (STAN dardization AG reement)
Variants existing	
Derived from method	
Typical users	All departments and agencies of the U.S. Department of Defense, intended for HF networks with intense voice and/or data message loading

Transmission method	MIL-STD-188-141B ¹⁾ (Appendix C)
Kind of data	(Universal data)
Reference to standard	MIL-STD-188-141B ¹⁾ (Appendix C): Military Standard "Interface Standard Interoperability and Performance Standards for Medium and High Frequency Radio Systems" (U.S. Department of Defense [DoD], March 1, 1999): "Third Generation HF Link Automation"
Frequency band	HF
Modulation method	PSK8
Shift/tone spacing	
Baud rate	2400 Bd
Modulating subcarrier	1800 Hz
Bandwidth	3 kHz
Operating method	Simplex, broadcast
Data protection	FEC, unprotected
Code table	Bit-transparent (no limitation to special kind of data)

¹⁾ supersedes MIL-STD-188-141A of Sept. 15, 1988 (see [chapter 3.66](#), "MIL-STD-188-141A", on page 198)

3.67.2 Description

MIL-STD-188-141B (Appendix C) defines the so-called third generation (3G) HF radio technology. Special features covered are automatic link establishment (ALE), automatic link maintenance, and high performance data link protocols. This technology is an improvement of previous similar techniques (e.g. 2G-ALE). Five types of burst waveforms (called BW0 to BW4) are proposed for the various kinds of signaling required in the system, so as to meet their distinctive requirements as to payload, duration, time synchronization, and acquisition and demodulation performance in the presence of noise, fading, and multi-path. All of the burst waveforms use the basic PSK8 serial tone modulation of an 1800 Hz carrier at 2400 Bd (symbols per second). The same modulation is used in MIL-STD-188-110A serial mode. FEC convolutional encoding and interleaving are also applied, but vary individually for each type of burst.

3.67.3 Channel Coding/Structure of Data Blocks

This [standard](#) describes 5 different waveforms. Their requirements according robustness and data rate are achieved through different coding methods.

- Burst waveform BW0 is used for establishing the communication link
- BW1 for traffic management
- BW2 to convey the high data rate protocol (HDL)
- BW3 to convey the low data rate protocol (LDL)

- BW4 to convey the acknowledgment for the LDL protocol

Each of the 5 types of burst is composed of three blocks:

- Transmit Level Control (TLC) (not BW3)
- preamble (not BW4)
- data

Due to different purposes of use of each type, duration and content of each of the elements as well as of the whole bursts vary in a wide range:

- BW0: for 3G-ALE PDUs (**P**rotocol **D**ata **U**nit)
- BW1: traffic management PDUs and HDL (**H**igh-rate **D**ata **L**ink Protocol) acknowledgment PDUs
- BW2: HDL traffic data PDUs
- BW3: LDL (**L**ow-rate **D**ata **L**ink Protocol) traffic data PDUs
- BW4: LDL acknowledgment PDUs

3.68 MORSE

3.68.1 General

Transmission method	MORSE
Explanation of name	After the inventor of the Morse method, Samuel Morse
Other designations	
Variants existing	
Derived from method	
Typical users	Identification of stations in aviation and navigation Radio amateurs
Kind of data	Telegraphy
Reference to standard	
Frequency band	HF
Modulation method	Direct ASK to the carrier frequency, code entered manually or automatically
Shift/tone spacing	
Baud rate	(Up to 90 words per minute [WPM])
Modulating subcarrier	
Bandwidth	45 Hz (for an example of 20 WPM)
Operating method	Simplex, duplex, broadcast

Transmission method	MORSE
Data protection	Unprotected, ARQ
Code table	Morse code (table 4-15 to table 4-19 in chapter 4.5)

3.68.2 History

The first useful single-wire telegraph system was invented in 1837 by *Samuel Morse*, an American inventor and professor in painting, sculpture and drawing. Morse also invented a special code for this purpose, the so-called Morse code. In 1899/1900 the first wireless telegraph routes were established. In today's world of communication sending in Morse code has largely lost its importance, but it is still popular and in use by radio amateurs. With a period of use of 160 years so far, Morse is the longest-used electronic encoding system.

3.68.3 Description

Sending in Morse code is done by just switching the carrier signal of a **CW** (**C**ontinuous **W**ave) transmitter – so even a modulation capability exceeding the availability of on-off-switching is not required. Coding and decoding is normally performed directly by the operator; well-skilled operators are able to achieve a better decoding quality than mechanical decoders. Transmitting speed is specified in **WPM** (**W**ords **P**er **M**inute); for speed measurements the standardized word "PARIS" is transmitted. Due to manual code entry and the requirement of direct human comprehensibility of the received signal, maximum attainable speeds are about 90 words per minute. Another advantage (besides the simple equipment required) of the Morse method is the small amount of bandwidth consumed by the transmitted signal.

3.68.4 Source Coding

Morse code: the characters (no distinguishing between small and capital letters)

- letters
- numerals
- some special signs

are formed by short ("dot" or "dit") and long elements ("dash" or "dah"). The length of the gaps between the elements depends on the kind of the element:

- *short* gap between elements within a letter
- *medium* gap between letters
- *long* gap between words

The count of elements per letter/numeral varies with the frequency of the letter in English language:

- the *most frequently* used letters "E" and "T" consist of just 1 element
- *moderately frequent* ones 2 or 3 elements

- *rarely occurring* letters like "Q" or "X" use 4 elements
- *Numerals* are represented by 5 elements
- some *special signs* by up to 6

In [table 4-15](#) to [table 4-19](#) ([chapter 4.5, "MORSE Code Table"](#), on page 344), the most common Morse characters are listed.

3.69 MPT1327

3.69.1 General

Transmission method	MPT1327
Explanation of name	Ministry of Postal service and Telecommunications – 1327 (UK)
Other designations	
Variants existing	
Derived from method	
Typical users	Trunked private land mobile radio
Kind of data	Speech and data messages
Reference to standard	" <i>MPT 1327, A Signalling Standard for Trunked Private Land Mobile Radio Systems</i> ", January 1988 (revised and reprinted October 1991 and June 1997)
Frequency band	VHF/UHF, may vary due to national regulations
Modulation method	FSK: Subcarrier MSK (FFSK), indirect FM
Shift/tone spacing	600 Hz
Baud rate	1200 Bd (1200 bit/s)
Modulating subcarrier	1500 Hz
Bandwidth	12.5 kHz
Operating method	Duplex (base station), two-channel simplex (mobiles)
Data protection	ARQ
Code table	BCD (e.g. phone numbers), other data formats allowable

3.69.2 History

MPT1327 was first published in January 1988 by the British Radiocommunications Agency and is primarily used in the United Kingdom (UK), Europe, South Africa, New Zealand, Australia and even China. Many countries had their own version of numbering/user interface, the most notable being *MPT1343* (UK), *Chekker/Regionet 43* (Ger-

many), *3RP/CNET2424* (France), *Entropia Networks/MPT1343* (Belgium and the Netherlands), *Multiax* (Australia), *Gong An* (China). MPT systems are still being built in many areas of the world, due to their cost-effectiveness.

3.69.3 Description

MPT1327 is an industry standard for trunked radio communications networks. In a trunked radio system many mobiles share a limited number of channels by appropriate access and signaling procedures on a control channel. The network is controlled by a fixed base station (TSC: **T**runked **S**ystem **C**ontroller). If wide areas are to be covered, they are divided into cells with their own TSCs, which are connected to a hub and managed by a Management Controller. TSC may have connection to the public telephone network. Available channels include traffic and control channels, the latter of which consists of a Forward (base station to unit) and a Return Control Channel (unit to base station). If the Forward Control Channel is the same for all TSCs, it is accessed by them in [TDMA](#).

3.69.4 Channel Coding/Structure of Data Blocks

- Forward Control Channel: timeslots carrying two 64-bit words each: Control Channel System Codeword (identifies the base station to the mobiles and synchronizes them to the following address codeword) and address codeword (first codeword of any message indicating the nature of the message). Each codeword is made up of 48 information bits and 16 check bits.
- Return Control Channel: randomly accessed by the mobiles in timeslots of 106.7 [ms](#) (128 bits).

3.70 NXDN

3.70.1 General

Transmission method	NXDN
Explanation of name	NeXt Generation D igital N arrowband (Trademark of <i>ICOM, Inc.</i> , and <i>JVC Kenwood Corp.</i>)
Other designations	IDAS (Icom D igital A dvanced S ystem; Trademark of <i>ICOM, Inc.</i>) NEXEDGE (Trademark of <i>JVC Kenwood Corp.</i>)
Variants existing	
Derived from method	
Typical users	
Kind of data	Voice and data applications

Transmission method	NXDN
Reference to standard	NXDN Technical Specifications: <i>"Part 1: Air Interface"</i> • <i>"Sub-part A: Common Air Interface"</i> • <i>"Sub-part B: Basic Operation"</i> • <i>"Sub-part C: Trunking Procedures (Type-C)"</i> • <i>"Sub-part D: Security"</i> <i>"Part 2: Conformance Test"</i> • <i>"Sub-part A: Transceiver Performance Test"</i> • <i>"Sub-part B: Common Air Interface Test"</i> • <i>"Sub-part C: Basic Operation Test"</i> • <i>"Sub-part D: Trunking Operation Test (Type-C)"</i> FIPS PUB (Federal Information Processing Standards Publication) 46-3: <i>"Data Encryption Standard (DES)"</i> (U.S. Department of Commerce [DoC]/ National Institute of Standards and Technology [NIST], reaffirmed Oct. 25, 1999, withdrawn May 19, 2005) FIPS PUB 197: <i>"Advanced Encryption Standard (AES)"</i>, Nov. 26, 2001
Frequency band	VHF: 136 MHz to 174 MHz UHF: 400 MHz to 520 MHz
Modulation method	FSK4
Shift/tone spacing	700 Hz - 700 Hz - 700 Hz
Baud rate	2400 Bd (data rate 4800 bit/s), 4800 Bd (data rate 9600 bit/s)
Modulating subcarrier	
Bandwidth	6.25 kHz, 12.5 kHz
Operating method	Simplex, half-duplex, broadcast, synchronous
Data protection	FEC, interleaving, scrambling
Code table	

3.70.2 History

With radio frequency bands becoming more and more crowded, in 1997 the FCC announced its "re-farming" mandate for the VHF and UHF bands of LMR in the U.S., demanding any LMR use to shift to narrowband capability from 2005, i.e. to offer capability for voice and data traffic at 6.25 kHz of bandwidth. In 2003 ICOM, Inc., and Kenwood Corp. (now JVC Kenwood Corp.) founded a technology alliance and developed the NXDN protocol. The NXDN Forum was formed in 2008 by 8 member companies, several more members joined it later on, total membership currently is 30.

3.70.3 Description

3.70.3.1 Abbreviations

NXDN makes use of plenty of abbreviations, moreover not well-known e.g. from comparable transmission methods. From that reason, the most often used abbreviations are comprised in [table 3-36](#).

Table 3-36: Abbreviations with NXDN.

AES	Advanced Encryption Standard	RAN	Radio Access Number
BCCH	Broadcast Control Channel	RCCH	RF Control Channel
CAC	Common Access Channel (type can be BCCH, CCCH or UPCH)	RDCH	RF Direct Channel
		RTCH	RF Traffic Channel
CCCH	Common Control Channel	RU	Repeater Unit
CR	Conventional Repeater	SACCH	Slow Associated Control Channel
CRS	Conventional Repeater Site	SU	Subscriber Unit
DES	Data Encryption Standard	TC	Trunking Controller
E	Collision Control Field	TR	Trunking Repeater
FACCH1	Fast Associated Control Channel 1	TRS	Trunking Repeater Site
FACCH2	Fast Associated Control Channel 2	UDCH	User Data Channel
FS	Fixed Station	UPCH	User Packet Channel
FSW	Frame Sync Word	USC	User Specific Channel (type can be VCH, UDCH, FACCH1, FACCH2 or SACCH)
G	Guard Time		
LICH	Link Information Channel	VCH	Voice Channel
MS	Mobile Station	Outbound	Downlink (from TR/CR to SU)
P	Preamble	Inbound	Uplink (from SU to TR/CR)
Post	Post Field		

3.70.3.2 Scope

NXDN, similar to dPMR ([chapter 3.37, "DPMR"](#), on page 112), is a narrowband digital transmission system with the ambition to obtain a structure of digital channels that should be compatible with the frequency structure of the existing analog system. Channels of 6.25 kHz width are arranged with FDMA, thus two channels can be accommodated in one 12.5 kHz channel of the analog system. Modulation used is FSK4 with a shift of 700 Hz from one frequency to another.

As with dPMR, three modes of architecture are in use: trunked (dynamic allocation of frequencies as required), conventional (frequencies fixed, but interconnection between stations only via a repeater) and direct (direct communication from station to station).

NXDN is preferably used in North and South America, whereas dPMR is supported by European standards.

3.70.3.3 NXDN Trunked Radio System

In an NXDN trunked system (see [figure 3-68](#)), operation is performed via RF traffic channels (frequencies) allocated dynamically. A permanently present control (timing) channel, the RCCH, is available for management purposes. If a station (SU) wishes to communicate with another, it has to be assigned a radio frequency (RF channel) and then synchronized to the system. SUs may optionally be mobile or fixed stations.

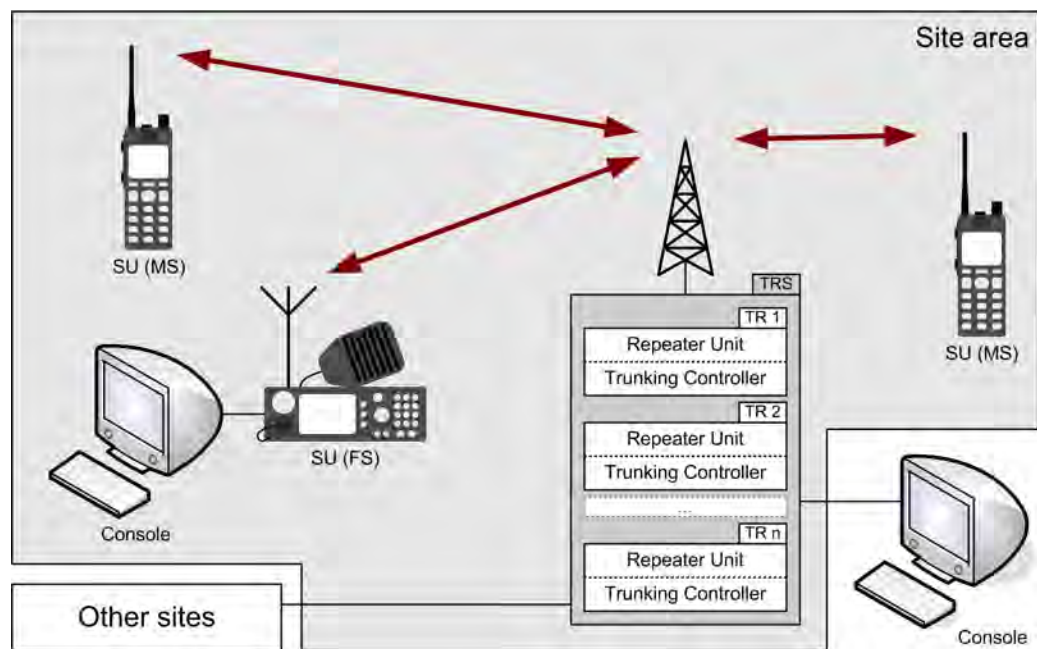


Fig. 3-68: NXDN trunked radio system configuration.

SU, MS, FS, TR, TRS = (see [table 3-36](#))

3.70.3.4 NXDN Conventional Radio System

A conventional radio system ([figure 3-69](#)) operates only on the predefined frequency channels of each SU, but switching is also done by repeater units (no direct station-to-station communication). Synchronization has to be established by the repeater after triggering has been done by the SU, and will be released after use, i.e. no permanent synchronization channel exists.

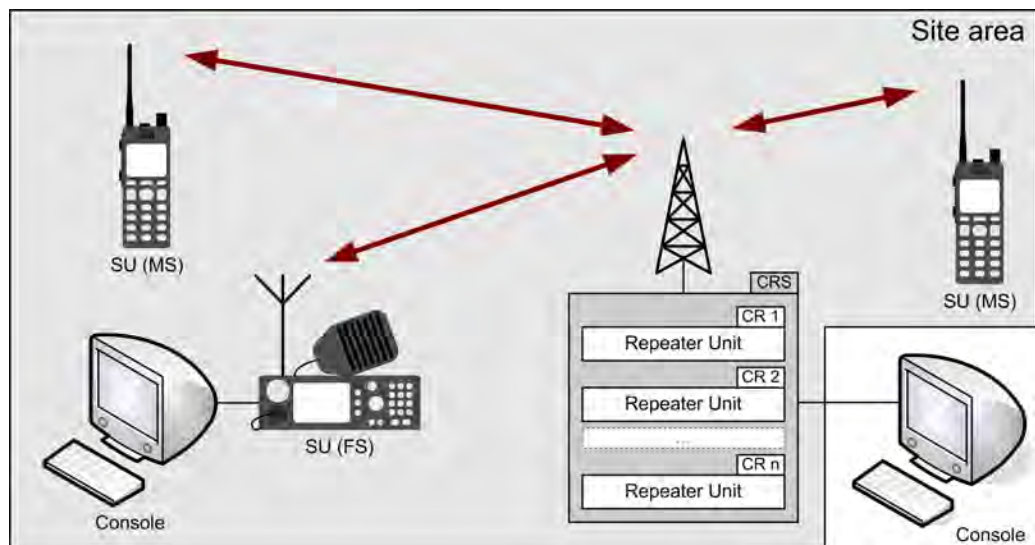


Fig. 3-69: NXDN conventional radio system configuration.

SU, MS, FS, CR, CRS = (see [table 3-36](#))

3.70.3.5 NXDN Direct Radio System

A direct radio system ([figure 3-70](#)) is a simple connection from one station to another without any switching circuitry. A specification of timing in this operation mode is not provided by the NXDN standard.

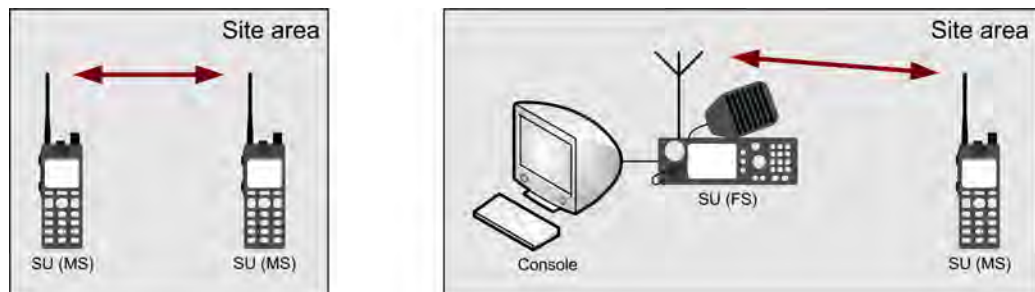


Fig. 3-70: NXDN direct radio system configurations.

Left = Subscriber Units only mobile stations
 Right = Subscriber Units mobile and fixed stations
 SU, MS, FS = (see [table 3-36](#))

3.70.3.6 Security

NXDN features some optional security functions:

- Encryption of voice information coming from the vocoder
- Encryption of user data such as texts or images
- Authentication

These functions are available for both trunked and conventional systems; they are to be implemented in the entire system and/or the SUs as options. Encryption is applied

exclusively to user information; control information (for example Group ID) is excluded thereof. Availability moreover depends on required security level:

- **No Guard Level**
means the unprotected mode: no encryption at all is performed with calls.
- **Low Guard Level**
is the low security level: user information is encrypted by a bit scrambling process (using a PN sequence) within the vocoder; therefore also called "Scramble Encryption".
- **High Guard Level**
represents high level security, achieved by the DES algorithm (cf FIPS PUB 46-3) and the AES algorithm (cf FIPS PUB 197). Details can also be found in the NXDN Specifications, Part 1, Sub-part D.

The authentication function is used to decide whether an SU that wishes to access the system is an eligible one. Verification takes place via the so-called ESN (electronic serial number, 48 bit in length) having been written to the SU by its manufacturer.

3.70.3.7 Channels

NXDN uses the term "channel" in two meanings: RF channel and functional channel.

RF Channels

An RF channel expresses a physical carrier (channel allocated to a frequency). Three types of RF channels are distinguished:

- **RF Control Channel (RCCH)**
The RCCH is used for location registration, system information broadcasts, paging and call request reception in a trunked radio system (3.70.3.3, "NXDN Trunked Radio System") and controls SUs to migrate to another RCCH or RTCH (see below). The RCCH exists permanently, but might be switched to another frequency if required.
- **RF Traffic Channel (RTCH)**
The RTCH is used for speech (voice-coding) data and user data transmissions in a trunked radio system.
- **RF Direct Channel (RDCH)**
The RDCH is used for speech (voice-coding) data and user data transmissions in a conventional radio system (3.70.3.4, "NXDN Conventional Radio System").

Functional Channels

A functional channel is a logical unit sorting transmission data by its functional affiliation.

- **Broadcast Control Channel (BCCH)**
Unidirectional channel used on RCCH: *outbound* (from TR to SU): broadcasting control information (location registration and system structure).
- **Common Control Channel (CCCH)**

Bidirectional channel used on RCCH: *outbound*: temporary control information or any paging information; *inbound* (from SU to TR): some data transmission and call request information.

- **User Packet Channel (UPCH)**
Bidirectional data channel used on RCCH: control information signal and user packet data, *inbound*: random access.
- **User Data Channel (UDCH)**
Bidirectional data channel used on RTCH and RDCH: control information signal and user packet data.
- **Slow Associated Control Channel (SACCH)**
Bidirectional control channel associated with a voice call on RTCH and RDCH: signaling and other information at a low speed.
- **Fast Associated Control Channel 1 (FACCH1)**
Bidirectional control channel associated with a voice call on RTCH and RDCH: temporarily used for signaling and other information at a high speed (by "stealing", i.e. replacing, a VCH, see 3.70.3.8, "Frame Structure").
- **Fast Associated Control Channel 2 (FACCH2)**
Bidirectional control channel associated with a data call on RTCH and RDCH: temporarily used for signaling information or a part of data at a high speed (by "stealing", i.e. replacing, a UDCH).
- **Voice Channel (VCH)**
Bidirectional channel used on RTCH and RDCH: voice-coding data.
- **Link Information Channel (LICH)**
Bidirectional channel allocated on all RF channels: information related to a radio link (RF channel type and functional channel allocation).

3.70.3.8 Frame Structure

All information to be transmitted is formed to the functional channels (see 3.70.3.6, "Security") and arranged in frames as is the information to control this arrangement, i.e. representing the kind and type of information contained in an individual structure of data. Controlling is done by "messages" defined in the technical specifications, the length of each individual message is indicated in "octets" (1 octet comprising 8 bits, and the first octet of each message telling the message type).

Any frame (figure 3-71, figure 3-73 and figure 3-75) is introduced by the Frame Sync Word (FSW), which is a fixed bit pattern of 20 bit length, followed by the Link Information Channel (LICH). LICH has a length of 7 bit payload (16 bit channel-coded) and contains the data telling the type of RF channel, the type of functional channel, the direction of transmission (outbound, i.e. from repeater to SU, or inbound, i.e. from SU to repeater) and some more channel type specification.

RCCH

In an RCCH frame (figure 3-71), the next data field is the Common Access Channel (CAC); it has three different formats of length: in outbound (downlink) direction the "CAC" (accommodating 18 octets), and in inbound (uplink) direction the "Long CAC"

(16 octets) and "Short CAC" (12 octets) format. Refer to the NXDN technical specifications for more detailed information.

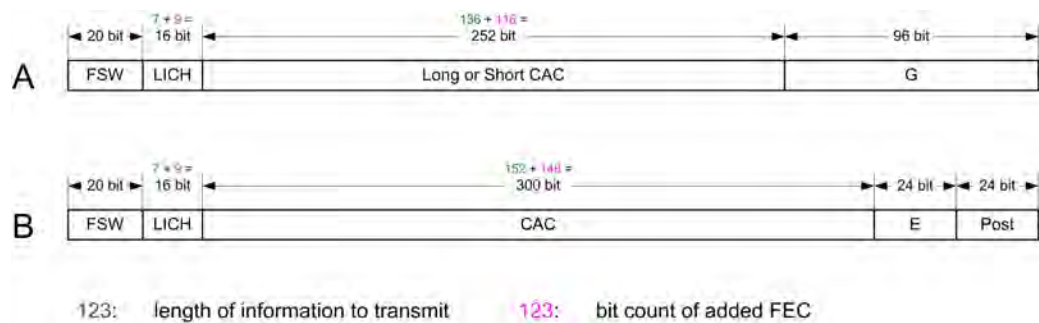


Fig. 3-71: RCCH frame.

A = Inbound (uplink) direction

B = Outbound (downlink) direction

The Guard Field (G) of the inbound RCCH (A in figure 3-71) is a "timing" field of 96 bit length without a special content for up/down power ramping purposes of the transmitter in an SU. With outbound (B), the Collision Control Field (E) comprises data used in random access periods (a SU wishes to transmit) to establish synchronicity, whereas the Post Field delivers a fixed bit pattern also usable (together with the FSW) for frame synchronization.

Outbound RCCH frames are organized in superframes of variable length (figure 3-72). The first frame of a superframe is always a BCCH type frame (CAC field is BCCH), all others CCCHs. If short data calls are to be made, the CCCH field is temporarily replaced by a UPCH field.

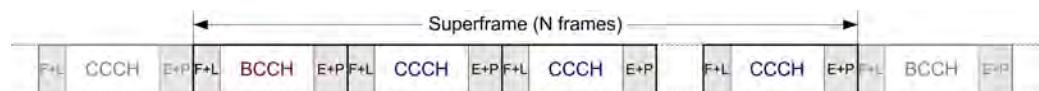


Fig. 3-72: Superframe structure RCCH.

F+L = FSW and LICH fields

E+P = E and Post fields

RTCH

In an RTCH frame (figure 3-73), the field following the FSW and LICH section is the Slow Associated Control Channel (SACCH). The original SACCH information of 9 octets (72 bits) is divided into 4 parts of 18 bits each, each part is amended an additional 8-bit field with some structure and radio access number information, resulting in 26 bits of length for each part. Then each part is subjected to a channel coding procedure leading to a finite length of the field of 60 bits.

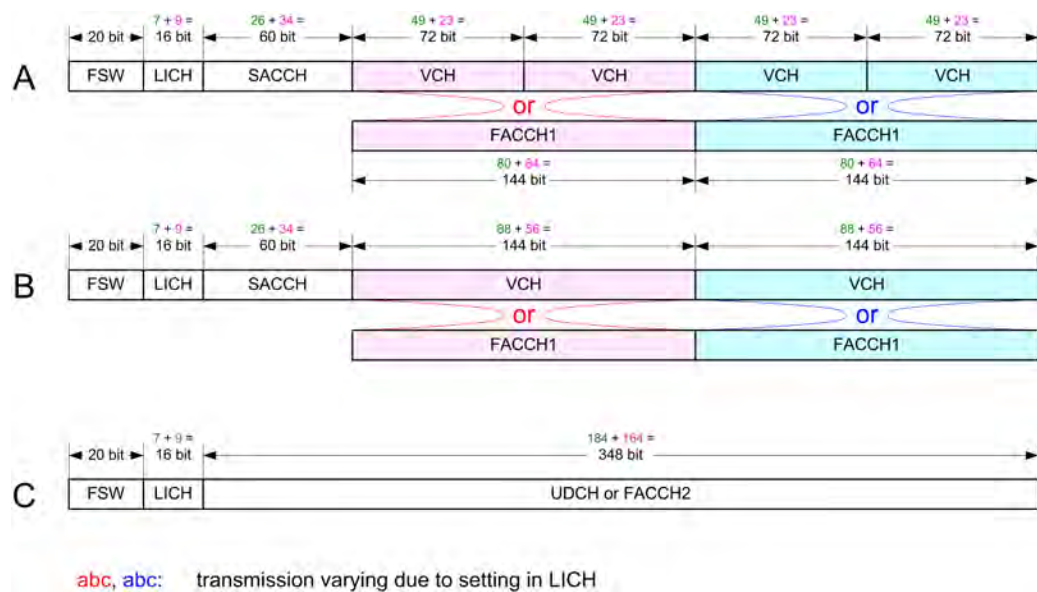


Fig. 3-73: RTCH frame (see also explanations with figure "RCCH frame").

A = Voice communication, voice coding mode half rate (4800 bit/s or 9600 bit/s)

B = Voice communication, voice coding mode full rate (9600 bit/s only)

C = Data communication

As with the RCCH frame, the RTCH and RDCH frames are also organized in a super-frame structure (figure 3-74), but now with always four frames forming one superframe. Each of the four frames is assigned one of the four SACCH parts, so the information which of the four is currently present can be derived thereof. Additionally a "non-super-frame" version of the SACCH (only 18 bits instead of 72 bits) exists, identifiable from LICH and indicating that a superframe sequence starts or ends.

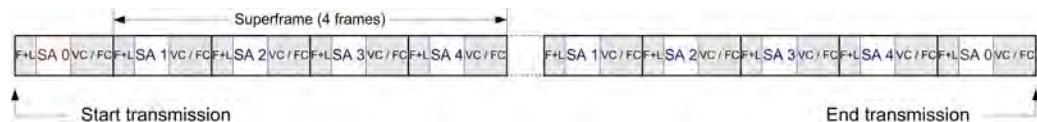


Fig. 3-74: Superframe structure RTCH and RDCH.

F+L = FSW and LICH fields

SA x = SACCH portion x field (x = 1 to 4) or non-superframe SACCH for start and end frames (x = 0)

VC / FC = VCH and FACCH1/2 fields

The Voice Channel (VCH) and Fast Associated Control Channel 1 (FACCH1) fields carry the payload data of the RTCH frame in voice communication mode, the VCH for voice-coded data and the FACCH1 for signaling or similar information. If such information (at a high speed) is to be transferred, the FACCH1 "steals" (replaces) a voice channel. Note that any combination of only VCHs, only FACCH1s or VCH and FACCH1 at a time are permitted, and that the voice codec (vocoder, 3.70.3.10, "Vocoder (Voice Codec)") operates in two modes, the half-rate (generating 49 bits per 20 ms interval, A in figure 3-73 and figure 3-75) and the full-rate mode (88 bits, B).

In data communication mode (C), the User Data Channel (UDCH) carries the digital payload data. Again, a Fast Associated Control Channel 2 (FACCH2) can "steal" a UDCH channel if necessary.

RDCH

In [figure 3-75](#) the RDCH frame is shown. Its architecture is the same as with RTCH frame ([figure 3-73](#)), but a preamble (a fixed bit pattern) is used to facilitate the initial synchronization capture in receivers. Length of the preamble is defined as 24 bits, but longer preambles are also acceptable if required.

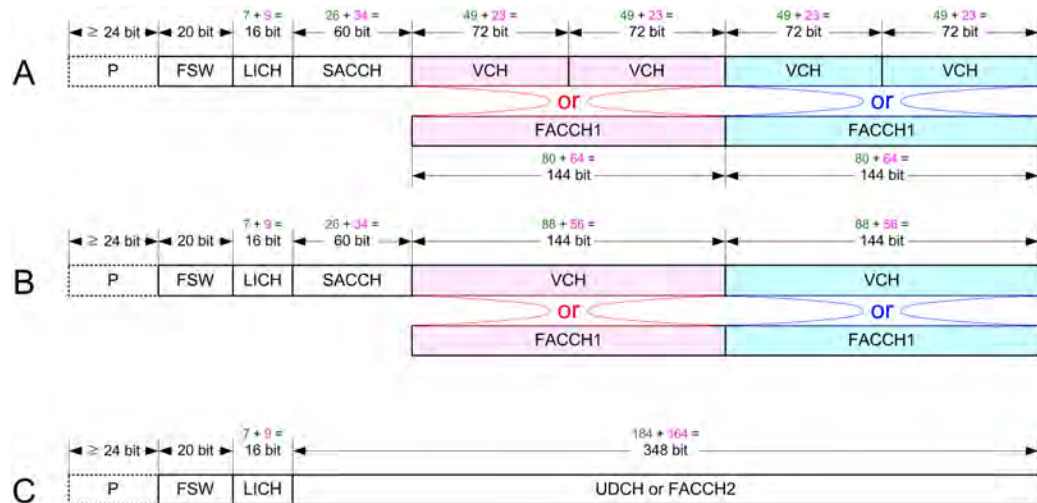


Fig. 3-75: RDCH frame (see also explanations with figures "RCCH frame" and "RTCH frame").

A = Voice communication, voice coding mode half rate (4800 bit/s or 9600 bit/s)

B = Voice communication, voice coding mode full rate (9600 bit/s only)

C = Data communication

3.70.3.9 Timing

Trunked System

An example of a timing in a trunked system is given in [figure 3-76](#). It is assumed that SU A wishes to send information (in some frames) to SU B, what in this architecture has to run via TR.

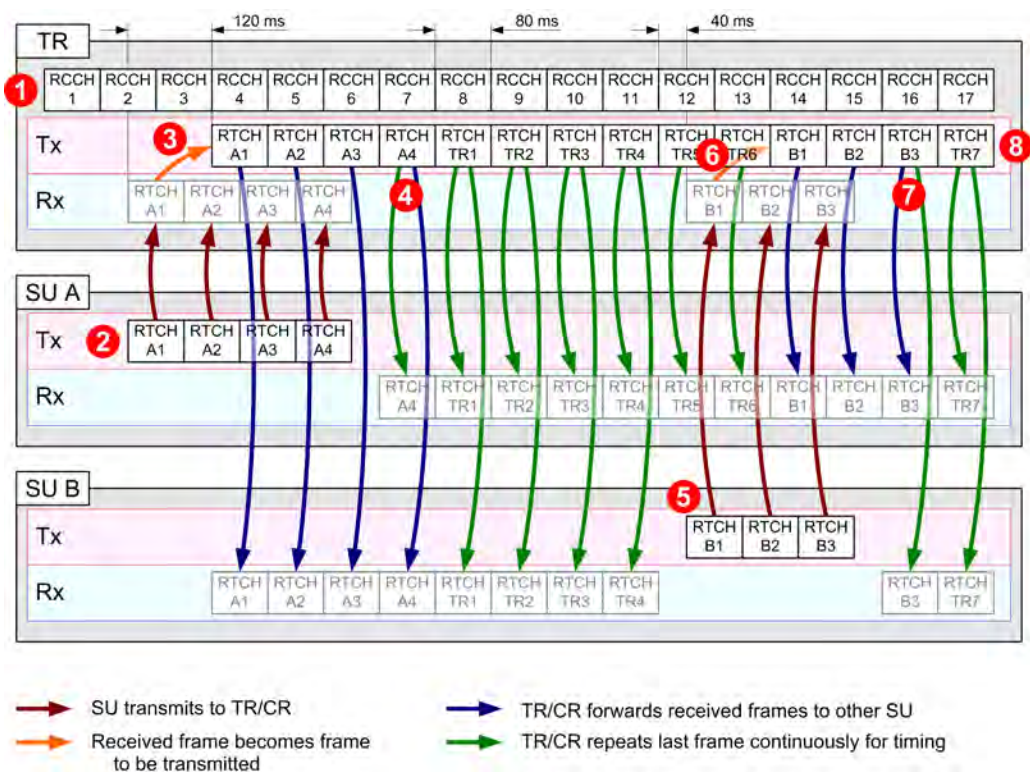


Fig. 3-76: Timing in a trunked system (4800 bit/s).

- ① The RCCH of TR runs continuously.
- ② SU A transmits to TR a message (4 frames) addressed to SU B.
- ③ With a delay of 120 ms (1.5 frames), TR forwards the message to SU B.
- ④ The last frame RTCH A4 of the message is being sent to SU B; SU A also receives the frame and uses it for maintenance of synchronization. Subsequently this frame is continuously repeated and received by both SU A and SU B to maintain synchronization (RTCH TR1 to RTCH TR6 are equivalent to RTCH A4).
- ⑤ SU B, at 120 ms delay from RTCH TR4, sends to TR a message (3 frames) addressed to SU A; therefore, SU B need not receive RTCH TR5.
- ⑥ With a delay of 120 ms, TR forwards the message to SU A.
- ⑦ Again, the last frame RTCH B3 is transmitted to both SU A and SU B due to synchronization (frames from RTCH TR7 up equivalent to RTCH B3).
- ⑧ Synchronization is kept established until a disconnect request appears from TR or some other events not explained here in detail.

Consult the technical specification for more detailed information.

Conventional System

Timing in the conventional case is shown in [figure 3-77](#). Again, SU A sends a message to SU B via CR.

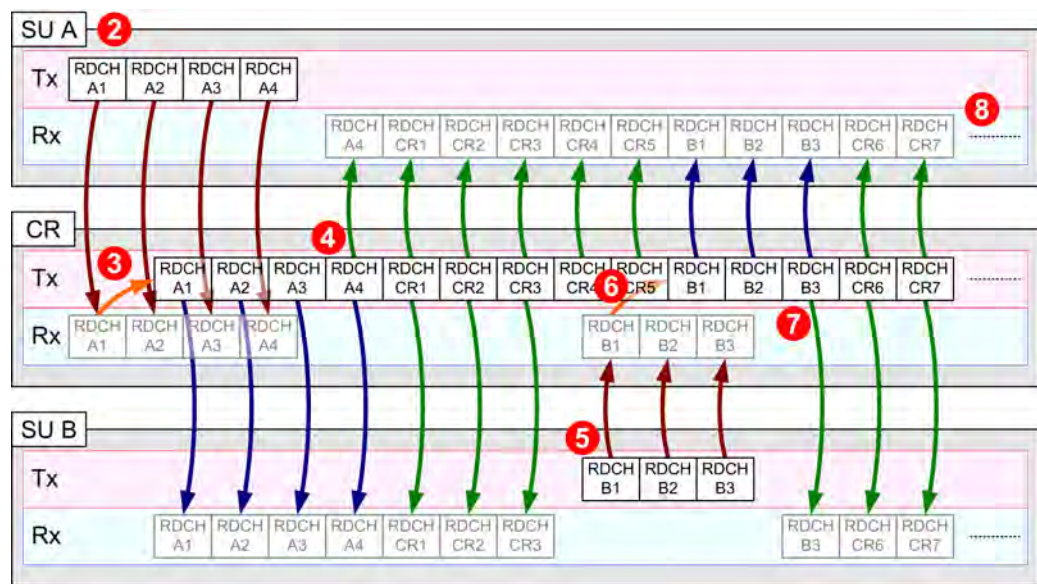


Fig. 3-77: Timing in a conventional system (4800 bit/s; see also explanations with figure "Timing in a trunked system").

- ② SU A transmits to CR a message (4 frames) addressed to SU B.
- ③ CR establishes an RDCH and, with a delay of 120 ms (1.5 frames), forwards the message to SU B.
- ④ The last frame RDCH A4 of the message is being sent to SU B; SU A also receives the frame and uses it for maintenance of synchronization. Subsequently this frame is continuously repeated and received by both SU A and SU B to maintain synchronization (RDCH CR1 to RDCH CR5 are equivalent to RDCH A4).
- ⑤ SU B, at 120 ms delay from RDCH CR3, sends to CR a message addressed to SU A; therefore, SU B need not receive RDCH CR4.
- ⑥ With a delay of 120 ms, CR forwards the message to SU A.
- ⑦ Again, the last frame RDCH B3 is transmitted to both SU A and SU B due to synchronization (frames from RDCH CR6 up equivalent to RDCH B3).
- ⑧ Synchronization is kept established until the hold time (if configured in the system) has elapsed, then synchronization is abandoned. For a potential continuation of the communication process, a resynchronization will be needed.

Direct System

In direct mode of a conventional system, timing is not specified explicitly.

3.70.3.10 Vocoder (Voice Codec)

The voice coding method used in NXDN is *AMBE+2*[®] (Advanced Multi Band Excitation), which is an improved and advanced multiband excitation (MBE) method. It was developed by *Digital Voice Systems, Inc. (DVS)*; voice-coding rates are **EHR** (enhanced half rate: 3600 bit/s) and **EFR** (enhanced full rate: 7200 bit/s).

- In **EHR**, the coding is processed at 2450 bit/s, voice-coding data come with 49 bit at 20 ms intervals. Adding 23 redundancy bits (for error correction) results in a VCH length of 72 bit.
- In **EFR**, processing speed is 4400 bit/s, data is 88 bit (interval 20 ms) or, with 56 bit redundancy added, 144 bit as VCH.

Refer to the *AMBE+2* technical documents by *DVSI* for detailed specifications.

3.71 Packet Radio 300 Bd

3.71.1 General

Transmission method	Packet Radio 300 Bd
Explanation of name	Packet switching technology on radio link instead of fixed connection line between stations, symbol rate 300 Bd
Other designations	Bell 103
Variants existing	
Derived from method	X.25 and HDLC computer network protocols
Typical users	Radio amateurs Transmission of computer programs or telemetry data
Kind of data	(Universal data)
Reference to standard	" <i>AX.25 Amateur Packet Radio Link-Layer Protocol</i> ", published by the American Radio Relay League Inc., 225 Main Street, Newington, CT 06111, U.S.A.
Frequency band	HF
Modulation method	FSK
Shift/tone spacing	200 Hz
Baud rate	300 Bd
Modulating subcarrier	
Bandwidth	540 Hz
Operating method	Duplex TDMA
Data protection	FEC (CRC)
Code table	ITA-5 (ASCII) (table 4-9 and table 4-10 in chapter 4.2)

3.71.2 History

The term "Packet Radio" has been formed in 1981 in Tucson, AZ, and has been accepted also in German speaking countries. A group of radio amateurs had joined

together to the TAPR (Tucson **A**mateur **P**acket **R**adio) and planned to build a local data network in the radio amateur band. Even in the 1960s the computers of the University of Hawaii (spread over several islands) had been linked together by radio. A protocol for data transmission was fixed by the AMSAT (Radio **A**Mateur **S**ATellite Corporation), derived from the existing X.25 protocol and called AX.25.

3.71.3 Description

Usually data communication is executed from one **PC** at the transmitting to another one at the receiving station.

Packet Radio, in contrast, is a form of packet switching technology (i.e. no fixed connection line between the two communicating stations is reserved exclusively during the entire data exchange) used to transmit digital data via radio or wireless communications links. An example of the late eighties – but in the field of wire-bound connections – is the time-division multiplex DATEX-P network of the German Telekom.

Data is transmitted in character blocks (similar to mode A of the **SITOR** system) of up to 256 bytes of length. To increase range and improve coverage, a number of relay stations, the so-called Digipeaters, have been established all over Germany and Europe on private initiative. Mobile stations are able to communicate their actual position via **APRS** (**A**utomatic **P**acket **R**eporting **S**ystem) at any time.

3.71.4 Channel Coding/Structure of Data Blocks

Data blocks, the so-called packets, are built by sharing out the bytes into fields. Three packet types are distinguished:

- Information (I, for payload data transfer)
- Supervisory (S, for transmission control)
- Unnumbered (U)

The length of a packet can be up to 332 bytes (minimum 19 bytes). The fields are:

- the *start flag* (1 byte), a fixed 8-bit sequence $0111\ 1110_2$, not to be used anywhere else within the packet
- the *address field* (14 to 70 bytes), consisting of the call signs of the receiving station, of the transmitting station and of up to 8 repeater stations in between
- a *control field* (1 byte), indicating the connection status and the type of the packet
- the *protocol identifier field* (1 byte), which only exists if also a data field is transmitted, and identifies the kind of layer 3 protocol in use
- the *data field* (0 to 256 bytes), containing the data to transmit in **ASCII**
- a *check field* (2 bytes), the frame check sequence for error detecting by a cyclic redundancy code (**CRC**), the only one of the fields being sent with **MSB** first
- the *end flag*, again the fixed 8-bit sequence $0111\ 1110_2$

An acknowledgment from the receiving station is only required after up to 7 packets received. The CRC code is calculated from the data with the polynomial

$$g(x) = x^{16} + x^{15} + x^2 + 1 .$$

In the case of 9600 Bd, a supplementary scrambling follows before transmission.

3.72 Packet Radio 1200 Bd

3.72.1 General

Transmission method	Packet Radio 1200
Explanation of name	Packet switching technology on radio link instead of fixed connection line between stations, symbol rate 1200 Bd
Other designations	Bell 202
Variants existing	
Derived from method	Packet Radio 300 Bd
Typical users	Radio amateurs Transmission of computer programs or telemetry data
Kind of data	(Universal data)
Reference to standard	"AX.25 Amateur Packet Radio Link-Layer Protocol", published by the American Radio Relay League Inc., 225 Main Street, Newington, CT 06111, U.S.A.
Frequency band	VHF/UHF
Modulation method	AFSK , indirect FM
Shift/tone spacing	1000 Hz
Baud rate	1200 Bd
Modulating subcarrier	1200 Hz
Bandwidth	25 kHz
Operating method	Duplex TDMA
Data protection	FEC (CRC)
Code table	ITA-5 (ASCII) (table 4-9 and table 4-10 in chapter 4.2)

3.72.2 Description

Packet Radio 1200 Bd is to a large extent (especially concerning the data protocol used) the same method as Packet Radio 300 Bd (see [chapter 3.71](#), "[Packet Radio 300 Bd](#)", on page 223). The differences are:

- frequency band is [VHF/UHF](#)

- modulation method is indirect [FM](#), i.e. a subcarrier of 1200 [Hz](#) is keyed (modulated) [AFSK](#) (keying of a carrier in the audio frequency range 20 Hz to 20 [kHz](#)) by the data stream and then modulated to the [RF](#) carrier

3.73 Packet Radio 9600 Bd

3.73.1 General

Transmission method	Packet Radio 9600
Explanation of name	Packet switching technology on radio link instead of fixed connection line between stations, symbol rate 9600 Bd
Other designations	
Variants existing	
Derived from method	Packet Radio 300 Bd Packet Radio 1200 Bd
Typical users	Radio amateurs Transmission of computer programs or telemetry data
Kind of data	(Universal data)
Reference to standard	" <i>AX.25 Amateur Packet Radio Link-Layer Protocol</i> ", published by the American Radio Relay League Inc., 225 Main Street, Newington, CT 06111, U.S.A.
Frequency band	VHF/UHF
Modulation method	MSK
Shift/tone spacing	4800 Hz
Baud rate	9600 Bd
Modulating subcarrier	
Bandwidth	15.4 kHz
Operating method	Duplex TDMA
Data protection	FEC (CRC)
Code table	ITA-5 (ASCII) (table 4-9 and table 4-10 in chapter 4.2)

3.73.2 Description

Packet Radio 9600 [Bd](#) is to a large extent (especially concerning the data protocol used) the same method as Packet Radio 300 Bd (see [chapter 3.71](#), "[Packet Radio 300 Bd](#)", on page 223) and also Packet Radio 1200 Bd ([chapter 3.72](#), "[Packet Radio 1200 Bd](#)", on page 225). The differences are:

- frequency band is [VHF/UHF](#)
- modulation method is direct [FSK](#), i.e. the [RF](#) carrier now is keyed directly. Due to the shift (4800 [Hz](#)) being half the Baud rate (9600 Bd), the modulation method also is called [MSK](#).

3.74 PACTOR I

3.74.1 General

Transmission method	PACTOR I
Explanation of name	PACKet Teleprinting Over Radio (alternative definition: pactor [Latin]: mediator), 1st variant
Other designations	PACTOR FSK PACTOR (F requency S hift K eying)
Variants existing	(not to be confused with PACTOR II/III, see chapter 3.76 and chapter 3.77) PACTOR 1 PACTOR 2, ICRC-PACTOR (I nternational C ommittee of the R ed C ross and R ed C rescent) PACTOR 3, UNHCR-PACTOR (U nited N ations H igh C ommissioner for R efugees) PACTOR 4, IFRC-PACTOR (I nternational F ederation R ed C ross and R ed C rescent S ocieties) PACTOR 5, UN-PACTOR (U nited N ations) PACTOR 6 PACTOR 7 Long-path option
Derived from method	AMTOR , Packet Radio
Typical users	PACTOR 1: Radio amateurs, NGOs , MARS (Military Auxiliary Radio System) stations PACTOR 2 to PACTOR 7: (see Variants existing)
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	200 Hz
Baud rate	100 Bd , 200 Bd (adaptive)
Modulating subcarrier	
Bandwidth	340 Hz (100 Bd), 480 Hz (200 Bd)

Transmission method	PACTOR I
Operating method	Half-duplex ("Simplex-ARQ"), synchronous
Data protection	ARQ (16 CRC bits per 80 data bits [100 Bd] or 176 data bits [200 Bd])
Code table	ITA-5 (ASCII) (table 4-9 and table 4-10 in chapter 4.2) Huffman (table 4-13 in chapter 4.4)

3.74.2 History

Standard PACTOR (PACTOR I) is a radio teletype mode based on FSK developed in Germany by *Ulrich Strate* and *Hans-Peter Helfert* ("by radio amateurs for radio amateurs") to improve on inefficient modes such as AMTOR/SITOR and Packet Radio (AX. 25) (see chapter 3.71, "Packet Radio 300 Bd", on page 223) in weak short wave conditions. Development goals were

- Error-free data transmission
- Transmission of binary data
- Low signal-to-noise ratio (SNR) requirement for maintaining a link
- Implementation using simple hardware
- Simple operation of the system
- Good utilization of the channel capacity

The synchronous transmission format and the short packet lengths of AMTOR/SITOR have been retained. These result in a protocol much more resistant to interference than Packet Radio under poor propagation conditions. The PACTOR protocol allows a much higher throughput than AMTOR/SITOR, with the efficient error correction and data transparency of Packet Radio.

PACTOR was released to the public in 1991. Meanwhile Strate and Helfert have founded their own company *SCS GmbH* (*Special Communications Systems, Ltd.*) developing special hardware and software for PACTOR operation.

3.74.3 Description



Denomination of modes

In relevant publications, naming of the different modes is not always performed consequently – not even in the original documents of the inventors. In the manual in hand, the differentiation is made between, on the one hand, the two transmission distance modes, called

- **Standard mode**
- **Long-path mode**

and, on the other hand, the two possible transmission cycles (only from PACTOR II), called

- **Normal mode** (normal cycle)
- **Data mode** (long cycle)

PACTOR is a synchronous ARQ system using a fixed **Transmission cycle** length of overall 1250 ms, divided in a Tx period of 960 ms and a listen cycle of 290 ms (figure 3-78). Two transmission speeds, 100 Bd and 200 Bd, are in use with adaptive switching due to the propagation conditions; the length of the data frame (ISS to IRS), however, remains the same, the bit count it contains is doubled from 96 bit to 192 bit instead. The ACK frame (IRS to ISS), in contrast, is always transmitted at 100 Bd and is 12 bit or 120 ms long.

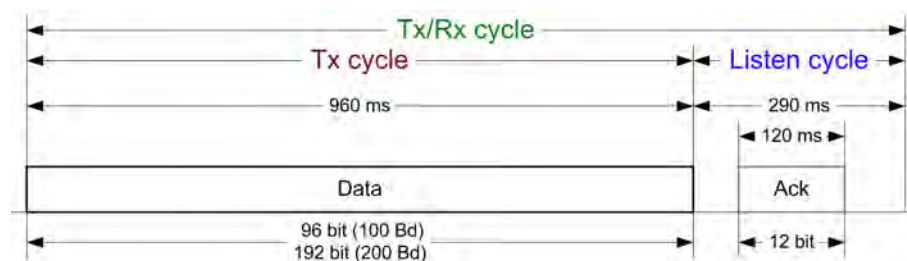


Fig. 3-78: Transmission cycle in PACTOR.

The **data block** (figure 3-79, A) falls into four sections: a leading synchronization byte with a fixed value of 55_{16} , a data section of 64 bit (100 Bd) or 160 bit (200 Bd), a status byte (containing packet number, break or shutdown request, transmitting mode etc.) and the 16-bit CRC checksum. Every second frame emitted is inverted completely and, besides, the Sync byte of every frame with new information is also inverted; hence, with correct transmission, the Sync byte in effect is never inverted (remains erect).

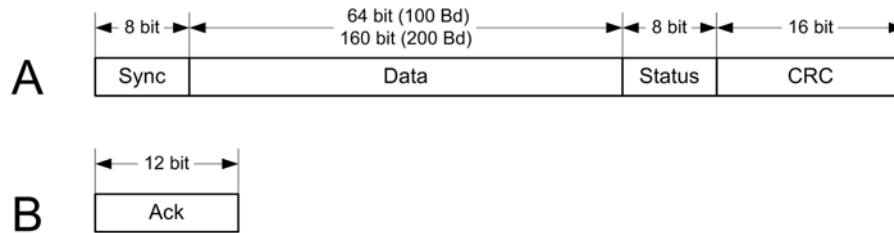


Fig. 3-79: Frame structure in PACTOR.

A = Transmission (ISS)

B = Acknowledge (IRS)

Coding of data can be in 8-bit ASCII ([chapter 4.2, "ITA-5 \(ASCII\) Code Table"](#), on page 336) or, for increasing data throughput, also in Huffman code ([chapter 4.4, "Huffman Code Table"](#), on page 340, complete code table in [table 4-13](#)), which codes frequently occurring characters with less bits than more rarely used ones. A compression factor of about 1.7 can be achieved this way, but, from a pure monitoring view, this kind of coding has the disadvantage that, in case of interference, the character synchronization and thus the text itself might be lost for the complete data block. Transmitting is done in **LSB** first, except the CRC word, which is transmitted in **MSB** first (and **MSByte** first).

The 12 bits of the **ACK frame** ([figure 3-79, B](#)) can be one of four pseudo-random noise (**PN**) sequences of maximum Hamming distance called CS1 to CS4: CS1/CS2 operate the normal acknowledge function, CS3 requests for break-in and change of traffic direction and CS4 for change of transmission speed.

Another feature of PACTOR is the so-called **Memory-ARQ**: with poor propagation conditions and hence erroneous received frames, an averaging process of the corresponding analog signal is performed and then tested whether the mean value passes the CRC.

Due to change-over time and signal propagation delay, the transmission distance of PACTOR is limited to about 20000 km. For longer distances (but accepting longer handshaking periods then), a **Long-path mode** exists in addition (to the **Standard mode**), enlarging the transmission cycle from 1250 ms to 1400 ms (i.e. the listen cycle from 290 ms to 440 ms).

PACTOR is a mode used very frequently by radio amateurs. Additionally, there are also commercial and other professional users of the system. In order to obey enhanced privacy requirements, several differing **variants** of the method have been created; modifications concern the way the CRC sum is calculated. (In variant 1, the 16-bit CRC is identical to the FCS [**F**rame **C**heck **S**equences] defined in the X.25 protocol of the ITU and is also used for G-TOR [[chapter 3.50, "G-TOR"](#), on page 143] and Packet Radio [[chapter 3.71](#)].) In [table 3-37](#) an overview is shown about known variants and their users, only the **HAM** variant 1 is well-documented, whereas the other variants are hardly ever documented.

Table 3-37: PACTOR variants¹⁾.

Variant	User group	Note
1	HAM	Radio amateurs
2	ICRC	International Committee of Red Cross and Red Crescent
3	UNHCR	United Nations High Commissioner for Refugees
4	IFRC	International Federation of Red Cross and Red Crescent
5 to 8	unknown	

¹⁾ not to be confused with PACTOR II/III, see [chapter 3.76](#) and [chapter 3.77](#)

3.75 PACTOR-FEC

3.75.1 General

Transmission method	PACTOR-FEC
Explanation of name	PAC k ^{et} TE leprinting O ver R adio, F orward E rro ^r C orrection (alternative definition: pactor [Latin]: mediator)
Other designations	
Variants existing	(see PACTOR I)
Derived from method	PACTOR I
Typical users	
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	200 Hz
Baud rate	100 Bd , 200 Bd (adaptive)
Modulating subcarrier	
Bandwidth	340 Hz (100 Bd), 480 Hz (200 Bd)
Operating method	Simplex, broadcast
Data protection	ARQ (16 CRC bits per 80 data bits [100 Bd] or 176 data bits [200 Bd])
Code table	ITA-5 (ASCII) (table 4-9 and table 4-10 in chapter 4.2) Huffman (table 4-13 in chapter 4.4)

3.75.2 Description

PACTOR-FEC is the broadcast variant of PACTOR I ([chapter 3.74, "PACTOR I"](#), on page 227). All signaling, frame construction, transmission speeds, variants existing etc. are the same, the only difference is that a Listen cycle does not exist, i.e. data blocks are emitted consecutively with no or very little space between.

3.76 PACTOR II

3.76.1 General

Transmission method	PACTOR II
Explanation of name	PAC ket TE leprinting O ver R adio (alternative definition: pactor [Latin]: mediator), II nd variant
Other designations	
Variants existing	PACTOR II ARQ
Derived from method	PACTOR I
Typical users	Radio amateurs Non-government organizations (NGOs)
Kind of data	(Universal data)
Reference to standard	
Frequency band	HF
Modulation method	PSK on 2 separate frequencies (tones) with 4 adaptively selected modulation schemes: PSK2 (DBPSK) (yielding 200 bit/s) PSK8 (D8PSK) (600 bit/s) PSK4 (DQPSK) (400 bit/s) PSK16 (D16PSK) (800 bit/s)
Shift/tone spacing	200 Hz (frequencies 1200 Hz and 1400 Hz)
Baud rate	100 Bd
Modulating subcarrier	1300 Hz
Bandwidth	300 Hz
Operating method	Half-duplex ("Simplex-ARQ"), synchronous; simplex
Data protection	ARQ , CRC
Code table	ITA-5 (ASCII) (table 4-9 and table 4-10 in chapter 4.2) Huffman (table 4-13 in chapter 4.4) Pseudo-Markov (PMC)

3.76.2 History

In 1991, *Ulrich Strate* and *Hans-Peter Helfert* released the PACTOR radio teletype mode ([chapter 3.74, "PACTOR I"](#), on page 227). Later on, when more powerful hard- and software had been developed and the cost of high-power processors dropped dramatically (and production of modules needed for PACTOR-I controllers was discontinued), the PACTOR creators' company *SCS GmbH (Special Communications Systems, Ltd.)*, founded in 1993) began to develop the advanced standard PACTOR II. First prototypes were presented in 1994 on the [HAM](#) Radio trade fair.

PACTOR II (using [PSK](#)) is 7 times faster than, but fully down-compatible to standard PACTOR (or PACTOR I), and the initial link setup is still done in PACTOR I ([FSK](#)).

3.76.3 Description



Denomination of modes

In relevant publications, naming of the different modes is not always performed consequently – not even in the original documents of the inventors. In the manual in hand, the differentiation is made between, on the one hand, the two transmission distance modes, called

- **Standard mode**
- **Long-path mode**

and, on the other hand, the two possible transmission cycles (only from PACTOR II), called

- **Normal mode** (normal cycle)
- **Data mode** (long cycle)

3.76.3.1 Scope

PACTOR II is a two-channel transmission method using 4 submodes, so-called speed levels, for improved adaptability: the most robust submode uses [PSK2](#) modulation, the highest speed level uses [PSK16](#). Also two lengths of the transmitted frame ("short", duration 1.25 s, and "long", 3.75 s) are possible. Selection of suitable submode and frame length is made automatically as propagation conditions change: high-level modulation and long frame length for good conditions, low-level and short for bad. Two transmission modes are available: a synchronous half-duplex [ARQ](#) protocol and a broadcast mode.

The goal when developing PACTOR II was to achieve a user bit rate as high as possible, but not to exceed the maximum reasonable modulation rate (on-air baud rate) of about 100 [Bd](#) to 200 Bd. With regard to the overcrowded radio spectrum, the new system should not only require a narrow bandwidth, but also provide an improved spectral efficiency to obtain a higher throughput.

A significant difference to **PACTOR I** is the concept of spreading the total amount of data to transmit onto two separate carriers (tones); these two tones have a frequency distance of 200 Hz.

3.76.3.2 Frames

From that, unlike with **PACTOR I**, a distinction is to be made from now on between

- the user data frame (carrying the original information data bits) and
- the on-air data frame (carrying more than one bit per symbol, due to accommodation on two modulation tones instead of just one, and to higher modulation order).

Additionally the original user data (synchronization, status and CRC information added as before) may be subjected to a data compression and afterwards are in any case to a convolutional coding (constraint length 9). Distribution onto the two tones is done using an interleaving procedure.

The on-air frame was aimed to remain the same as with **PACTOR I**, i.e. the Transmission cycle length of 1250 ms also exists with **PACTOR II**, but, with respect to the control signals having been increased to improve reliability under poor conditions (enlarged Hamming distance between control signals), internal layout of the frame was modified. This "short" type of frame now is called **Normal mode** (figure 3-80, A). Additionally, a new, longer type of frame has been created, now called **Data mode** (B). Both frame types are shown in figure 3-80.

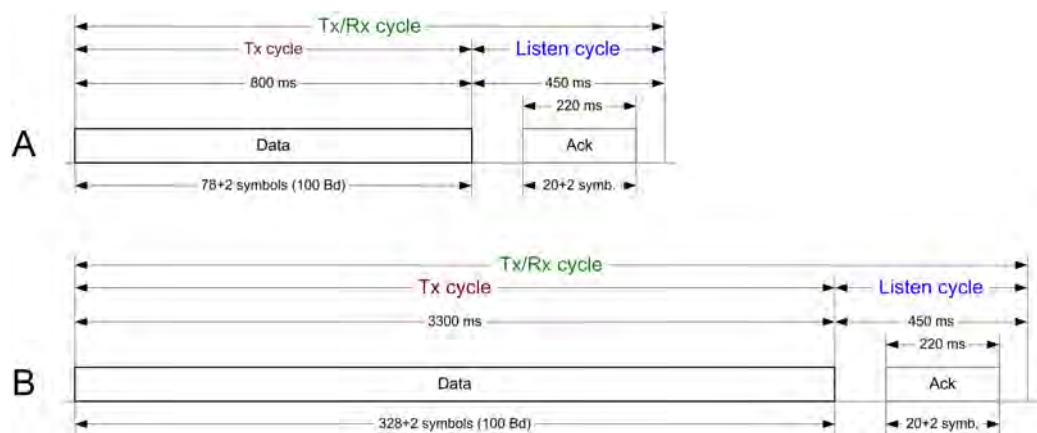


Fig. 3-80: Transmission cycles in PACTOR II.

A = Normal mode

B = Data mode

Information carried on the two channels is swapped between the channels after every cycle, thus providing resistance to strong narrowband interference (e.g. CW), which might completely overpower the one channel; the signal can still get transferred on the other one (but at a reduced speed) this way. Swapping mode commonly begins a short time after start of an emission.

As with **PACTOR I**, in order to bridge larger transmission distances than with common frame lengths (the **Standard mode**) (but getting longer responding times), a **Long-Path mode** has been established both in Normal and in Data mode. In Normal mode,

Transmission cycle length increases from 1250 ms to 1400 ms, in Data mode from 3750 ms to 4200 ms.

In PACTOR II, the ACK signal comprises six different control signals (CS), each consisting of 20 symbols. As with PACTOR I,

- CS1 and CS2 are used to acknowledge/request packets
- CS3 forces a break-in
- CS4 and CS5 handle the speed changes
- CS6 is a toggle for the packet length

For maximum robustness, CSs are always sent in PSK2 (DBPSK).

Every data and ACK frame is started and terminated by a single phase reference pulse (2 symbols in addition); and the 8 symbols subsequent to the starting pulse of the data frame comprise a header supporting QRG tracking (**Q**uick **R**eference **G**uide: tracking of the frequency currently transmitted on), Listen mode and Memory-ARQ.

Frame lengths that can be accommodated in the above-mentioned on-air frames (i.e. that are obtained after convolutional decoding [Viterbi decoding]) depend on order of modulation and mode (Normal or Data). They are given in [figure 3-81](#) for Normal mode (**A**) and Data mode (**B**) and the four modulation types (**1** to **4**); status byte and CRC word as in PACTOR I also exist here, but synchronization is done on another protocol layer; thus, visually the frame formats are equal, but layout differs slightly. This is signified by the "S+C+T" (Status, CRC, Termination of FEC) term. A compression of user data with another coding scheme than ASCII (see [3.76.3.3, "Data Compression"](#)) is not considered in the figure.

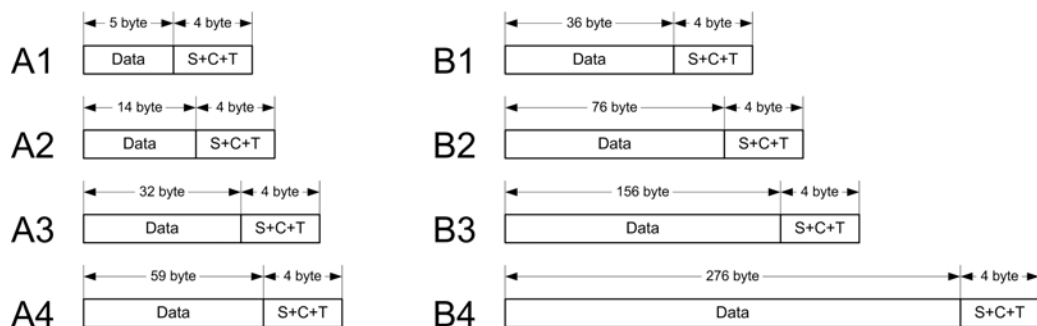


Fig. 3-81: Decodable frames.

A = Normal mode
 B = Data mode
 1 = PSK2 (DBPSK)
 2 = PSK4 (DQPSK)
 3 = PSK8 (D8PSK)
 4 = PSK16 (D16PSK)
 S+C+T = Status, CRC, Termination of FEC

3.76.3.3 Data Compression

For an even higher throughput of text data, some variants of compression of user data (instead of using pure 8-bit ASCII code) may be applied:

- Huffman coding: As explained in [chapter 3.50, "G-TOR"](#), on page 143, Huffman codes characters with bit lengths corresponding to their frequency of occurrence in a special language. Two modes are defined,
 - the one comprising all **lower and upper case** characters, showing a reduction factor of about 1.7, compared to ASCII coding, and
 - the other one only considering **upper case** (more precisely: exchanging, i.e. swapping, the codes for lower and upper case), leading to a still shorter coding and hence additional compression factor in texts containing no lower, but only upper case letters.

The complete code table can be seen from [table 4-13](#) in [chapter 4.4, "Huffman Code Table"](#), on page 340.

- Pseudo-Markov coding (PMC): The pure Markov method of coding also takes into account the probability of the character following the current character (e.g. a "t" is more likely to follow an "s" than an "x"). But, as a tradeoff between expense of memory for the corresponding lookup tables and additional compression achievable, a Pseudo-Markov coding is applied, considering only the 16 most frequent preceding characters; all other characters use normal Huffman coding.

As explained with [PACTOR I](#), in case of transmission errors along with data compression character synchronization will be lost, and hence the complete text of the current data block.

Information about which kind of coding is contained in a special data packet is carried in the status byte of the frame; [table 3-38](#) shows assembly of the byte; "swapped" means the upper case mode explained above.

Table 3-38: Status byte of decodable frame.

Bits	Meaning	Comb.	Explanation
0 to 1	Packet Number (modulo 4)		
2 to 4	Data type (compression factor)	000	ASCII 8-bit
		001	Huffman
		010	Huffman swapped (upper case)
		011	(reserved)
		100	PMC German normal
		101	PMC German swapped
		110	PMC English normal
		111	PMC English swapped
5 to 7	Misc.		Cycle length suggestion, changeover request, QRT packet

As with G-TOR ([chapter 3.50](#)), a run-length encoding ([RLE](#)) structure feature exists; for specific details see relevant publications.

3.76.3.4 Frequencies

As mentioned in 3.76.3.1, "Scope", the two carriers are spaced at 200 Hz and can be modulated with PSK in 2 up to 16 states (PSK2 [DBPSK], PSK4 [DQPSK], PSK8 [D8PSK], PSK16 [D16PSK]). The convolutional code applied is also changed together with the modulation method. Selection is done adaptively, depending on current quality of the transmission channel.

In table 3-39 code rates of the used codes, achievable data rates (data compression not considered) and number of transferable bytes per packet (on-air frame) are summarized. The calculation formula for these bytes is

$$BP = BF * CH * CR * \lg(MS) - CB$$

BP bytes/packet

BF bytes/on-air frame Normal mode: 9 (80 symbols – 8 symbols/header = 72 symbols = 9 bytes)
Data mode: 40 (328 – 8 = 320 symbols = 40 bytes)

CH number of channels 2 with PACTOR II

CR code rate

MS modulation states PSK2 (DBPSK): 2
PSK4 (DQPSK): 4
PSK8 (D8PSK): 8
PSK16 (D16PSK): 16

CB control bytes/decodable frame 4

Table 3-39: Modulation and data rates.

Modulation		PSK2 (DBPSK)	PSK4 (DQPSK)	PSK8 (D8PSK)	PSK16 (D16PSK)
Code rate		1/2	1/2	2/3	7/8
Data rate [bit/s]		100	200	400	700
Bytes/packet	Mode Normal	5	14	32	59
	Mode Data	36	76	156	276

3.76.3.5 Link Establishing

Establishing of a link is always done in FSK in order to maintain compatibility to PACTOR I. If PACTOR II capability of both stations involved is confirmed, switching to PACTOR II is also performed automatically.

3.76.3.6 Memory-ARQ

Memory-ARQ is available also in PACTOR II, cf chapter 3.74 for information.

3.76.3.7 Unproto Mode

PACTOR II, additionally to the ARQ mode described in the previous paragraphs of [3.76.3, "Description"](#), offers a broadcast mode, the so-called Unproto mode. The main difference is the lack of any ARQ sequences and thus of nearly the entire listen cycle (only a small gap exists between on-air frames), and, as a substitute for error correction purposes, the method to transmit frames repeatedly. Usual repeat counts are 1 (no repetition) to 5.

3.77 PACTOR III

3.77.1 General

Transmission method	PACTOR III
Explanation of name	P AcKet T eleprinting O ver R adio (alternative definition: pactor [Latin]: mediator), Illrd variant
Other designations	
Variants existing	PACTOR II FEC
Derived from method	PACTOR
Typical users	Radio amateurs Non-government organizations (NGOs)
Kind of data	Universal data
Reference to standard	
Frequency band	HF
Modulation method	PSK on 2 to 18 separate frequencies (tones) with 2 adaptively selected modulation schemes: PSK2 (DBPSK) (yielding up to 1400 bit/s) PSK4 (DQPSK) (up to 3600 bit/s)
Shift/tone spacing	120 Hz (frequencies from 480 Hz to 2520 Hz)
Baud rate	100 Bd
Modulating subcarrier	1500 Hz
Bandwidth	960 Hz to 2200 Hz (depending on speed level and coding)
Operating method	Half-duplex ("Simplex-ARQ"), synchronous; simplex
Data protection	ARQ , CRC
Code table	ITA-5 (ASCII) (table 4-9 and table 4-10 in chapter 4.2) Huffman (table 4-13 in chapter 4.4) Pseudo-Markov (PMC)

3.77.2 History

Similar to PACTOR I ([chapter 3.74, "PACTOR I"](#), on page 227) and PACTOR II ([chapter 3.76, "PACTOR II"](#), on page 232), PACTOR III is also a half-duplex synchronous ARQ system. In the standard mode, the initial link setup is still performed using the [FSK](#) (PACTOR I) protocol, in order to achieve compatibility to the previous systems. If both stations are capable of PACTOR III, automatic switching to this highest protocol level is then performed.

While earlier PACTORs I and II were developed for operation within a bandwidth of 500 [Hz](#), PACTOR III is designed specifically for the commercial market to provide higher throughput and improved robustness utilizing a complete [SSB](#) channel. A maximum of 18 tones spaced at 120 [Hz](#) is used in optimum propagation conditions. The highest raw bit rate transferred on the physical protocol layer is 3600 [bit/s](#), corresponding to a net user data rate of 2722.1 [bit/s](#) without compression. As different kinds of online data compression are provided, the effective maximum throughput depends on the transferred information, but typically exceeds 5000 [bit/s](#), which is more than 4 times faster than PACTOR II. At the low [SNR](#) edge, PACTOR III also achieves a higher robustness compared to PACTOR II.

PACTOR III was introduced to the public in 2002.

3.77.3 Description



Denomination of modes

In relevant publications, naming of the different modes is not always performed consequently – not even in the original documents of the inventors. In the manual in hand, the differentiation is made between, on the one hand, the two transmission distance modes, called

- **Standard mode**
- **Long-path mode**

and, on the other hand, the two possible transmission cycles (only from PACTOR II), called

- **Normal mode** (normal cycle)
- **Data mode** (long cycle)

3.77.3.1 Scope

Depending on the propagation conditions, PACTOR III utilizes 6 different speed levels (SL), which can be considered as independent sub-protocols with distinct modulation and channel coding. On all speed levels the physical data rate is 100 [Bd](#). As can be seen from [figure 3-82](#) (coloring concerns information swapping, see [3.77.3.3, "Frequencies"](#)), up to 18 tones (frequencies) are used, spacing between each two of them is 120 [Hz](#), the center frequency of the entire signal 1500 [Hz](#) and the maximum occupied bandwidth 2.2 [kHz](#) (from about 400 [Hz](#) to 2600 [Hz](#)).

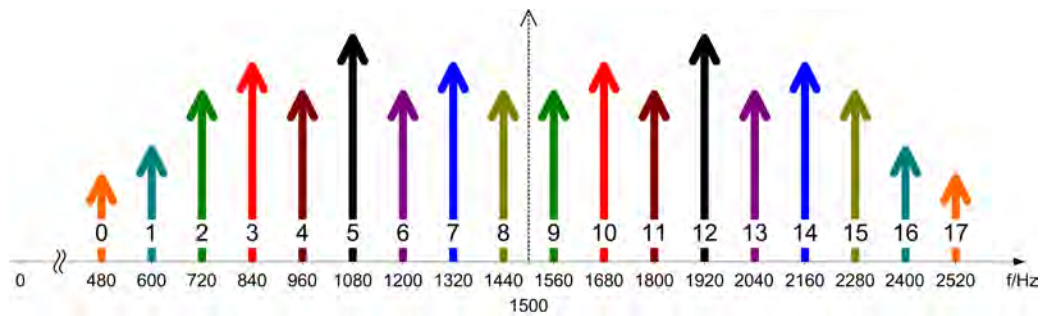


Fig. 3-82: Frequencies in PACTOR III.

3.77.3.2 Frames, Data Compression

All that has been explained in [PACTOR II](#) concerning frame structure (user frame and on-air frame), cycle duration (Normal and Data mode), control signals, distance modes (Standard and Long-Path) etc. is also valid here. Information swapping now is performed between dedicated channels, see [3.77.3.3, "Frequencies"](#). Modifications have to be made in [figure 3-81](#): the number of bytes conveyed is to be extracted from [table 3-41](#), the differences now result not only from modulation scheme (only PSK2 [DBPSK] and PSK4 [DQPSK] used), but from number of frequencies occupied in each speed level.

Differences also exist with regard to the headers used in the on-air frames. PACTOR III distinguishes the so-called

- Variable Packet Headers

(16 different with 32 bits each), carried on tone 5 and tone 12, from the

- Constant Packet Headers

(16 different with 16 bits each), initiating all other tones. For detailed informations refer to relevant publications.

Also, data compression (ASCII [i.e. no compression], Huffman, Pseudo-Markov) in PACTOR III is identical to PACTOR II.

3.77.3.3 Frequencies

As explained in [3.77.3.1, "Scope"](#), up to 18 frequencies are used in PACTOR III to establish the 6 speed levels. The tone representing the lowest channel is sent at a frequency of 480 Hz, the highest tone is 2520 Hz, resulting in an overall bandwidth consumption of 2200 Hz. But not each tone is used in all speed levels; rather, full occupation of the complete tone spectrum is made use of even only in the highest speed level, level 6. When reducing level, the outer tones are ceased gradually, and in the lowest levels intermediate tones are skipped, thus the gaps between remaining tones increase to multiples of 120 Hz in these cases; [table 3-40](#) illustrates usage of the tones in each speed level together with their frequency and numbering.

Table 3-40: Speed levels and frequencies in use.

Level No.		1	2	3	4	5	6
f [Hz]	Channel No.						
480	0						X
600	1					X	X
720	2			X	X	X	X
840	3		X	X	X	X	X
960	4			X	X	X	X
1080	5	X	X	X	X	X	X
1200	6			X	X	X	X
1320	7		X	X	X	X	X
1440	8			X	X	X	X
1560	9			X	X	X	X
1680	10		X	X	X	X	X
1800	11			X	X	X	X
1920	12	X	X	X	X	X	X
2040	13			X	X	X	X
2160	14		X	X	X	X	X
2280	15			X	X	X	X
2400	16					X	X
2520	17						X

Swapping of the information between two channels from cycle to cycle, as performed in [PACTOR II](#), is also done here: when observing [table 3-40](#) from left to right (increasing speed level), most obvious swapping is

- tone 5 with tone 12
- 3 with 10
- 7 with 14
- 2 with 9
- 4 with 11
- 6 with 13
- 8 with 15
- 1 with 16
- 0 with 17

Tone 5 and tone 12 transfer the Variable Packet Headers (see [3.77.3.2, "Frames, Data Compression"](#)) and the control signals, hence they can be considered as equivalent to the two carriers of PACTOR II.

In [figure 3-82](#) frequencies that swap information to each other are given in the same color.

PACTOR III does not use higher modulation schemes than PSK4 (DQPSK, 4 states). In [table 3-41](#), for each speed level code rates of the used codes, achievable data rates (data compression not considered) and number of transferable bytes per packet (on-air frame) are summarized. The calculation formula for these bytes is

$$BP = BF * CH * CR * ld(MS) - CB$$

BP bytes/packet

BF bytes/on-air frame Normal mode: 9 (80 symbols – 8 symbols/header = 72 symbols = 9 bytes)
Data mode: 40 (328 – 8 = 320 symbols = 40 bytes)

CH number of channels

CR code rate

MS modulation states PSK2 (DBPSK): 2
PSK4 (DQPSK): 4

CB control bytes/decodable frame 4

Table 3-41: Modulation and data rates.

Speed Level	1	2	3	4	5	6
Channels	2	6	14	14	16	18
Modulation	PSK2 (DBPSK)			PSK4 (DQPSK)		
Code rate	1/2	1/2	1/2	1/2	3/4	8/9
Data rate [bit/s]	100	300	700	1400	2400	3200
Bytes/packet	Mode Normal	5	23	59	122	284
	Mode Data	36	116	276	556	1276

3.77.3.4 Link Establishing, Memory-ARQ, Unproto Mode

Link Establishing, Memory-ARQ and Unproto Mode are identical to [FACTOR II](#).

3.78 Piccolo-6 (MK 6)

3.78.1 General

Transmission method	Piccolo-6 (MK 6)
Explanation of name	Piccolo (flute) (derived from Italian for "small"): onomatopoeic description of the sound of the signal, 6 tones
Other designations	Piccolo ITA-2
Variants existing	Piccolo MK 10 (tone duration 25 ms and special 5-bit alphabet)
Derived from method	
Typical users	Government and military stations
Kind of data	

Transmission method	Piccolo-6 (MK 6)
Reference to standard	
Frequency band	HF
Modulation method	FSK: MTONE (MFSK)
Shift/tone spacing	20 Hz
Baud rate	Tone duration 50 ms, thus "tone speed" 20/s
Modulating subcarrier	
Bandwidth	100 Hz
Operating method	Simplex
Data protection	None
Code table	ITA-2 (table 4-2 in chapter 4.1.2)

3.78.2 History

Most of the known telegraph systems operate on a binary principle, i.e. information is conveyed by selection of one of two possible signaling states; in case of FSK, these are represented by two frequencies. The information of a character of an alphabet, which contains e.g. five or seven bits, is carried by sequentially sending such selections. Mathematical investigations on expanding this to more than two selections (frequencies) reveal that a decrease in errors and even a decrease in bandwidth consumption can be achieved, but only up to a count of about twelve frequencies (tones).

A first Piccolo system (called Mark I, followed later by the improved Marks II and III) used 32 tones (one for each of the 32 combinations of the ITA-2 alphabet) and a 33rd for "stand by", with a tone duration of 100 ms and a frequency spacing of 10 Hz, leading to an overall bandwidth need of 370 Hz. It was established by the UK in 1962 (replacing the manual Morse system) and formed the HF radio network of the UK FCO (United Kingdom Foreign and Commonwealth Office), thus carrying traffic from the UK to over 50 embassies until the early nineties; the system in sum has proved very effective.

This early Piccolo system was then replaced by the Mark VI (MK 6) system; using less than 32 different tones and not a single, but instead two consecutive tones (tone sequence) was recognized to give a better compromise between performance and bandwidth demand; especially the high frequency stability of the oscillator(s) used required by a large count of tones could be relaxed this way.

3.78.3 Description



Denotation

- **Tone n**

means the **tone (frequency) no. n** out of the underlying tone table, whereas

- **m-th tone**

denotes the **m-th (sent) tone** out of the transmitted tone sequence.

Table 3-42: Frequency assignment in Piccolo MK 6.

ITA-2 (6 tones)													
Tone No.		0	1	2		3	4	5					
ITA-5 (12 tones)													
Tone No.	0	1	2	3	4	5		6	7	8	9	10	11
Freq [Hz]	−110	−90	−70	−50	−30	−10	Center tuning	10	30	50	70	90	110

Piccolo MK 6 is divided into two different modes, both using two sequential tones with 50 ms duration and 20 Hz shift (i.e. frequency spacing between the tones available).

- The one, called Piccolo-6, selects from six tones, the resulting 36 combinations picturing the 32 codes of the ITA-2 alphabet,
- the other one, Piccolo-12 (see [chapter 3.79, "Piccolo-12 \(MK 6\)"](#), on page 246), has twelve tones so that 144 combinations cover the 128 codes of the ITA-5 (ASCII) alphabet.

As can be seen from [table 3-42](#) (Piccolo-12 given for comparison), frequency span ranges from −50 Hz to 50 Hz or −110 Hz to 110 Hz, respectively, related to the center tuning frequency.

A baud rate cannot be told for a multitone system; supposed the 100 ms duration of the two-tone sequence and (for Piccolo-6 with ITA-2) a 7.5-bit Baudot code word (cf [chapter 3.21, "BAUDOT"](#), on page 84), a 75 Bd rate follows. Defining a "baud rate" from the 50 ms tone duration leads to a rate of 20 Bd.

Assignment of the particular codes to the tone combinations could of course have been done arbitrarily (no special cross-connection to the original code table needed in principle). The assignment used in reality with Piccolo-6 is shown in [table 3-43](#) (meaning of each character omitted): it can be seen that special code symmetries have been taken advantage of, resulting in the ability to infer special bit combinations in an easier way. So bit 4 (the MSB) is always determined by 1st tone only, bit 3 by 2nd tone only, either bit 2 or bit 0 (the LSB) also follow from 1st tone only, and either bit 1 or bit 0 from 2nd tone only. The maximum number of bits (out of the totalling 5) having to be derived from the complete tone combination is 2, this event arises only with 2nd tone = tone 0 or 2nd tone = tone 5.

Table 3-43: Code assignment in Piccolo-6.

1st Tone	2nd Tone			0	1	2	3	4	5
	Bit	3		0	0	0	1	1	1
		1			0	1	1	0	
	4	2	0			0	0		
0	1	1		10111	10101	10110	11110	11101	11111
1	1	0		10011	10001	10010	11010	11001	11011
2	1		0	10100	10000	X	standby	11000	11100
3	0		0	00100	00000	X	X	01000	01100
4	0	0		00011	00001	00010	01010	01001	01011
5	0	1		00111	00101	00110	01110	01101	01111

When decoding Piccolo, it cannot be determined whether a tone is the 1st or the 2nd tone of a tone sequence, and also not whether the received sideband comes in regular or inverted position. Therefore, always the resulting four possibilities of correct decoding must be indicated concurrently as four text data streams. Only an operator can determine which of the four text data streams is correct.

The tone table is given in [chapter 4.13, "Piccolo-6 \(MK 6\) Tone Table"](#), on page 357.

Piccolo-6 can be frequency-multiplexed in up to 4 channels (2, 3 or 4 of them being used). Usually the channel distance of such systems is found as 400 Hz, the channel offsets (measured from the carrier frequency) therefore as

- 510 Hz (channel 1)
- 910 Hz (channel 2)
- 1310 Hz (channel 3)
- 1710 Hz (channel 4)

Channel 1 is called the "engineers' channel", it usually sends plain text or idle signals, whereas the other (traffic) channels send bitstream encrypted traffic.

Also known is a double speed variant (called MK 10), therefore using a tone speed of 40/s, but a special alphabet and also different idle (standby) tones. This system is in use by the British government.

The 6-tone MK 6 variant is considered a common system, whereas the 12-tone MK 6 and the MK 10 are rarely found.

3.79 Piccolo-12 (MK 6)

3.79.1 General

Transmission method	Piccolo-12 (MK 6)
Explanation of name	Piccolo (flute) (derived from Italian for "small"): onomatopoeic description of the sound of the signal, 12 tones
Other designations	Piccolo ITA-5
Variants existing	
Derived from method	Piccolo-6 (MK 6)
Typical users	Government and military stations
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK: MTONE (MFSK)
Shift/tone spacing	20 Hz
Baud rate	Tone duration 50 ms , thus "tone speed" 20/s
Modulating subcarrier	
Bandwidth	220 Hz
Operating method	Simplex
Data protection	None
Code table	ITA-5 (ASCII) (table 4-9 and table 4-10 in chapter 4.2)

3.79.2 History

(See [chapter 3.78](#), "[Piccolo-6 \(MK 6\)](#)", on page 242)

3.79.3 Description



Denotation

- **Tone n**

means the **tone (frequency) no. n** out of the underlying tone table, whereas

- **m-th tone**

denotes the **m-th (sent) tone** out of the transmitted tone sequence.

Table 3-44: Frequency assignment in Piccolo MK 6.

ITA-2 (6 tones)													
Tone No.		0	1	2		3	4	5					
ITA-5 (12 tones)													
Tone No.	0	1	2	3	4	5		6	7	8	9	10	11
Freq [Hz]	-110	-90	-70	-50	-30	-10	Center tuning	10	30	50	70	90	110

Piccolo MK 6 is divided into two different modes, both using two sequential tones with 50 ms duration and 20 Hz shift (i.e. frequency spacing between the tones available).

- The one, called Piccolo-6 ([chapter 3.78](#)), selects from six tones, the resulting 36 combinations picturing the 32 codes of the ITA-2 alphabet,
- the other one, Piccolo-12, has twelve tones so that 144 combinations cover the 128 codes of the ITA-5 (ASCII) alphabet.

As can be seen from [table 3-44](#) (Piccolo-6 given for comparison), frequency span ranges from -50 Hz to 50 Hz or -110 Hz to 110 Hz, respectively, related to the center tuning frequency.

A baud rate cannot be told for a multitone system; supposed the 100 ms duration of the two-tone sequence and (for Piccolo-12 with ITA-5) a 7-bit code word with 1 start, 1 stop and 1 parity bit (see [chapter 3.16](#), "ASCII", on page 72), a 100 Bd rate follows. Defining a "baud rate" from the 50 ms tone duration leads to a rate of 20 Bd.

For assignment of the particular codes to the tone combinations, analog considerations as with Piccolo-6 (see [table 3-43](#) in [chapter 3.78](#)) can be made with Piccolo-12; again, the maximum number of bits (out of totalling 7) having to be derived from the complete tone combination is 2.

Table 3-45: Code assignment in Piccolo-12.

2nd Tone		0	1	2	3	4	5	6	7	8	9	10	11
1st Tone	5	0	0	0	1	1	1	1	1	1	0	0	0
	Bit 3	0	0	0	0	0	0	1	1	1	1	1	1
	1	1	0			0	1	1	0			0	1
	6 4 2 0	0					0	0					0
0	0 1 0	X	DLE	DC4	4	0	X	X	8	<	FS	CAN	X
			0010 000	0010 100	0110 100	0110 000			0111 000	0111 100	0011 100	0011 000	
1	0 1 0	DC2	DC1	DC3	3	1	2	:	9	;	ESC	EM	SUB
		0010 010	0010 001	0010 011	0110 011	0110 001	0110 010	0111 010	0111 001	0111 011	0011 011	0011 001	0011 010
2	0 1 1	SYN	NAK	ETB	7	5	6	>	=	?	US	GS	RS
		0010 110	0010 101	0010 111	0110 111	0110 101	0110 110	0111 110	0111 101	0111 111	0011 111	0011 101	0011 110
3	1 1 1	V	U	W	w	u	v	~	}	DEL	_	]	^

		1010 110	1010 101	1010 111	1110 111	1110 101	1110 110	1111 110	1111 101	1111 111	1011 111	1011 101	1011 110
4	1 1 0	R	Q	S	s	q	r	z	y	{	[	Y	Z
		1010 010	1010 001	1010 011	1110 011	1110 001	1110 010	1111 010	1111 001	1111 011	1011 011	1011 001	1011 010
5	1 1 0	X	P	T	t	p	X	stnd by	x		\	X	X
			1010 000	1010 100	1110 100	1110 000			1111 000	1111 100	1011 100	1011 000	
6	1 0 0	X	@	D	d	`	X	X	l	h	L	H	X
			1000 000	1000 100	1100 100	1100 000			1101 000	1101 100	1001 100	1001 000	
7	1 0 0	B	A	C	c	a	b	j	i	k	K	I	J
		1000 010	1000 001	1000 011	1100 011	1100 001	1100 010	1101 010	1101 001	1101 011	1001 011	1001 001	1001 010
8	1 0 1	F	E	G	g	e	f	n	m	o	O	M	N
		1000 110	1000 101	1000 111	1100 111	1100 101	1100 110	1101 110	1101 101	1101 111	1001 111	1001 101	1001 110
9	0 0 1	ACK	ENQ	BEL	`	%	&	.	-	/	SI	CR	SO
		0000 110	0000 101	0000 111	0100 111	0100 101	0100 110	0101 110	0101 101	0101 111	0001 111	0001 101	0001 110
10	0 0 0	STX	SOH	ETX	#	!	"	*	)	+	VT	HT	LF
		0000 010	0000 001	0000 011	0100 011	0100 001	0100 010	0101 010	0101 001	0101 011	0001 011	0001 001	0001 010
11	0 0 0	X	ZERO	EOT	\$	SPC	X	X	(	,	FF	BS	X
			0000 000	0000 100	0100 100	0100 000			0101 000	0101 100	0001 100	0001 000	

Thus, the Piccolo-6 code table ([table 3-43](#)) can be interpreted as the "central part" of the Piccolo-12 table (the codes shown in bold notation in [table 3-45](#)) – if only the bit combinations are considered, not the character meaning, the 2 leading bits are ignored and tone 0 to tone 5 of Piccolo-6 are imaged to tone 3 to tone 8 of Piccolo-12.

When decoding Piccolo, it cannot be determined whether a tone is the 1st or the 2nd tone of a tone sequence, and also not whether the received sideband comes in regular or inverted position. Therefore, always the resulting four possibilities of correct decoding must be indicated concurrently as four text data streams. Only an operator can determine which of the four text data streams is correct.

The tone table is given in [chapter 4.14, "Piccolo-12 \(MK 6\) Tone Table"](#), on page 358.

The 6-tone MK 6 variant is considered a common system, whereas the 12-tone MK 6 is rarely found.

3.80 POCSAG

3.80.1 General

Transmission method	POCSAG
Explanation of name	Post Office Code Standardization Advisory Group
Other designations	PAGER1 Service providers using POCSAG: • Cityruf (466.075 MHz) • Quix (448.475 MHz) • Scall (466.230 MHz) • Skyper (465.970 MHz) • TelMi (448.425 MHz) • CCIR 584
Variants existing	
Derived from method	
Typical users	Paging systems Radio amateurs
Kind of data	Short messages
Reference to standard	ITU-R Recommendation M.584-2: "Codes and Formats for Radio Paging"
Frequency band	VHF/UHF
Modulation method	FSK; 512 bit/s 1200 bit/s, 2400 bit/s (commonly called Super-POCSAG)
Shift/tone spacing	4.5 kHz
Baud rate	512 Bd, 1200 Bd, 2400 Bd
Modulating subcarrier	455 kHz, 10.7 MHz or 21.4 MHz
Bandwidth	10.5 kHz
Operating method	Simplex, asynchronous
Data protection	BCH Code
Code table	ITA-5 (ASCII) (table 4-9 and table 4-10 in chapter 4.2) BCD

3.80.2 History

Pager services using the POCSAG standard are introduced by a number of PTT (Post, Telephone and Telegraph) administrations. The POCSAG protocol is standardized in ITU-R M.584-2, FLEX (chapter 3.46, "FLEX", on page 135) was invented by *Motorola* and introduced in 1994. Some service providers offer POCSAG and FLEX services on the same radio frequency. Pagers are one-way devices. A base station controls a large number of receivers sending different kinds of messages to them. A return channel for transmission of reception acknowledgments or text as an answer is not available.

3.80.3 Description

POCSAG is a standard defining the principles of paging systems. Four different modes are supported:

- Tone-only mode (Modes 0 and 1): only 4 different messages are defined the meaning of which must be defined in advance; letters "A" to "D" are displayed on the receiver. Capability for this mode is mandatory to all pagers.
- Numeric mode (Mode 2): messages consist of digits and some special characters; in this way a telephone number to be called by the receiver may be conveyed.
- Alphanumeric mode (Mode 3): the easiest-to-use pager type, the received message (up to 80 characters) is displayed on the pager.

Larger (e.g. country-wide) pager networks are divided into cells which are serviced by a base stations each, like a mobile telephone network.

3.80.4 Source Coding

Two message formats are defined for the text of messages (dependent on transmission mode, see [3.80.3, "Description"](#)): 7-bit ASCII and BCD. In case of ASCII, data is segmented to subsequent code words (20 message bits [see [3.80.5, "Channel Coding/Structure of Data Blocks"](#)] not divisible by 7), i.e. bits are transmitted consecutively regardless of ASCII word borders.

3.80.5 Channel Coding/Structure of Data Blocks

Code words to be transmitted always consist of 32 bits:

- 1 bit distinction address/message word
- 20 bits address (including mode) or message
- 10 bits checksum
- 1 parity bit

Two code words are grouped to a frame, eight frames to a batch. A synchronization word precedes each batch, and a preamble (a continuously alternating sequence of '0' and '1', at least 576 bits long, to force the receiver to the clock frequency) a group of one or more batches.

3.81 POL-ARQ

3.81.1 General

Transmission method	POL-ARQ
Explanation of name	POL and- A utomatic R epeat R e Q uest
Other designations	ARQ-POL CCIR 476 variant
Variants existing	Repetition cycles of 4, 5 or 8 characters
Derived from method	(very similar to ARQ-E)
Typical users	Polish (Ministry of Foreign Affairs) and other diplomatic services
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	230 Hz
Baud rate	100 Bd , 200 Bd
Modulating subcarrier	
Bandwidth	380 Hz
Operating method	Duplex, synchronous
Data protection	Mark to space ratio 3 to 4, ARQ
Code table	SITOR (CCIR 476-5) (table 4-7 in chapter 4.1.6)

3.81.2 Description

POL-ARQ is a full-duplex, synchronous [ARQ](#) teleprinting system very similar to ARQ-N ([chapter 3.14, "ARQ-N"](#), on page 68) and ARQ-E ([chapter 3.11, "ARQ-E"](#), on page 61). Special features are:

- Alphabet used is [SITOR](#) (CCIR 476-5) (see [table 4-7](#) in [chapter 4.1.6, "SITOR Code Table"](#), on page 332), permitting error detection owing to the 3 to 4 mark-to-space ratio.
- Repetition cycles known are
 - 4 (100 [Bd](#) transmission speed)
 - 5 (200 [Bd](#))
 - 6
- No character bit inversion is performed, therefore, automatic detection of repetition cycle length is not possible.

Again, "Idle" characters are sent between the [ISS](#) and the [IRS](#) while no data have to be transmitted. POL-ARQ shares these "Idle" signs with other systems using SITOR code, thus, for identifying the individual mode active traffic is needed.

3.82 PSK31, PSK63, PSK125, PSK220, PSK250 (BPSK)

3.82.1 General

Transmission method	PSK31 (BPSK)
Explanation of name	Phase Shift Keying, bandwidth 31.25 Hz (Binary Phase Shift Keying)
Other designations	Varicode BPSK BPSK31
Variants existing	PSK63, PSK125, PSK220, PSK250
Derived from method	
Typical users	Radio amateurs
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	PSK2 (DBPSK)
Shift/tone spacing	
Baud rate	31.25 Bd, 62.5 Bd, 125 Bd, 220 Bd, 250 Bd
Modulating subcarrier	
Bandwidth	• PSK31: 40 Hz • PSK63: 80 Hz • PSK125: 160 Hz • PSK220: 275 Hz • PSK250: 315 Hz
Operating method	Half-duplex
Data protection	none
Code table	Varicode (table 4-23 in chapter 4.9)

3.82.2 History

PSK31 was developed and named by British amateur radio operator *Peter Martinez* and introduced to the wider amateur radio community in December 1998. It then was enthusiastically received, and its usage lent a new popularity and tone to the on-air conduct of digital communications. Due to the efficiency of the mode, it became, and still remains, especially popular with operators whose circumstances do not permit the erection of large antenna systems and/or the use of high power.

PSK31 was the result of Martinez's belief that the variety of "data" modes had left a gap in amateur radio operating (previously filled by [AMTOR](#) [see [chapter 3.88, "SITOR-B"](#), on page 268] or even traditional [RTTY](#)): the situation that two or more operators chat to each other on an open channel. Other data modes are highly complex, unsuited to multiway conversations, and, in particular, the long block lengths introduce an unacceptable delay in the processing of text such that even normal conversation is unpleasant and quick-break question/answer sessions are impossible. So the move to automated unattended message forwarding ignored the person-to-person communication field. PSK31 was an attempt to remedy this situation with a simple but efficient code structure coupled with the narrowest possible bandwidth, and with only enough error-correction to match typical typing-error rates, and with no time-consuming synchronization, changeover, and [ARQ](#) processes.

3.82.3 Description

In contrast to most data transmission modes being operated with [FSK](#), PSK31 uses [PSK](#) modulation. (Be aware that an "absolute" signal phase never can be told, so any phase considerations have to take place in relation to other signal states – in other words, PSK modulation always has to be [DPSK](#), coding not the absolute bit value to the phase state, but the bit difference to the previous bit. A single bit error would result in two falsified bits in DPSK, but in a completely inverted subsequent datastream in "absolute" PSK.)

As also explained in detail in [chapter 2.3, "PSKn"](#), on page 14, phase keying should not happen in a "hard" manner (just switching the carrier from one phase state to another or, in case of [BPSK](#), merely reversing the polarity) – the "hard" phase changes would rise a lot of harmonics in frequency range, i.e. consume additional bandwidth –, but the modulating data stream is subjected to pulse forming by a raised-cosine filter. Doing so ("soft keying"), the remarkably small bandwidth of 31.25 [Hz](#) per data channel with 31.25 [Bd](#) transmission speed can be achieved, not exceeding the baud (bit) rate of the original data stream. Word length observations in common text had led to the result that the normal typing speed of about 50 words per minute matches a bit rate of approx. 32 bits per second.

Another reason for choosing the "not round" bandwidth value is that it can easily be derived (divided) from the 8 kHz sample rate in many [DSP](#) systems by halving it 8 times, because 8 [kHz](#) divided by $2^8 = 256$ results in 31.25 Hz.

The alphabet used also was introduced by Martinez and is called Varicode. A complete code table and explanation of its creation can be found in [table 4-23 \(chapter 4.9, "Varicode Code Table"](#), on page 350). Similarly to Morse ([chapter 3.68, "MORSE"](#), on page 208) code, words occurring frequently (in English language) were given a shorter representation than rarer words.

Due to the original intention to just handle hand-sent typed text easily, no error correction facility was implemented with the first PSK31.

Efficiency and narrow bandwidth of PSK31 make it highly suitable for low-power and crowded-band operation. PSK31 contacts can be conducted at less than 100 Hz separation, so with disciplined operation at least twenty simultaneous PSK31 contacts can be carried out side-by-side in the bandwidth required for just one [SSB](#) voice contact.

PSK63, PSK125, PSK220 and PSK250 are used in amateur radio emergency networks for information transfer with the FLARQ-protocol (Fast Light Automatic Repeat Request), a file transfer application that is based on the [ARQ](#) specification developed by *Paul Schmidt*. It is capable of transmitting and receiving frames of ARQ data requiring no operator intervention.

3.83 PSK31, PSK63, PSK125, PSK220 (QPSK)

3.83.1 General

Transmission method	PSK31 (QPSK)
Explanation of name	Phase Shift Keying, bandwidth 31.25 Hz (Quaternary Phase Shift Keying)
Other designations	Varicode QPSK QPSK31
Variants existing	PSK63, PSK125, PSK220
Derived from method	PSK31
Typical users	Radio amateurs
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	PSK4 (DQPSK)
Shift/tone spacing	
Baud rate	31.25 Bd , 62.5 Bd , 125 Bd , 220 Bd
Modulating subcarrier	
Bandwidth	• PSK31: 40 Hz • PSK63: 80 Hz • PSK125: 160 Hz • PSK220: 275 Hz
Operating method	Half-duplex
Data protection	FEC
Code table	Varicode (table 4-23 in chapter 4.9)

3.83.2 History

In December 1997, PSK31 (cf [chapter 3.82](#), "[PSK31, PSK63, PSK125, PSK220, PSK250 \(BPSK\)](#)", on page 252) introduced the QPSK (PSK4) mode.

3.83.3 Description

In contrast to [PSK31](#) in [BPSK](#) mode without any error correction feasibility, its [QPSK](#) ([PSK4](#)) mode uses a 4-phase modulated signal ([DQPSK](#)). Due to the double data rate provided within the same bandwidth, additional redundancy now can be added. This is done by convolutional coding with a code rate of 1/2 and a constraint length (K) of 5, i.e. every original data stream bit produces 2 transmission bits by 2 polynomials.

Selection of BPSK or QPSK mode with a PSK31 transmitter normally is done by the operator according to current propagation conditions.

3.84 PSK63F, PSK125F, PSK220F

3.84.1 General

Transmission method	PSK63F
Explanation of name	Phase Shift Keying, bandwidth 63 Hz, FEC
Other designations	
Variants existing	PSK125F, PSK220F
Derived from method	PSK31
Typical users	Radio amateurs
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	PSK2 (DBPSK)
Shift/tone spacing	
Baud rate	31.25 Bd , 62.5 Bd , 110 Bd
Modulating subcarrier	
Bandwidth	• PSK63F: 80 Hz • PSK125F: 160 Hz • PSK220F: 275 Hz
Operating method	Half-duplex
Data protection	FEC
Code table	MFSK Varicode (table 4-24 in chapter 4.10)

3.84.2 Description

PSK63F is another variant of PSK31 (cf [chapter 3.82](#), "[PSK31](#), [PSK63](#), [PSK125](#), [PSK220](#), [PSK250](#) ([BPSK](#))", on page 252). Like with PSK31 with QPSK (cf [chap-](#)

ter 3.83, "PSK31, PSK63, PSK125, PSK220 (QPSK)", on page 254), additional error correcting redundancy is introduced, in use is convolutional coding with a code rate of 1/2 and a constraint length (K) of 7: every original data stream bit produces 2 transmission bits by 2 polynomials. This doubles the baud rate of the original data stream of 31.25 Bd to an on-air baud rate of 62.5 Bd, hence the bandwidth consumed to about 80 Hz.

To PSK125F and PSK220F, the same applies accordingly.

The mode was designed to provide better performance than PSK31 in two areas – first, the higher on-air baud rate significantly reduces the effect of polar Doppler instability, and second, errors are reduced through the use of full-time FEC. Unlike with PSK31 with QPSK, Doppler sensitivity is not increased when FEC is used.

3.85 RUM-FEC

3.85.1 General

Transmission method	RUM-FEC
Explanation of name	RUM ania (Romania) - F orward E rror C orrection
Other designations	ROU-FEC SAU-FEC SAUD-FEC
Variants existing	
Derived from method	
Typical users	Romanian diplomatic services (Ministry of Foreign Affairs [MFA] in Bucharest)
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	400 Hz to 500 Hz
Baud rate	164.48 Bd, 218.3 Bd
Modulating subcarrier	
Bandwidth	700 Hz
Operating method	Simplex, broadcast
Data protection	FEC, interleaving
Code table	RUM-FEC (table 4-21 in chapter 4.7)

3.85.2 History

RUM-FEC is a teleprinter system invented in Romania and used by Romanian diplomatic services. Formerly it had been referred to as SAU-FEC or SAUD-FEC, but then it has been renamed to RUM-FEC (or ROU-FEC) by relevant publications.

3.85.3 Description

Two standard speeds are known for this system: 164.5 Bd and 218.3 Bd. Emissions in clear as well as encrypted (for example bit-masked) have been observed.

The RUM-FEC code table can be seen from [table 4-21](#) ([chapter 4.7](#), "RUM-FEC Code Table", on page 347). Similar to the HNG-FEC system ([chapter 3.58](#), "HNG-FEC", on page 161), it is formed by the 32 characters of the ITA-2 code table. Each character is 16 bits long, but a resemblance to the original ITA-2 code leaping to the eye cannot be determined. See [chapter 4.7](#) for further details.

Like with [HNG-FEC code](#), the code has a minimum Hamming distance of 8 and therefore can correct up to 3 bit errors. To preferably have also burst errors corrected, additionally an interleaving scheme is established, it is shown in [figure 3-83](#). The interleaving mode is nearly the same as with HNG-FEC; due to the different character length (16 bits instead of 15), the spread (delay after interleaving between two originally consecutive bits) is 129 bits, and new characters begin every 16 bits (not 15), in the figure at bit numbers divisible by 16. Again, a schematized illustration is given in [figure 3-84](#); the first block shows the starting (filling), the center block the operating (busy) and the last block the terminating (emptying) phase of the interleaving process. For more details, refer to [chapter 3.58](#).



Fig. 3-83: Interleaving with RUM-FEC.

A = First characters starting in (first line of) interleaving block
 B = Last characters starting in first line of interleaving block
 C = First character starting in second line of interleaving block
 D = Last characters starting in (last line of) interleaving block
 E = Interleaving block with characters entered

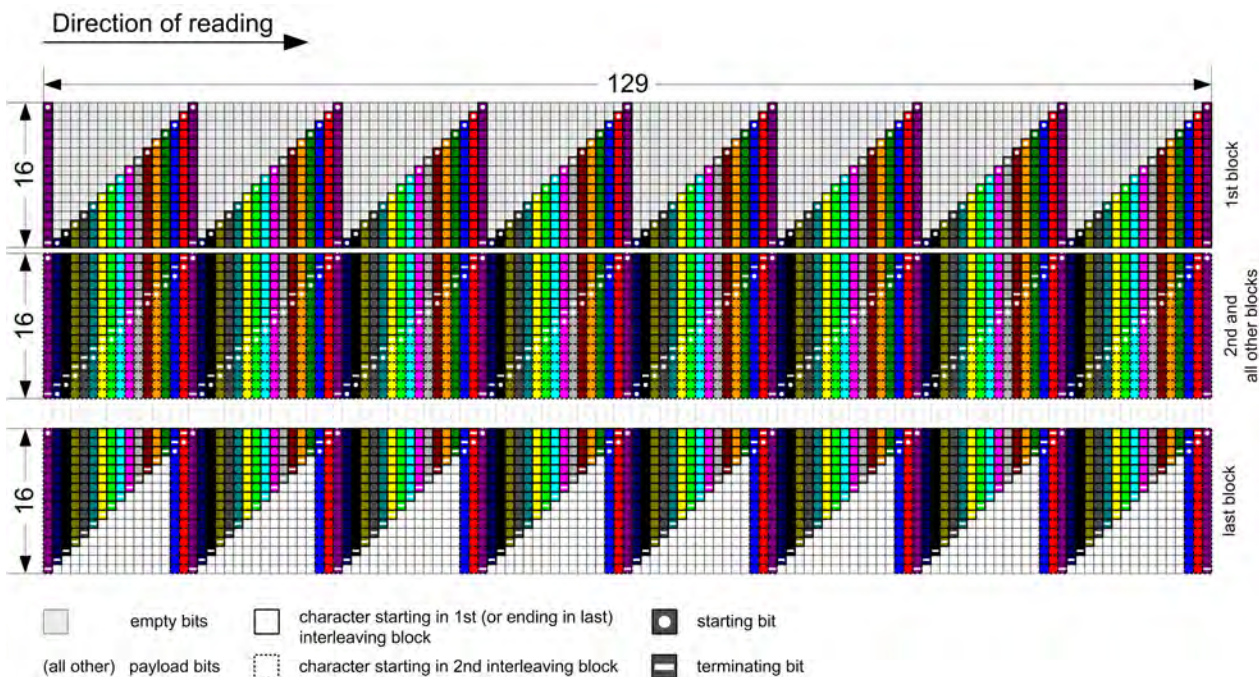


Fig. 3-84: Simplified interleaving scheme.

Also like with [HNG-FEC](#), bit inversion of a valid character code delivers another valid character code (complementary code) so that a final decision of polarity present cannot be made, but the user has to select from both alternatives being displayed concurrently.

3.86 SELCAL-5T

3.86.1 General

Transmission method	SELCAL-5T
Explanation of name	SElective CALling, 5 Tones
Other designations	
Variants existing	ZVEI1 (German institution "ZentralVerband Elektrotechnik und ElektronikIndustrie e.V." [Central Association of Electrical and Electronic Industries]) ZVEI2 (ditto) CCIR1 (Comité Consultatif International des Radiocommunications [International Consultative Committee on Radio]) CCIR2 (ditto)

Transmission method	SELCAL-5T
	VDEW (German institution "Vereinigung Deutscher ElektrizitätsWerke e.V." [Union of German Power Companies]) CCITT (Comité Consultatif International Téléphonique et Télégraphique [International Telegraph and Telephone Consultative Committee]) EEA (Electronic Engineering Association [United Kingdom]) EIA (Electronics Industries Association [United States]) EURO (EUROsignal, six tone sequential high power AM paging for CEPT [Conférence Européenne des Administrations des Postes et des Télécom-munications/European Conference of Postal and Telecommunications Administrations] countries) NATEL (Scandinavian National TELEphone) numerous other sub-modes existing
Derived from method	
Typical users	
Kind of data	
Reference to standard	
Frequency band	HF, VHF/UHF (signaling in voice-frequency band)
Modulation method	FM
Shift/tone spacing	
Baud rate	
Modulating subcarrier	
Bandwidth	
Operating method	Broadcast
Data protection	
Code table	

3.86.2 History

SELCAL is a radio signaling protocol mainly in use in Europe, Asia, Australia and New Zealand, and continues to be incorporated in radio equipment marketed in those areas.

3.86.3 Description

SELCAL (selective calling) is used in radio communications systems to select (address) particular receivers by emitting a number code representing the specific address of the desired receiver. An activated (selected) receiver will then open its squelch and thus make audible the following announcements; other receivers will remain muted.

SELCAL is an analog system, i.e. the address codes consisting of five digits are represented by a sequence of five tones (the SELCAL code). These tones are taken from a pool (tone set) of up to 16 tone frequencies so that 16 digits can be reproduced, commonly digits 0 to 9 form the address itself, whereas the six "hexadecimal" extensions A_{16} to F_{16} are used for signaling purposes. The tone frequencies are audio tones (in the audible frequency range), their duration depends on the standard (variant) chosen, but the most common tone duration is 70 ms. The number encoded in a SELCAL burst is used to address one or also more receivers.

Since a receiver normally merely decides the tone frequency of each individual tone, but cannot detect the tone duration, two consecutive tones of the same frequency (in case of a repeated digit in the original code) are to be avoided. A repeat digit is established instead: the second appearance of a digit will not be given by the tone of the digit, but by the repeat tone (but the third again by the digit tone), so that, for example, a "12334" sequence would be converted to "123R4" ("R" being the repeat tone), or a "12222" sequence to "12R2R".

Disadvantages of analog signaling are the long time consumed by a single signaling (alarming) process (several seconds, followed by the voice message itself, and even more if the signaling is to be repeated for security) and the lack of any protection against tapping or even generation of malicious false alarms.

Some common SELCAL standards are shown (tone frequencies and timing) in table 3-46.

Table 3-46: Tone frequencies [Hz] and timing for some common SELCAL methods.

	Tone frequency [Hz]									
	ZVEI		CCIR							
Digit	-1	-2	-1	-7	VDEW	CCITT	EEA	EIA	EURO	NATEL
0	2400	2200	1981		2280	400	1981	600	979.8	1633
1	1060	970	1124		370	697	1124	741	903.1	631
2	1160	1060	1197		450	770	1197	882	832.5	697
3	1270	1160	1275		550	852	1275	1023	767.4	770
4	1400	1270	1358		675	941	1358	1164	707.4	852
5	1530	1400	1446		825	1209	1446	1305	652.0	941
6	1670	1530	1540		1010	1335	1540	1446	601.0	1040
7	1830	1670	1640		1240	1477	1640	1587	554.0	1209
8	2000	1830	1747		1520	1633	1747	1728	510.7	1336
9	2200	2000	1860		1860	1800	1860	1869	470.8	1477
A ₁₆	2800 ¹⁾	2600 ¹⁾	2400 ¹⁾		2000 ¹⁾	1900	1055 ¹⁾	2151	1062.9	1633
B ₁₆	810	2800	930		2100	2000	930	2433		600
C ₁₆	970	810	2247		2200	2100	2247	2010 ¹⁾		1995 ¹⁾
D ₁₆	885	885	991		2300	2200	991	2292		2205

	Tone frequency [Hz]									
Digit	ZVEI		CCIR							
	-1	-2	-1	-7	VDEW	CCITT	EEA	EIA	EURO	NATEL
E ₁₆	2600	2400	2110		2400	2300	2110	459		1805
F ₁₆							2400			
Tone duration [ms]	70		100	70	100	100	40	33	100	70

¹⁾ Repeat tone

3.87 SITOR-A

3.87.1 General

Transmission method	SITOR-A
Explanation of name	S implex T eletype O ver R adio, variant A
Other designations	SITOR-ARQ (A utomatic R epeat R equest) ARQ ARQ 625 TOR AMTOR-ARQ (A mateur M icroprocessor T eleprinting O ver R adio)
Variants existing	
Derived from method	
Typical users	Radio amateurs, Marine services, Government Diplomatic services (all 170 Hz shift) Other Air Force, Navy, Ministry usages with 300 Hz, 400 Hz or 850 Hz shift
Kind of data	
Reference to standard	ITU-R Recommendation M.476-5: "Direct-Printing Telegraph Equipment in the Maritime Mobile Service" ITU-R Recommendation M.625-3: "Direct-Printing Telegraph Equipment employing Automatic Identification in the Maritime Mobile Service"
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	
Baud rate	100 Bd
Modulating subcarrier	

Transmission method	SITOR-A
Bandwidth	300 Hz
Operating method	Half-duplex ("Simplex-ARQ"), synchronous
Data protection	Mark to space ratio 3 to 4, ARQ
Code table	SITOR (CCIR 476-5) (table 4-7 in chapter 4.1.6)

3.87.2 History

In contrast to wired transmission, where teletype was a usual method over decades and a wide network had been established, radio-based teletyping without any data protection proved unreliable. Therefore, a method had been searched to translate the 5-bit teletype alphabet (ITA-2 alphabet, see [table 4-2](#) in [chapter 4.1.2, "ITA-2 Code Table"](#), on page 325), which has no protection against erroneous transmitting, into a protected alphabet in a way as simple as possible. Morse telegraphy, the only method known in these days for radio data transmission and thus being commonly in use, also seemed susceptible to disturbances and, moreover, was not fitted for an automatic operation, especially not for automatic recognition of the received data.

One of the methods to convey teletype signals via a radio link in a protected manner had been established by *Philips* into stationary radio-communication service some decades ago. Theoretically as well as in practical operation had been found out that a redundancy of two additional bits delivers a satisfactory reliability of transmission for telegraphy data. This method, slightly modified, has been adopted with SITOR later on. The two additional bits are used to induce a fixed ratio of '0' to '1' bits: with SITOR, this ratio is 3 '1's to 4 '0's. Doing so, an error detecting system is obtained.

The number of codes that can be represented this way is 35, thus 3 more than the 32 with ITA-2.

3.87.3 Description

Construction of the [SITOR](#) alphabet (also called [CCIR 476-5](#) alphabet) is explained in [chapter 4.1.6, "SITOR Code Table"](#), on page 332, the resulting code is shown in [table 4-7](#).

Therewith, an original teletype signal is handed to the SITOR device and stored there. Before emitting, the 7-bit code of SITOR is produced from the 5-bit [ITA-2](#) code.

In principle, SITOR-A is a half-duplex (so-called "Simplex-ARQ") system (transmitting station [ISS](#) and receiving station [IRS](#) operating alternately and usually on the same frequency) working on a synchronous basis, i.e. clocking of both stations is coupled. As shown in [figure 3-85](#), the one, commonly the calling station is defined the master station and the other one the slave station, this assignment being kept for the whole link period: even though the ISS and IRS roles are temporarily interchanged, timing is always done by the master station.

SITOR-A works with a transmission rate of 100 [Bd](#) and uses data packets of 3 characters, comprising, as explained above, 7 bits each; from these overall 21 bits and the bit

transmission time of 10 ms, a 210 ms transmission cycle arises. The listen cycle (time period for receiving the acknowledge signal) following is given a length of 240 ms (complete repetition cycle length 450 ms), during this period the IRS sends its confirmation signal, either for correct or for erroneous reception; depending on this signal, the ISS in the following transmission cycle sends the next data block or repeats the last one.

As can be seen from the timing, two propagation delays have to be considered and also an IRS equipment "reaction" time; the left-over time until beginning of the next cycle is calculated as

$$t_x = 450 \text{ ms} - 210 \text{ ms} - 70 \text{ ms} - 2 * t_p - t_d$$

(containing the ISS equipment reaction time). If a reversion of data transmission took place, i.e. ISS and IRS have been interchanged, the master station controls timing, however. Thus, the transmission cycle duration is only 70 ms (the 7-bit control signal), followed by a listen cycle of 380 ms and thus resulting in the habitual 450 ms duration of the complete cycle.

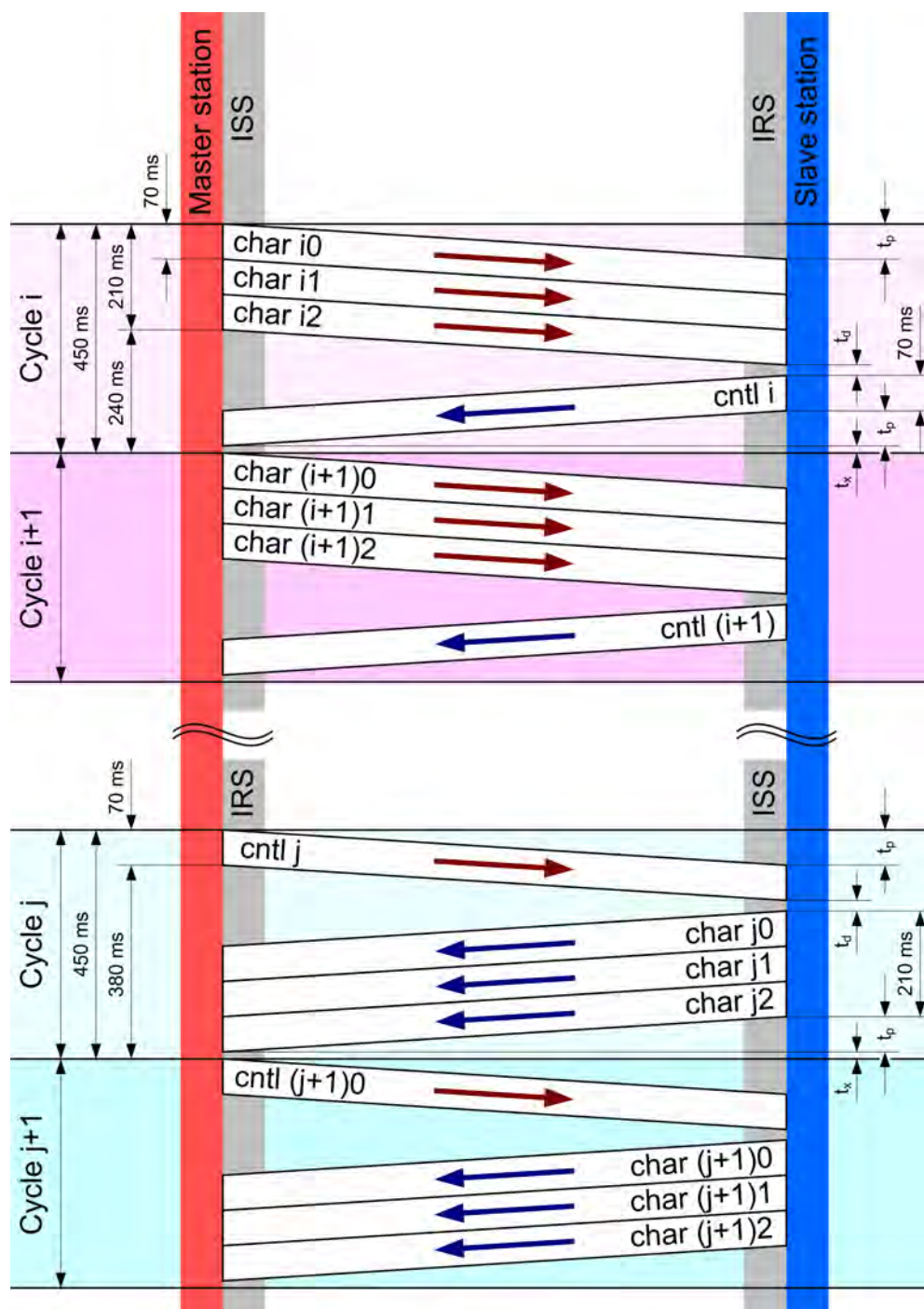


Fig. 3-85: General timing with SITOR-A.

t_d = equipment delay time

t_p = propagation time (one-way)

t_x = remaining time until next cycle

The first step of a traffic process is a calling (addressing) procedure; this is not described in detail here. Normal traffic takes course as follows:

- During the complete traffic process (until fallback into stand-by condition), both stations involved have to retain some relevant information:
 - their respective status "Master" or "Slave" station,
 - the address (identity) of the corresponding station (if applicable),
 - their respective status "ISS" or "IRS",
 - the current status of traffic (level) *Letter* or *Figure*.
- The ISS transmits the data in blocks with 3 characters each (as described above), filling in "Idle β" characters to complete a data block if not enough traffic characters are present.
- A data block transmitted is retained by the ISS until it has received a control signal confirming correct reception by the IRS.
- The IRS numbers the received data blocks internally in "Block 1" and "Block 2" (the first transmitted control signal gives the reference); any Block 1 received without errors is confirmed with a "CS2" control signal and any Block 2 with "CS1" – whereas a mutilated Block 1 is redeemed with a "CS1" and Block 2 with "CS2".
- If an erroneous reception by the IRS has been signaled to the ISS, it repeats the last block – in other words, a "CS1" signal always results in transmitting Block 1 and a "CS2" signal Block 2.
- If the control signal itself is received mutilatedly by the ISS, it reacts to it transmitting a block of three "RQ" (signal repetition request) characters, the control signal in question is repeated by the IRS then.

In [figure 3-86](#) two operation examples are shown.

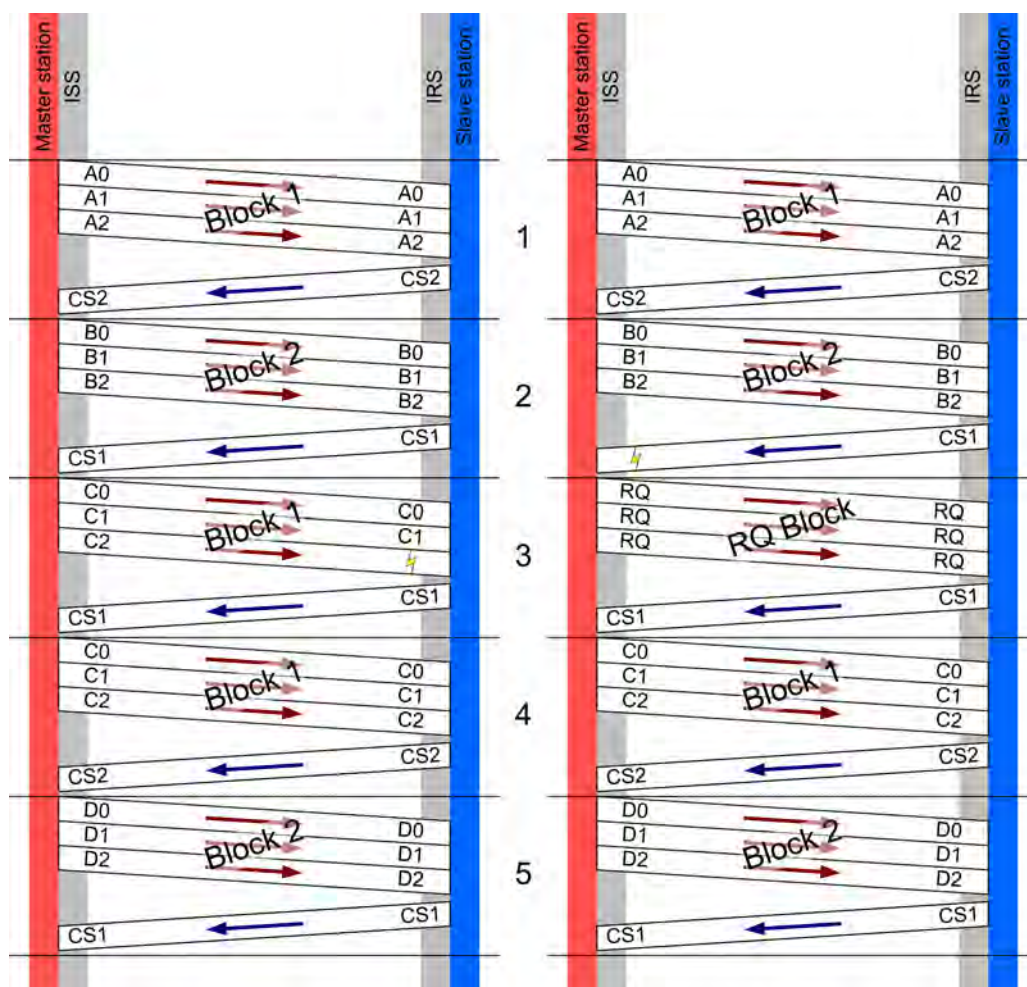


Fig. 3-86: Data telegram with erroneous operation.

left = bad ISS data (mutilated Block 1 in 3rd block)

right = bad IRS data (mutilated "CS1" after 2nd block)

3.88 SITOR-B

3.88.1 General

Transmission method	SITOR-B
Explanation of name	S implex T eletype O ver R adio, variant B
Other designations	AMTOR (A mateur M icroprocessor T eleprinting O ver R adio) AMTOR-FEC (F orward E rror C orrection) FEC FEC 625 FEC B NAVTEX (N AVigational T EXt Messages) SITOR-FEC
Variants existing	
Derived from method	
Typical users	Marine Information services Radio amateurs
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	
Baud rate	100 Bd , 109.4 Bd
Modulating subcarrier	
Bandwidth	350 Hz
Operating method	Simplex
Data protection	Mark to space ratio 3 to 4, FEC by character repetition
Code table	SITOR (CCIR 476-5) (table 4-7 in chapter 4.1.6)

3.88.2 Description

Unlike SITOR-A (see [chapter 3.87](#), "[SITOR-A](#)", on page 262), SITOR-B is a method operating in simplex mode, i.e. transmission takes place in just one direction and commonly no backward channel exists. A

- "Collective Mode"

(broadcast operation where one transmitting station sends to a number of receiving stations) and a

- "Selective Mode"

(the transmitting station sends to just one selective receiving station in a point-to-point manner; correct addressing has to precede the sending process) are distinguished thereby. Transmitting speed (baud rate) and alphabet used are the same as with [SITOR-A](#): 100 Bd leading to 10 ms bit duration and the [CCIR 476-5 code table](#) with 7 bits (3 '1's and 4 '0's with any character), delivering a character transmission period of 70 ms.

Because a request for repetition of erroneously received characters ([ARQ](#)) is not possible this way, a forward error correcting ([FEC](#)) method is applied in this SITOR mode, consisting of just a twice repeating transmission of each character. This repetition is not done immediately after the first transmission of the character, however, but after a period of time corresponding to four times the length of a character, i.e. a character is transmitted, then four other characters, then the repeated transmission is executed. In [figure 3-87](#) the situation is shown: For an easier distinction of the two transmission operations, two transmitting levels,

- direct transmitting ([DX](#)) level and
- repeated transmitting ([RX](#)) level,

are commonly introduced. The message to send is doubled from DX to RX level, the RX level signal is delayed by 2 characters (4 in the resulting data stream), and then the DX and the RX level signal are transmitted alternately character by character, resulting in an interleaving of both signals with an overall repetition delay of 350 ms for a particular character.

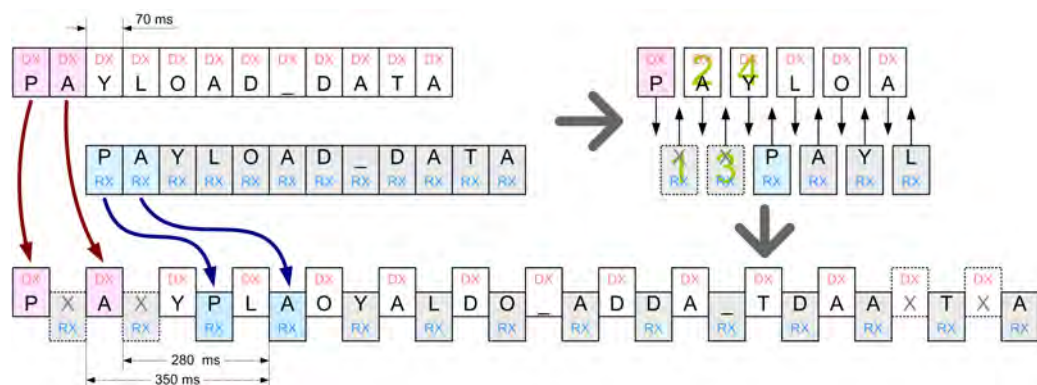


Fig. 3-87: Character repetition and interleaving with SITOR-B.

Error detection thus presupposes the unambiguous recognition of the two levels – identifying them is the first thing to be done when having detected a new emission. Additionally a sending station at regular intervals has to deliver phasing information for regaining synchronization if it has got lost. The detection of errors itself occurs according to [table 3-47](#): if a character received is considered feasible (correct number of '0' and '1' bits) in only one of both levels (case 2 and 3) or, the of course most common case, the (feasible) characters of both levels coincide (case 1), the respective character is output, whereas, if two unfeasible characters (case 4) or two feasible, but different ones (case 5) are recognized, an error is output.

Table 3-47: Error detection scheme.

Case	DX character	RX character	Decision (output)
1	correct	correct, same as DX	DX = RX
2	correct	erroneous	DX
3	erroneous	correct	RX
4	erroneous	erroneous	"_" (error)
5	correct	correct, different from DX	"_" (error)

An example for a data transmission (character sequence) can be seen in [figure 3-88](#):

Sending station

- A station that wants to send data initiates a transmission process by sending phasing characters, in detail "ph2" characters (RQ signs) are sent on the DX level and "ph1" characters ("α" signs) on RX. At least 16 phasing character pairs are transmitted.
- Immediately before the data characters, the station sends a sequence CR and LF.
- The message to transmit is sent adjacently.
- If breaks in the information flow occur, again phasing signals in the manner described above are sent.
In any case, after every 100 data character pairs, at least 4 consecutive phasing signal pairs should be inserted for a possibly required re-phasing operation.
- For terminating the transmission process, "α" characters are emitted (directly after the last data character) for at least 2 s; afterwards the station falls back to the stand-by condition.

Receiving station

- The receiving station (only the Collective Mode is regarded here, not the calling procedure existing in the Selective Mode) recognizes a "ph1"/"ph2" or a "ph2"/"ph1" character sequence; it is thereby enabled to decide the DX (from "ph2") and the RX level (from "ph1"). If at least two more phasing signal pairs in the appropriate levels are detected, the station changes from stand-by to receive operation.
- Continuous stop polarity is signaled to the output device until a CR or LF is received.
- The received characters are determined with the error detection process described above and printed to the output device. In case of an error, a "SP" character or another (user-defined) error character is printed.
- The receiving station enters stand-by condition not earlier than 210 ms after two consecutive "α" characters have been accepted.

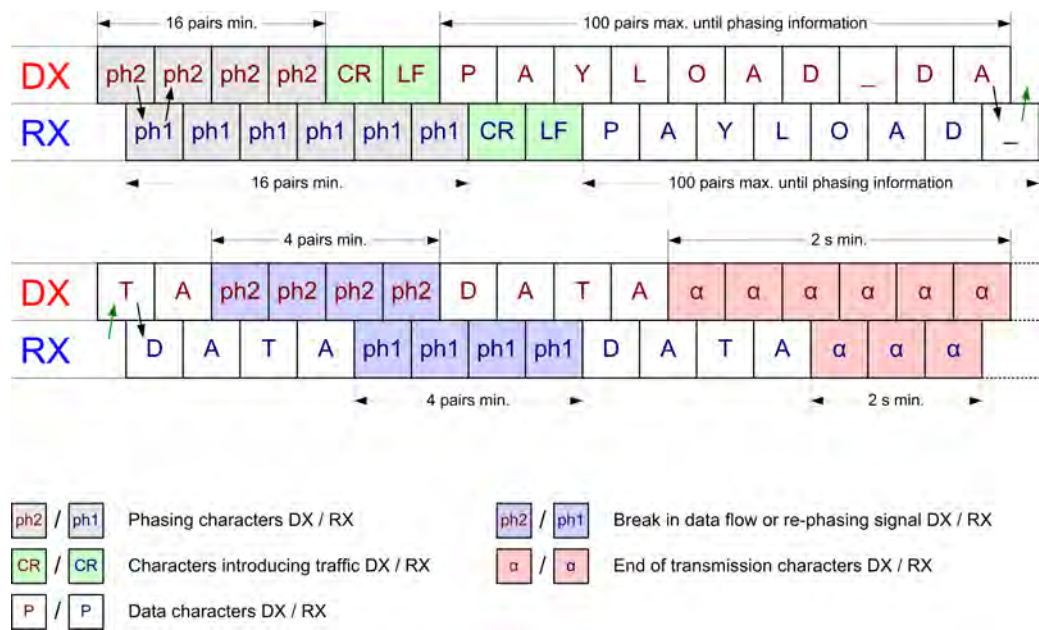


Fig. 3-88: Character sequence in SITOR-B.

3.89 SkyFax

3.89.1 General

Transmission method	SkyFax
Explanation of name	
Other designations	Javelin Racal MSM-1250 (military system, 10.126 MHz, bandwidth 2200 Hz) RACE SKYFAX-HSM (High Speed Modem) SKYFAX-MSM1250 (Medium Speed Modem)
Variants existing	
Derived from method	
Typical users	
Kind of data	Telefaxes or computer data files
Reference to standard	
Frequency band	HF

Transmission method	SkyFax
Modulation method	Three modes (or modems) • High Speed Modem HSM: PSK2, PSK4, PSK8 • Medium Speed Modem MSM: FSK2 • Robust Modem or Low Speed Modem LSM: FSK8, i.e. 8 tones serially
Shift/tone spacing	HSM: (Single channel PSK, therefore not defined) MSM: 10 tones from 437.5 Hz to 2687.5 Hz, spacing 250 Hz, shift 125 Hz LSM: 8 tones from 750 Hz to 2500 Hz, spacing 250 Hz
Baud rate	HSM: 2400 Bd, user data rate 1200 bit/s, 2400 bit/s, 3600 bit/s (selectable) MSM: 125 Bd, user data rate 125 bit/s per channel, thus overall 1250 bit/s LSM: 125 Bd, user data rate 53.57 bit/s or 187.5 bit/s
Modulating subcarrier	HSM: 1800 Hz MSM: (10 tones, see "Shift/tone spacing") LSM: 1375 Hz (8 tones, see "Shift/tone spacing")
Bandwidth	2.4 kHz
Operating method	Half-duplex
Data protection	ARQ with CRC error detection and FEC
Code table	

3.89.2 History

The SkyFax/RACE/Javelin Modem is said to have been established by RACAL (factory name is abbreviation for its founders' first names **Ray Brown** und **George Calder Cunningham**) Canada company (later purchased by Thomson-CSF [Compagnie Générale de Télégraphie Sans Fil / General company for wireless telegraphy], thus now a part of *Thales Group*).

3.89.3 Description

The SkyFax Modem is a standalone modem enabling transmission and error-free reception of faxes and computer data files via HF radios. This error-free reception is accomplished by dividing the mode of transmission into three individual modes (operated by individual modems) being selected alternatively. Selection is done automatically in accordance with current conditions of propagation (particularly fading conditions); the current state of these conditions is identified by the current bit error rate derived from a sophisticated error detection and correction system consisting of Automatic Repeat Request (ARQ), Forward Error Correction (FEC) and Cyclic Redundancy Checks (CRC) adapted to the adverse conditions usually found with ionospheric propagation.

The three modes (or modems) are called:

- High Speed Modem (HSM)
The HSM is a high speed serial tone modem offering user data rates of 3600 bit/s, 2400 bit/s and 1200 bit/s. Selection of the desired user data rate (and therewith

selection of HSM itself) is done by the operator; in case of favourable propagation conditions, fax and data files can be transferred significantly faster than with MSM. The HSM is said to support the STANAG 4285 protocol (see [chapter 3.92, "STANAG 4285"](#), on page 280).

- **Medium Speed Modem (MSM)**
The MSM uses 10 parallel data channels (tones, see [table 3-48](#)) located in the (approx.) 3 kHz bandwidth, each of which being modulated in FSK2 with data packets. The primary data is partitioned into these packets in advance. Thus, the achievable data rate is 10 times the rate on each channel.
- **Low Speed Modem (LSM)**
The LSM supplies an extremely robust transmission mode to be used in case of propagation conditions being too poor for higher data rates. The two low-end data rates of below 200 bit/s only are suited for transmission of single page faxes (or small data files). The single data channel is modulated with FSK8, resulting in 8 serial tones, see [table 3-49](#)). The LSM is found to be also MIL-STD-188-141A (see [chapter 3.66, "MIL-STD-188-141A"](#), on page 198).

If repeated attempts to transfer the data with the user-selected data rate have failed, SkyFax puts into effect an automatic fall-back, i.e. it will try again transmission after having switched to a lower data rate (to an alternative modem if required). Before activating robust mode (LSM) during this process, however, a check of the size of the document to transfer and comparison with a threshold size is done.

Table 3-48: Frequency table for SkyFax MSM.

Channel	1	2	3	4	5	6	7	8	9	10
Frequency [Hz]	437.5	687.5	937.5	1187.5	1437.5	1687.5	1937.5	2187.5	2437.5	2687.5
Space [Hz]	375	625	875	1125	1375	1625	1875	2125	2375	2625
Mark [Hz]	500	750	1000	1250	1500	1750	2000	2250	2500	2750

Table 3-49: Frequency table for SkyFax LSM.

Channel	1	2	3	4	5	6	7	8
Frequency [Hz]	500	750	1000	1250	1500	1750	2000	2250

3.90 SPREAD-11, SPREAD-21, SPREAD-51

3.90.1 General

Transmission method	SPREAD-11, SPREAD-21, SPREAD-51
Explanation of name	Bit interleaving of AUTOSPEC characters induces a SPREADING of the characters; bit distances 11 bits, 21 bits, 51 bits
Other designations	AUTOSPEC Mark II AUTOSPEC MK 2

Transmission method	SPREAD-11, SPREAD-21, SPREAD-51
Variants existing	
Derived from method	AUTOSPEC
Typical users	Diplomatic stations Navy and shore stations (SPREAD-51)
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	
Baud rate	62.3 Bd, 68.5 Bd, 102.6 Bd, 137 Bd or 218.3 Bd
Modulating subcarrier	
Bandwidth	- SPREAD-11: 270 Hz - SPREAD-21: 270 Hz - SPREAD-51: 590 Hz
Operating method	Simplex, synchronous
Data protection	FEC
Code table	Bauer code (ITA-2 derivative) (table 4-8 in chapter 4.1.7)

3.90.2 Description

The SPREAD method is exactly the same as AUTOSPEC (see [chapter 3.19, "AUTOSPEC"](#), on page 78), except that the transmission is not done character by character, but the bits of the characters are interleaved. A better robustness against burst errors (errors concerning many adjacent bits) is intended to obtain this way.

The difference between the three variants SPREAD-11, SPREAD-21 and SPREAD-51 is the spread factor, i.e. the distance of the bits of a particular character in the bit stream sent. Thus, the next bit of a character follows the previous one

- in SPREAD-11 11 bits
- in SPREAD-21 21 bits
- in SPREAD-51 51 bits

later. A new character is started every 10 bits in all three modes. The consecutive bits destroyed by burst errors occurring commonly belong to different characters, resulting in a good prospect that only one-bit errors emerge in a particular character that can be corrected subsequently due to use of the 10-bit Bauer code (cf [chapter 3.19](#)).

The scheme of interleaving can be seen from [figure 3-89](#), [figure 3-90](#) and [figure 3-91](#). Shown are some original Bauer code characters (**A**), the continuous bit stream (no grouping, **B**), a 10-bitwise grouping (**C**) illustrating any peculiar bit position (especially first and last) of the characters and an 11-, 21- and 51-bitwise grouping, respectively (**D**), for giving a better understanding of the interleaving process itself. Note that all three displays show the same issue (bit order), just the grouping (line break) is varied.

As also can be seen easily, the count of bits a particular character spans is calculated as

$$\text{Displacement} = \text{Spread factor} \times (\text{Code word length} - 1) + 1,$$

thus, for

- SPREAD-11: $11 \times 9 + 1 = 100$ bits
- SPREAD-21: $21 \times 9 + 1 = 190$ bits
- SPREAD-51: $51 \times 9 + 1 = 460$ bits

In the idle case, the signal sent is the same as with AUTOSPEC.

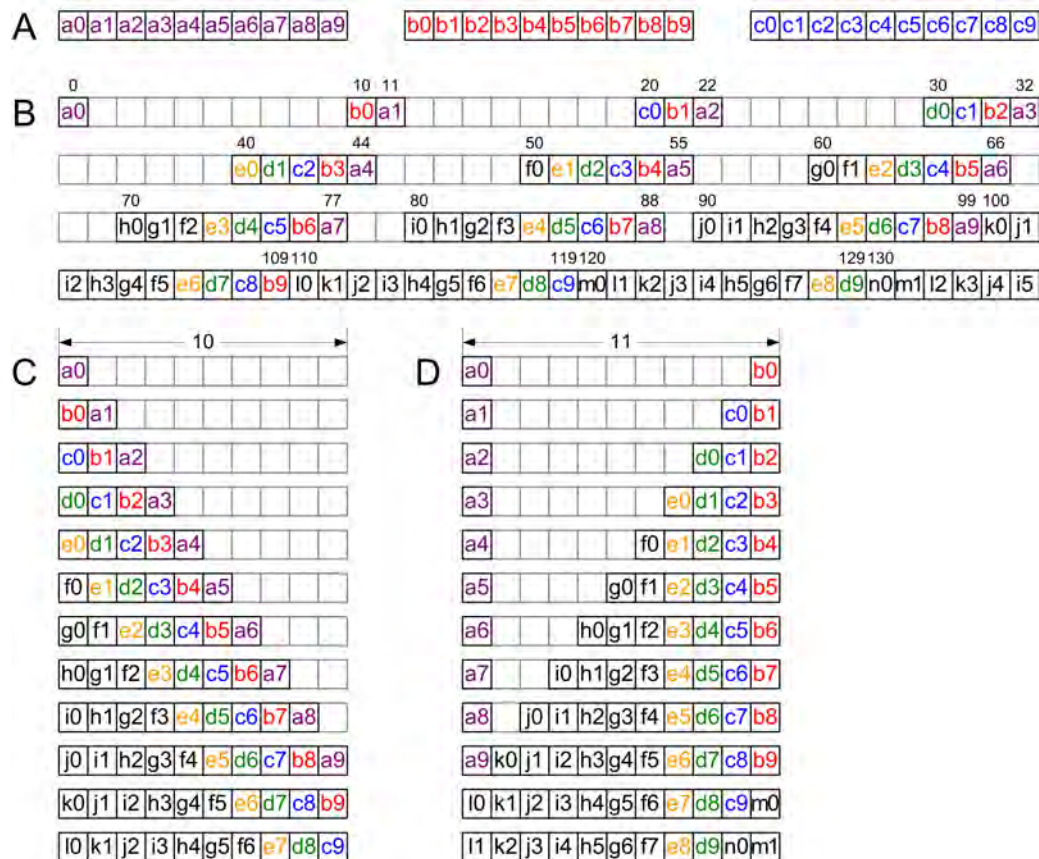


Fig. 3-89: Bit-interleaving in SPREAD-11.

- A = Original Bauer code characters
 B = Bit-interleaved characters, continuous (no grouping)
 C = Bit-interleaved characters, 10-bitwise grouping
 D = Bit-interleaved characters, 11-bitwise grouping

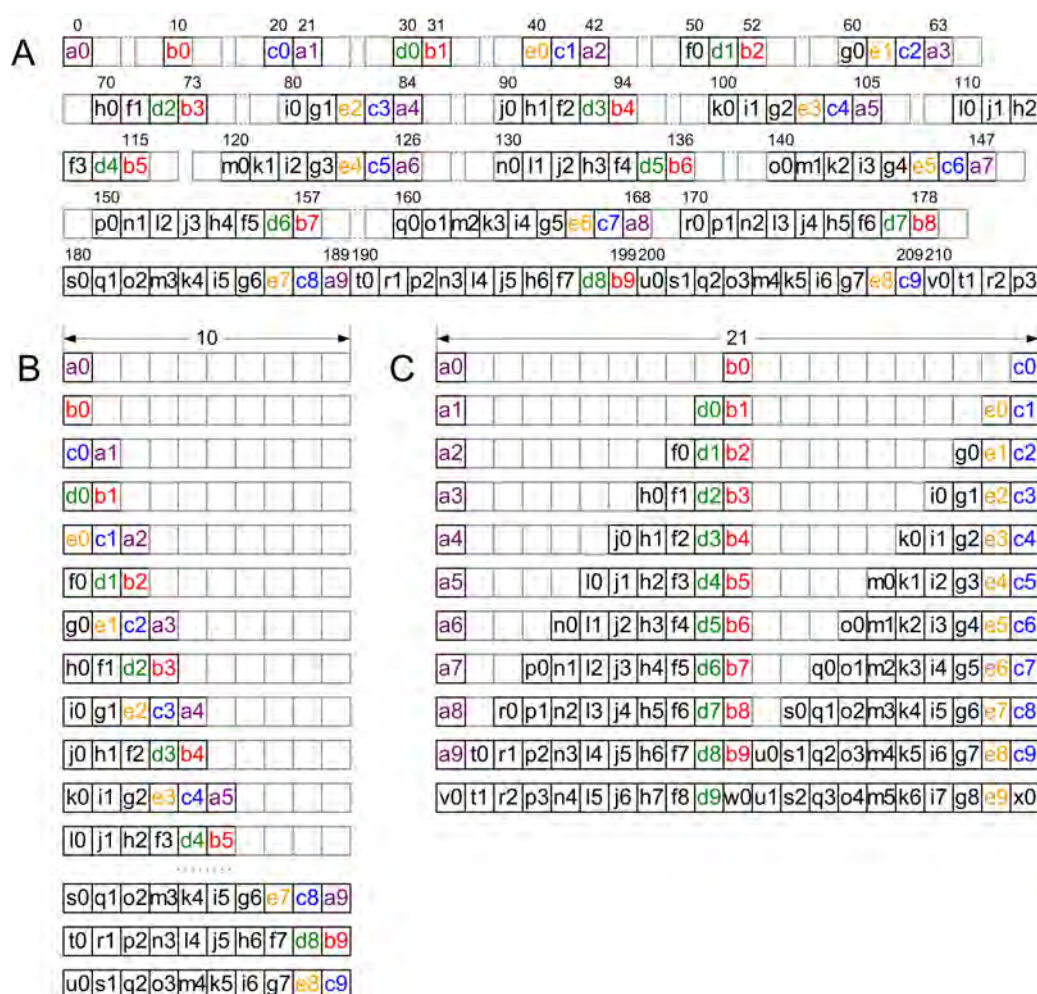


Fig. 3-90: Bit-interleaving in SPREAD-21.

A = Bit-interleaved characters, continuous (no grouping)

B = Bit-interleaved characters, 10-bitwise grouping

C = Bit-interleaved characters, 21-bitwise grouping

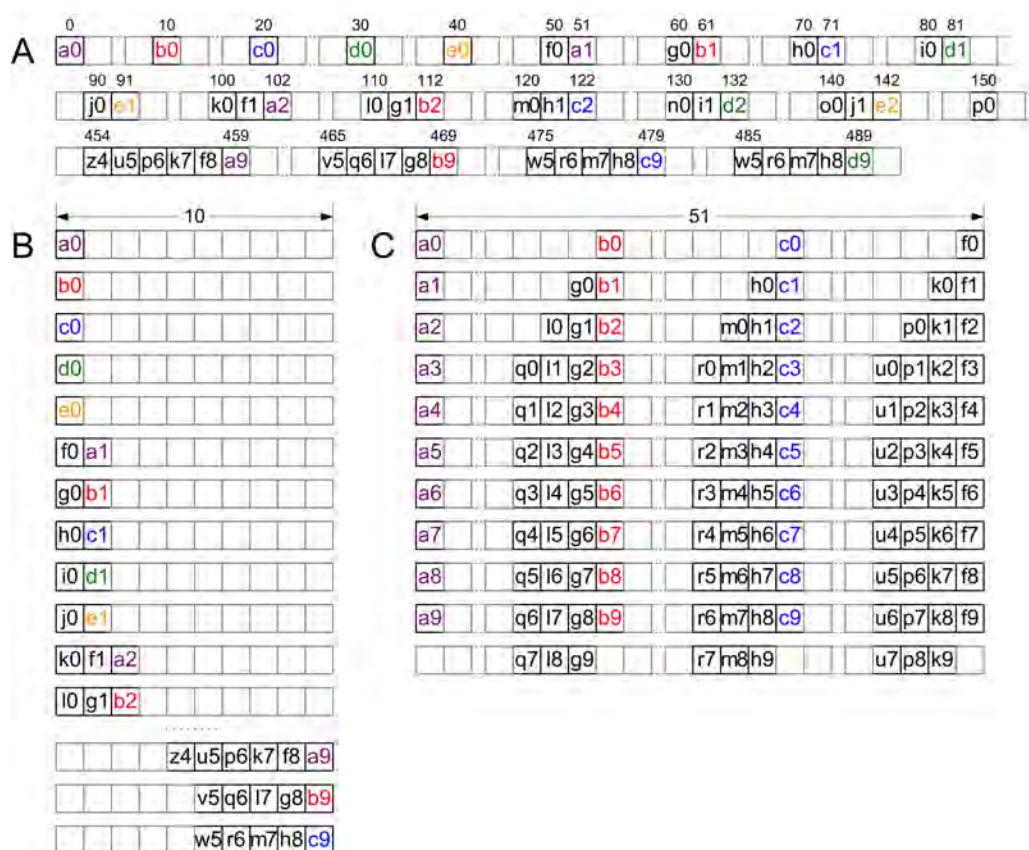


Fig. 3-91: Bit-interleaving in SPREAD-51.

A = Bit-interleaved characters, continuous (no grouping)

B = Bit-interleaved characters, 10-bitwise grouping

C = Bit-interleaved characters, 51-bitwise grouping

3.91 SSTV

3.91.1 General

Transmission method	SSTV
Explanation of name	Slow Scan TeleVision
Other designations	
Variants existing	Numerous sub-modes existing
Derived from method	
Typical users	Radio amateurs
Kind of data	Still images
Reference to standard	

Transmission method	SSTV
Frequency band	HF
Modulation method	FM
Shift/tone spacing	800 Hz
Baud rate	
Modulating subcarrier	Modulator specific (not visible on air)
Bandwidth	2 kHz
Operating method	Broadcast
Data protection	
Code table	

3.91.2 History

The concept of SSTV was introduced by *Copthorne McDonald* in 1957/58. In those days it seemed sufficient to use 120 lines and about 120 pixels per line to transmit a black-and-white still picture within a 3 kHz phone channel. First live tests were performed on the 11 m HAM band, which was later given to the CB service in the U.S. SSTV later was used to transmit images of the far side of the Moon from Luna 3. Commercial systems started appearing in the United States in 1970, after the FCC (Federal Communications Commission, U.S. authority for licensing of communications equipment) had legalized the use of SSTV for advanced level amateur radio operators in 1968.

3.91.3 Description

SSTV uses analog frequency modulation: every different value of brightness in the image gets a different audio frequency. In other words, the signal frequency shifts up or down to designate brighter or darker pixels, respectively. The image to be sent has to be scanned in horizontal lines (from left to right). Color is achieved by dividing the image into

the three color components

- R (red),
- G (green)
- B (blue)

or into

the brightness (luminance) component

- Y
- and the two color (chrominance) components
- U
 - V

and sending the brightness of each separately. This signal is fed into an SSB transmitter. A numerous multitude of modes exists (table 3-50), each of which describes the number of lines to be scanned, thus defining the size of the used image, the quality of the transmitted copy and the time consumed for transmission.

Table 3-50: Some commonly used SSTV transmission modes.

Mode Family	Mode Name	Color Type ¹⁾	Time (s)	Pixels/Line	Scan Lines ²⁾
Acorn	PD 180	YUV	187	320	240
	PD 290		290	400	300
Martin	M1	RGB	114	320	16 + 240
	M2		58	160	
	M3		57	320	8 + 120
	M4		29	160	
Pasokon TV	P3	RGB	203	640	16 + 480
	P5		305		
	P7		406		
Robot	8	B&W	8	160	120
	12		12	320	
	24		24		240
	36		36		
	43		43		
	12	YUV	12	160	120
	24		24	320	
	36		36		240
	72		72		
	Scottie		S1	RGB	110
S2		71	160		
S3		55	320		8 + 120
S4		36	160		
DX		269	320		16 + 240
Wraase SC-1	8	B&W	8	128	8 + 120
	16		16	256	
	24		24	128	
	16	RGB	16	256	
	24		24	128	
	32		32	256	
	48		48		
	96		96		
Wraase SC-2	30	RGB	30	256	128
	60		60		256

Mode Family	Mode Name	Color Type ¹⁾	Time (s)	Pixels/Line	Scan Lines ²⁾
	120		120	512	
	180		180		

- ¹ B&W **B**lack and **W**hite, no color transmission
- RGB **R**ed, **G**reen and **B**lue: color transmission in 3 color components
- YUV **Y**, **U** and **V**: color transmission in a luma (brightness, Y) and two chrominance (color, U and V) components
- ² "+" 1st value: lines with grey scale, 2nd value: lines with image information

3.92 STANAG 4285

3.92.1 General

Transmission method	STANAG 4285
Explanation of name	ST andardization AG reement, an agreement of the NATO member states on the use of standardized methods or similar equipment
Other designations	
Variants existing	
Derived from method	
Typical users	
Kind of data	(Universal data)
Reference to standard	STANAG 4285 EL (Edition 1): " <i>Characteristics of 1200/2400/3600 Bits per Second Single Tone Modulators/Demodulators for HF Radio Links</i> " (February 16, 1989)
Frequency band	HF
Modulation method	PSK8 , PSK4 , PSK2
Shift/tone spacing	
Baud rate	2400 Bd User data rates: • 75 bit/s, 150 bit/s, 300 bit/s, 600 bit/s, 1200 bit/s, 2400 bit/s, 3600 bit/s
Modulating subcarrier	1800 Hz
Bandwidth	3 kHz
Operating method	Simplex, broadcast

Transmission method	STANAG 4285
Data protection	FEC , unprotected
Code table	Bit-transparent (no limitation to special kind of data)

3.92.2 Description

STANAG 4285 is specified by the [NATO](#) as the physical layer of the [HF](#)-House protocol layers: for transmitting universal data at a fixed baud rate of 2400 [Bd](#), but different bit rates of more or less than 2400 bit/s, depending on the modulation method ([PSK2](#), [PSK4](#) or [PSK8](#)) and the [FEC](#) code rate (from 1/16 to no coding). A single tone of 1800 [Hz](#) is used for modulation, and user data rates defined vary from 75 bit/s to 3600 bit/s. User data is organized to portions of 128 symbols (4 x 32 symbol blocks) and expanded to 256 symbol frames by additional blocks: 1 preamble (80 symbols) and 3 channel probe segments (3 x 16 symbols). If FEC is active, a FEC encoder (repetition rate 2 to 8) in conjunction with a convolutional interleaver (rate $r = 1/2$ and constraint length $l = 7$, interleaving time 0.853 s or 10.24 s) is used.

3.92.3 Channel Coding/Structure of Data Blocks

Frames of 256 symbols: preamble (80 symbols), 3 blocks of 32 data symbols and 16 channel probe symbols (3 x 48 symbols), 1 block of 32 data symbols, overall duration 106.67 [ms](#). End of a transmission marked by the fixed bit pattern $4B65\ A5B2_{16}$ (hexadecimal notation, [MSB](#) first), followed by flush bits for [FEC](#) coder flushing and for complete transmission of the remainder of the interleaver data block. Additionally FEC coding and interleaving (see [3.92.2](#), "[Description](#)").

3.93 STANAG 4529

3.93.1 General

Transmission method	STANAG 4529
Explanation of name	STAN dardization AG reement, an agreement of the NATO member states on the use of standardized methods or similar equipment
Other designations	
Variants existing	
Derived from method	STANAG 4285
Typical users	Ship to shore circuits
Kind of data	(Universal data)

Transmission method	STANAG 4529
Reference to standard	STANAG 4529 EL (Edition 1): " <i>Characteristics of Single Tone Modulators/ Demodulators for Maritime HF Radio Links with 1240 Hz Bandwidth</i> " (January 20, 1998)
Frequency band	HF
Modulation method	PSK8, PSK4, PSK2
Shift/tone spacing	
Baud rate	1200 Bd, User data rates: 75 bit/s, 150 bit/s, 300 bit/s, 600 bit/s, 1200 bit/s, 1800 bit/s
Modulating subcarrier	1700 Hz (default value, selectable in 100 Hz steps from 800 Hz to 2400 Hz)
Bandwidth	1240 Hz
Operating method	Simplex, broadcast
Data protection	FEC, unprotected
Code table	Bit-transparent (no limitation to special kind of data)

3.93.2 Description

STANAG 4529 is the same method as STANAG 4285 (see description in [chapter 3.92, "STANAG 4285"](#), on page 280), with the following differences:

- Baud rate 1200 Bd
- Center frequency 1700 Hz (selectable from 800 Hz to 2400 Hz)
- Maximum user data rate 1200 bit/s
- Interleaving time 1.706 s or 20.48 s
- Frame duration 213.33 ms

3.93.3 Channel Coding/Structure of Data Blocks

(See STANAG 4285, [chapter 3.92](#), overall frame duration 213.33 ms)

3.94 STANAG 5066

STANAG 5066 (**STAN**dardization **AG**reement, an agreement of the [NATO](#) member states on the use of standardized methods or similar equipment) is not a demodulation or decoding method, but a protocol describing connecting data transmission applications to (analog) HF radio. It is called "Profile for High Frequency (HF) Radio Data Communication", this is, it stands for a NATO specification to enable applications to communicate efficiently over HF Radio. The original demand was to send e-mail via HF channels thus reducing the need of scarce satellite communication resources (reserving them to requirements genuinely needing large bandwidths). So, by develop-

ing a modern, adaptive and flexible HF system, much of NATO's messaging, data, data link, facsimile and voice requirements could be met within the HF band.

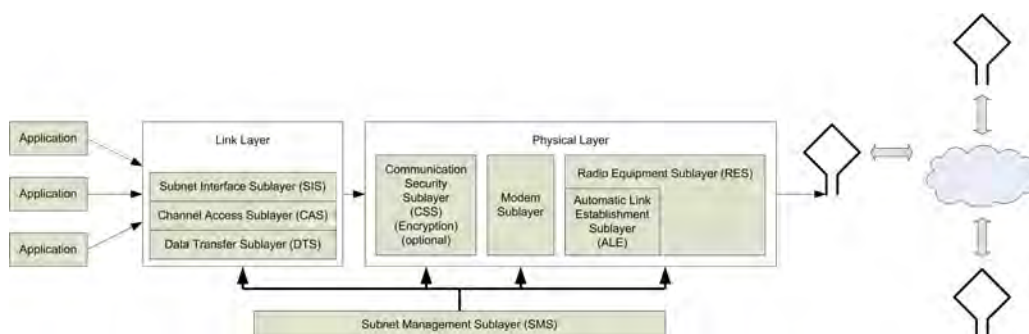


Fig. 3-92: Block diagram STANAG 5066.

STANAG 5066 provides peer protocols that link an HF modem to the application level (operate above the HF modem and below the application level), including the (mandatory) SIS (Subnet Interface Service) protocol that enables an application to connect to an HF modem through a STANAG 5066 server over [TCP/IP](#). This enables a clean separation between application and modem.

As can be seen in [figure 3-92](#), definition of the communication is split up into communication layers. The two main layers are

- the **Link Layer**, divided into the sublayers
 - **Subnet Interface Sublayer (SIS)**
providing a common, standard interface to all users and being the interface between the subnet and the "rest of the world"
 - **Channel Access Sublayer (CAS)**
providing additional functionality as needed to allow different forms of channel access, thus supporting communication over a "dedicated" HF radio channel
 - **Data Transfer Sublayer (DTS)**
containing the data transfer protocol that provides a reliable ([ARQ](#)) data link service
- the **Physical Layer**, divided into the sublayers
 - **Communications Security Sublayer (CSS)**
providing communications security using hardware crypto equipment (a number of NATO approved cryptos, including BID-950 and KG-84C, have been shown to be suitable to provide this function)
 - **Modem Sublayer**
providing a means for transmitting digital data over an analog channel
 - **Automatic Link Establishment Sublayer (ALE)**
automating the process of establishing a radio path (link) with one or more remote nodes
 - **Radio Equipment Sublayer (RES, not defined by STANAG 5066, but by STANAG 4203)**
comprising the equipment required to establish a radio link between two or more nodes, i.e. transmitters, receivers, transceivers, antennas, etc.

The **Subnet Management Sublayer** (SMS) is a layer with interfaces to each sublayer. The main subnet management function, in the context of this STANAG, is Automatic Link Maintenance (ALM) in the form of adaptive control of the HF modem. The management sublayer messages and associated procedures which are required for ALM are defined in Annex C of the STANAG 5066 document, whereas the other functions of the Subnet Management Sublayer, which may be critically important to a successful implementation, need not be standardized for interoperability.

Beyond these mandatory sublayer definitions, STANAG 5066 defines recommended and advisory support for the subnetwork profiles with standard modem and radio equipment, based on the use of STANAG 4285 ([chapter 3.92, "STANAG 4285"](#), on page 280), MIL-STD-188-110A ([chapter 3.62, "MIL-STD-188-110A"](#), on page 176), and STANAG 4529 ([chapter 3.93, "STANAG 4529"](#), on page 281). In addition, the STANAG supports evolutionary growth to include high-speed serial-tone waveforms at rates as high as 9600 bit/s. The protocol profile includes definition of the subnet interface layer requirements for standard application clients (but not of the clients themselves) for reliable message transfer, Z-modem applications, an HF Simple Mail Transfer Protocol (HF-SMTP), and HF-POP (Post-Office-Protocol) Mail (to name a few).

The protocol profile defined in STANAG 5066 provides a common air interface and open systems specification for the following data services over arbitrary HF channels:

- Reliable point-to-point data transfer using an automatic repeat request (ARQ) protocol
- Unreliable (or non-ARQ) point-to-point, broadcast, or multicast (i.e., group broadcast) data transfer
- Regular data services using ARQ and non-ARQ delivery modes
- Expedited data services using ARQ and non-ARQ delivery modes
- Link establishment and teardown services for simple channel access
- Management services for automatic data rate change (DRC) protocols

It is useful to consider the key characteristics of HF Radio, which is sufficiently different to other systems, so that a specially designed protocol becomes imperative.

Key characteristics are:

- Low bandwidth: HF Radio is slow, with bandwidths ranging from 75 bit/s to 9600 bit/s, with a typical rate of 1200 bit/s
- Noise: HF transmission is subject to varying levels and types of noise and interference
- Variable bandwidth: A modern modem/radio system will respond to varying signal/noise ratio by adopting appropriate waveforms and forward error correction. This will result in varying bandwidth for the system using the modem
- Simplex mode: An HF radio cannot detect incoming signals when it transmits, and so is not even half duplex. If more than one radio transmits at once, nothing gets through and none of the transmitting radios can detect the problem
- Broadcast: HF Radio is a broadcast medium, and it is important to enable applications to use this in order to provide broadcast and multicast services
- Receive only: Some military applications need to work where a radio is in EMCON (Emission Control) and not sending data

- Long turnaround time: Turnaround time is the time taken from one radio to stop sending to another radio to start. This can vary from a few seconds to a few tens of seconds. Interleaving is a technique commonly used to reduce the impact of burst noise, and this substantially increases turnaround time. To optimize throughput, a radio needs to transmit for a reasonably long period and then allow other radios to transmit. To get reasonable utilization of the bandwidth, the transmit time needs to be quite a lot longer than the turnaround time
- Interface: An HF modem provides a quite basic interface; essentially send OR receive data. This combination of requirements is quite unlike any other communications medium, and special protocols are needed to efficiently transmit data over HF

3.95 SWED-ARQ

3.95.1 General

Transmission method	SWED-ARQ
Explanation of name	Automatic Repeat ReQuest, SWED ish
Other designations	ARQ-SWE ARQ-SWED
Variants existing	
Derived from method	SITOR-A
Typical users	Swedish diplomatic services
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK2
Shift/tone spacing	170 Hz
Baud rate	100 Bd
Modulating subcarrier	
Bandwidth	580 Hz
Operating method	Half-duplex ("Simplex-ARQ")
Data protection	Mark to space ratio 3 to 4, ARQ
Code table	SITOR (CCIR 476-5) (table 4-7 in chapter 4.1.6)

3.95.2 Description

SWED-ARQ is a method similar to SITOR-A (cf [chapter 3.87, "SITOR-A"](#), on page 262). The difference is that it is an adaptive system, i.e. three different cycle lengths are predefined, and the system is able to change cycle length in mid transmission, depending on conditions of propagation.

In literature, the three lengths are commonly referred to as short, medium and long. Again, baud rate is 100 Bd, and the 7-bit alphabet [CCIR 476-5](#) is used, resulting in a bit duration of 10 ms and a character duration of 70 ms. Definitions are as shown in [table 3-51](#) (see also [figure 3-93](#)).

Table 3-51: Cycle length parameters in SWED-ARQ.

Cycle length notation (cf figure 3-93)		Short (A)	Medium (B)	Long (C)
Transmission (Tx) cycle	[characters]	3	9	22
	[ms]	210	630	1540
Listen cycle (pause)	[ms]	240	270	260
Overall repetition cycle	[ms]	450	900	1800
	tallying with bits	45	90	180
Effective baud rate [Bd] (with error-free transmission)		46.7	70	85.6

With the short cycle length active, the method is identical to [SITOR-A](#).

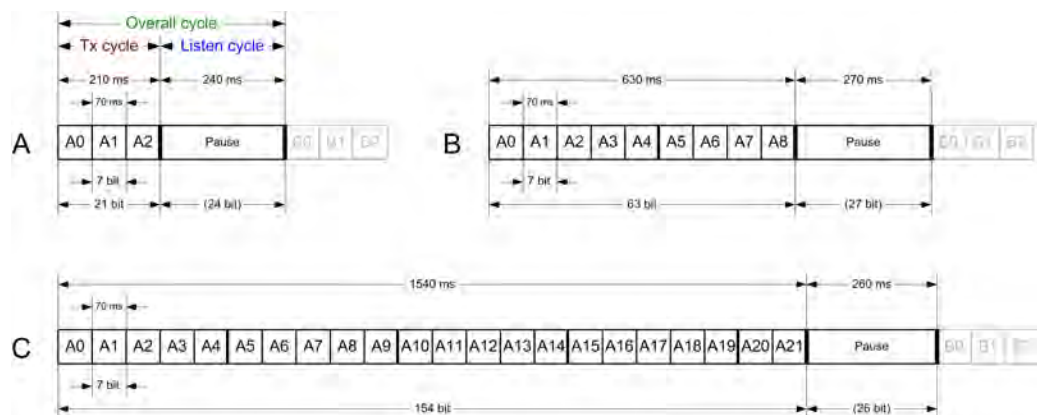


Fig. 3-93: Cycle lengths in SWED-ARQ.

A = short
B = medium
C = long

The [ISS](#) decides due to current conditions of propagation whether to change-over to a different cycle length (switching always one stage onward, no direct switching from short to long or back possible). It switches to the new cycle length autonomously, signaling this to the [IRS](#) by 3 control characters at the beginning of the next data block, these being normally a combination of "α", "β" and "CSx" characters. If necessary the new block is padded by "RQ" characters; it will be repeated until the IRS has confirmed the change-over.

3.96 TETRA

3.96.1 General

Transmission method	TETRA
Explanation of name	TErrestrial Trunked RAdio formerly: Trans- E uropean Trunked R Adio
Other designations	
Variants existing	
Derived from method	
Typical users	
Kind of data	Voice and data applications
Reference to standard	ETSI EN (European Standard) 300 392: " <i>Terrestrial Trunked Radio (TETRA); Voice plus Data (V+D); Part 1</i> " to " <i>Part 18</i> "
Frequency band	UHF: • 380 MHz to 385 MHz (Authorities and organizations with security concerns, uplink) • 390 MHz to 395 MHz (ditto, downlink) • 385 MHz to 390 MHz • 440 MHz to 470 MHz • 395 MHz to 400 MHz • 870 MHz to 876 MHz • 410 MHz to 430 MHz • 915 MHz to 921 MHz (all others civilian)
Modulation method	a) PSK • PSK4B ($\pi/4$-DQPSK) • PSK8B ($\pi/8$-D8PSK) b) QAM (each with each bandwidth) • QAM4 (4-QAM) • QAM16 (16-QAM) • QAM64 (64-QAM)
Shift/tone spacing	
Baud rate	a) 18000 Bd b) 2400 Bd per subcarrier
Modulating subcarrier	b1) 8 subcarriers, b2) 16 subcarriers, b3) 32 subcarriers, b4) 48 subcarriers
Bandwidth	a) 25 kHz b1) 25 kHz, b2) 50 kHz, b3) 100 kHz, b4) 150 kHz
Operating method	Simplex, half-duplex, broadcast, synchronous
Data protection	FEC , interleaving, scrambling
Code table	

3.96.2 History

TETRA was specifically designed for use by government agencies, emergency services (police forces, fire departments, ambulance) for public safety networks, rail transportation staff for train radios, transport services and the military.

Until the late eighties, radio communications between public authorities had been operated worldwide the analog way. TETRA originally arised as an initiative of providers of these analog networks as a response to a competition threat by [GSM](#); the standard was developed in the mid-nineties, the first version having been published in 1995 and now also based on a European Telecommunications Standards Institute ([ETSI](#)) standard. Today, several European and non-European countries use it in the form of countrywide authority radio networks or in local coverings by different users.

3.96.3 Description

3.96.3.1 Scope

Similar to [GSM](#), TETRA uses a combined [FDMA/TDMA](#) approach. Radio frequency bands appear in pairs, the one part of which being used for downlink and the other for uplink direction. For [PSK](#) modulation (see [3.96.3.2, "Modulation"](#)), a carrier spacing of 25 kHz is in use. Each carrier conveys four independent user channels in four timeslots ([3.96.3.4, "Frame Structure"](#)), in contrast to the eight slots with [GSM](#).

3.96.3.2 Modulation

The modulation used with TETRA is either PSK4 or PSK8 in the so-called "B"-variants (see chapter [chapter 2.3, "PSKn"](#), on page 14), i.e. an additional phase change of half the nominal phase transition is performed with each symbol change: PSK4B has a nominal phase transition of $\pi/2$ and thus the additional phase change of $\pi/4$, PSK8B $\pi/4$ and $\pi/8$, respectively. This also means that in no case the phase state remains unchanged referred to the one of the previous symbol, a phase change of an odd multiple of the plain additional phase change is traversed with every new symbol. A permanent exchange in state from even to odd multiples of $\pi/4$ (PSK4B) or $\pi/8$ (PSK8B) happens this way, inhibiting, as desired, phase transitions of 180° (zero crossings in the phase plane).

In [figure 3-94](#) the situation is shown for PSK4B; as an example, the phase transitions originating from the 0° state are given for each symbol. These phase changes also apply to each other initial phase state, but, for clarity reasons, are not explicitly shown in the figure. See also [table 3-52](#).

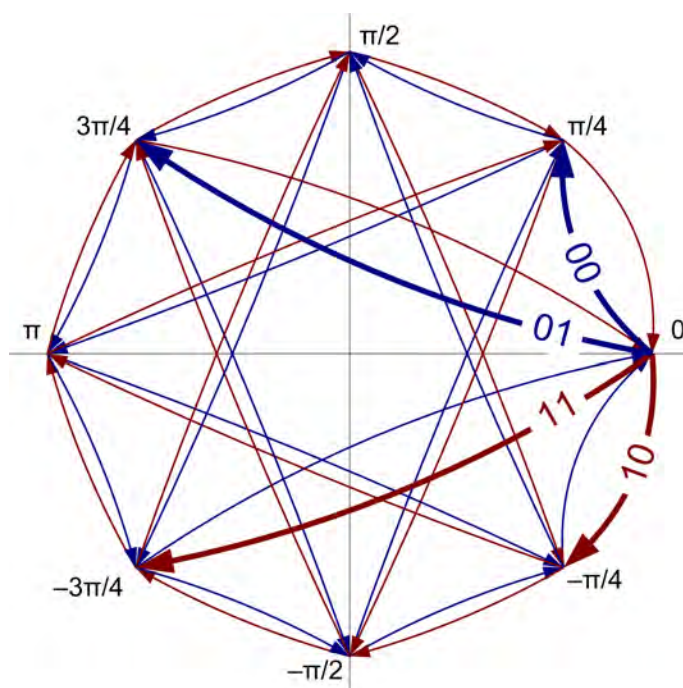


Fig. 3-94: Modulation constellation diagram and example transitions for each symbol (2 bits) with PSK4B.

Table 3-52: Phase transitions with PSK4B.

Symbol	1st bit	2nd bit	Phase change
00	0	0	$\pi/4$
01	0	1	$3\pi/4$
11	1	1	$-3\pi/4$ ($= 5\pi/4$)
10	1	0	$-\pi/4$ ($= 7\pi/4$)

Equivalently, [figure 3-95](#) and [table 3-53](#) describe PSK8B.

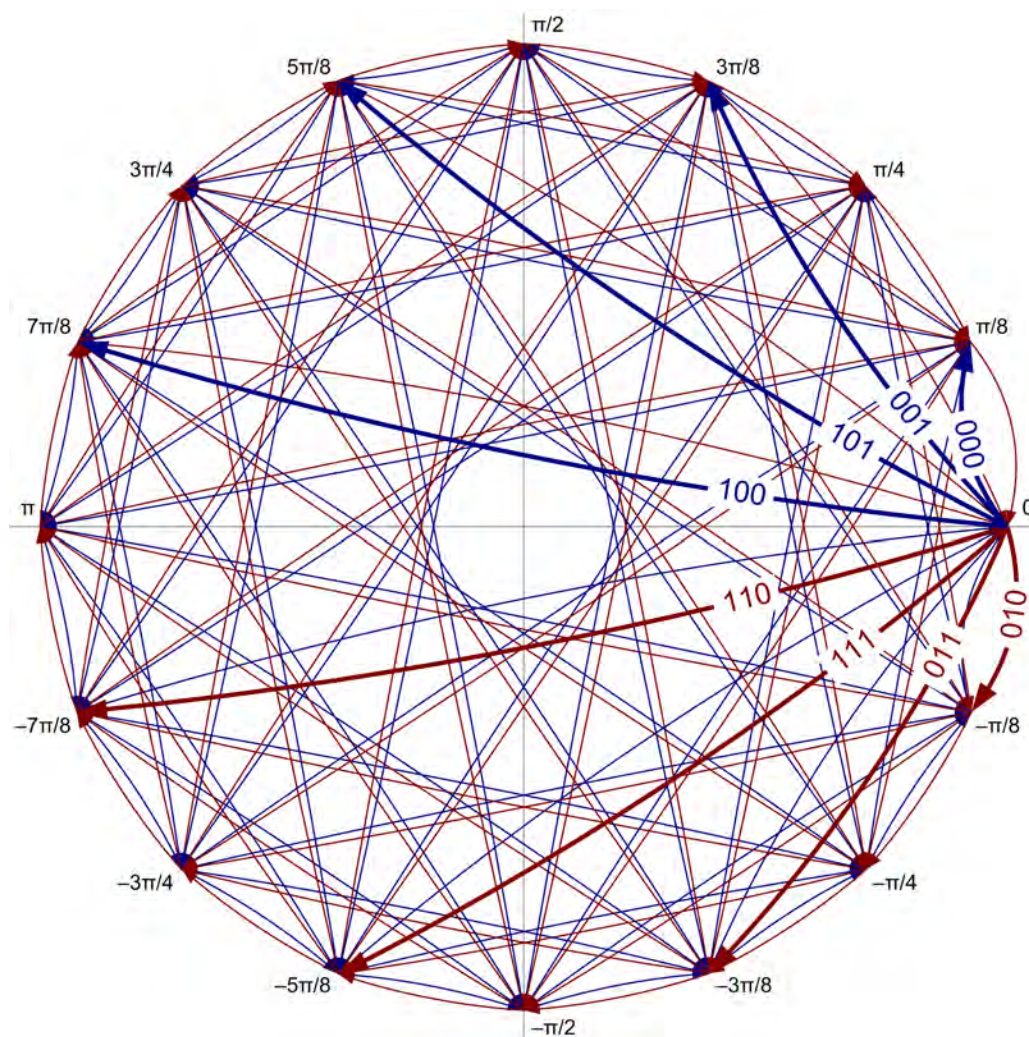


Fig. 3-95: Modulation constellation diagram and example transitions for each symbol (3 bits) with PSK8B.

Table 3-53: Phase transitions with PSK8B.

Symbol	1st bit	2nd bit	3rd bit	Phase change
000	0	0	0	$\pi/8$
001	0	0	1	$3\pi/8$
101	1	0	1	$5\pi/8$
100	1	0	0	$7\pi/8$
110	1	1	0	$-7\pi/8$ (= $9\pi/8$)
111	1	1	1	$-5\pi/8$ (= $11\pi/8$)
011	0	1	1	$-3\pi/8$ (= $13\pi/8$)
010	0	1	0	$-\pi/8$ (= $15\pi/8$)

Also existing is a TETRA variant applying modulation of type **QAM** (QAM4, QAM16 and QAM64). Until further notice, this variant is not part of the description in this manual.

3.96.3.3 Channels

Similarly to NXDN (see [chapter 3.70, "NXDN"](#), on page 211), TETRA differs between two kinds of "channel": the logical channel and the physical channel.

Logical Channels

The logical channels represent the interface between the protocol and the radio. An overview of the logical channels offered is given in [figure 3-96](#).

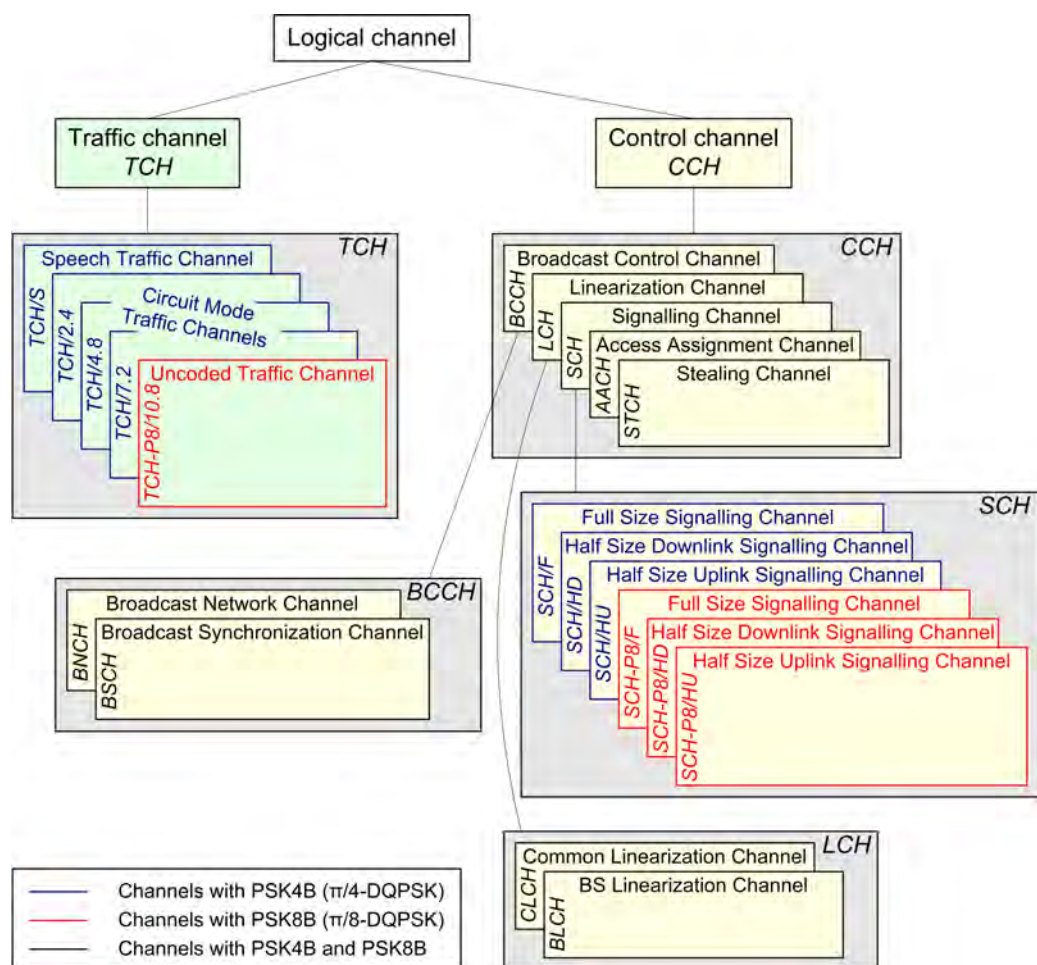


Fig. 3-96: TETRA logical channels.

The logical channels in principle are subdivided into

- **Traffic channels (TCH)**
- **Control channels (CCH)**

Traffic channels carry only user information. For PSK4B modulation, different traffic channels are defined for speech or data applications and for different data message speeds:

- **Speech Traffic Channel (TCH/S)**
- **Circuit Mode Traffic Channels:**
 - 7.2 kbit/s net rate (TCH/7.2)
 - 4.8 kbit/s net rate (TCH/4.8)
 - 2.4 kbit/s net rate (TCH/2.4)

Up to 4 times higher net rates can be achieved by allocating up to 4 Traffic Physical channels (see below) to the same communication process. With PSK8B, only one, the Uncoded Traffic Channel with 10.8 kbit/s net rate (TCH-P8/10.8), is defined.

Control channels carry signaling messages and packet data. The five categories defined are:

- **Broadcast Control Channel (BCCH)**
Unidirectional channel (downlink only) for common reception by all MSs (mobile stations): broadcasts general information to all MSs. Two categories exist:
 - *Broadcast Network Channel (BNCH)*: network information to MSs.
 - *Broadcast Synchronization Channel (BSCH)*: information used for time and scrambling synchronization of the MSs.
- **Linearization Channel (LCH)**
Bidirectional channel to be used by the BSs (base stations) and MSs to linearize their transmitters. Two categories:
 - *Common Linearization Channel (CLCH)*: uplink, shared by all MSs.
 - *BS Linearization CHannel (BLCH)*: downlink, used by the BS.
- **Signalling Channel (SCH)**
Shared by all MSs, but carrying messages specific to one MS or a group of MSs. System operation requires establishing of at least one SCH per BS. Three categories:
 - *Full Size Signalling Channel (SCH/F [PSK4B], SCH-P8/F [PSK8B])*: bidirectional channel for full size messages.
 - *Half Size Downlink Signalling Channel (SCH/HD [PSK4B], SCH-P8/HD [PSK8B])*: downlink only, for half size messages.
 - *Half Size Uplink Signalling Channel (SCH/HU [PSK4B], SCH-P8/HU [PSK8B])*: uplink only, for half size messages.
- **Access Assignment Channel (AACH)**
Present on all transmitted downlink slots. Indicates on each physical channel the assignment of uplink and downlink slots.
- **Stealing Channel (STCH)**
Associated to a TCH temporarily "stealing" a part of the capacity to transmit control messages (if fast signaling is required), unidirectional with same direction as the associated TCH.

Physical Channels

A physical channel is given by a pair of carrier frequencies (downlink and uplink) and a timeslot number. Due to the 4 timeslots in TETRA, 4 physical channels exist per carrier pair. A scope of the physical channels is shown in [figure 3-97](#).

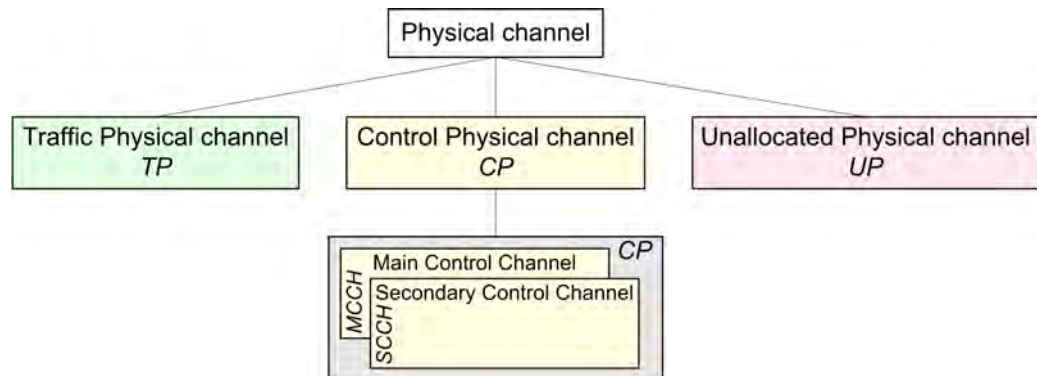


Fig. 3-97: TETRA physical channels.

Three types of physical channel exist:

- **Traffic Physical channel (TP)**
Carries only TCHs (see "Logical Channels").
- **Control Physical channel (CP)**
Carries exclusively CCHs; two types exist (the type is indicated in the AACH):
 - *Main Control Channel (MCCH)*
In each radio cell one RF carrier constitutes the main carrier. Whenever an MCCH is in use, it is located on timeslot 1 of the main carrier.
 - *Secondary Control Channel (SCCH)*
May be used to extend the signaling capacity of the MCCH, is only to be assigned when the MCCH is used.
- **Unallocated Physical channel (UP)**
Not allocated to any MS(s).

3.96.3.4 Frame Structure

Timeslots and Frames

The basic unit of the TDMA structure of TETRA is the **timeslot**. With PSK4B, a time-slot comprises 255 phase modulation symbols; from the baud rate of 18 kBd a duration of 255/18 ms (85/6 ms = 14,167 ms approx.) results. The frame structure derived from that is shown in [figure 3-98](#).

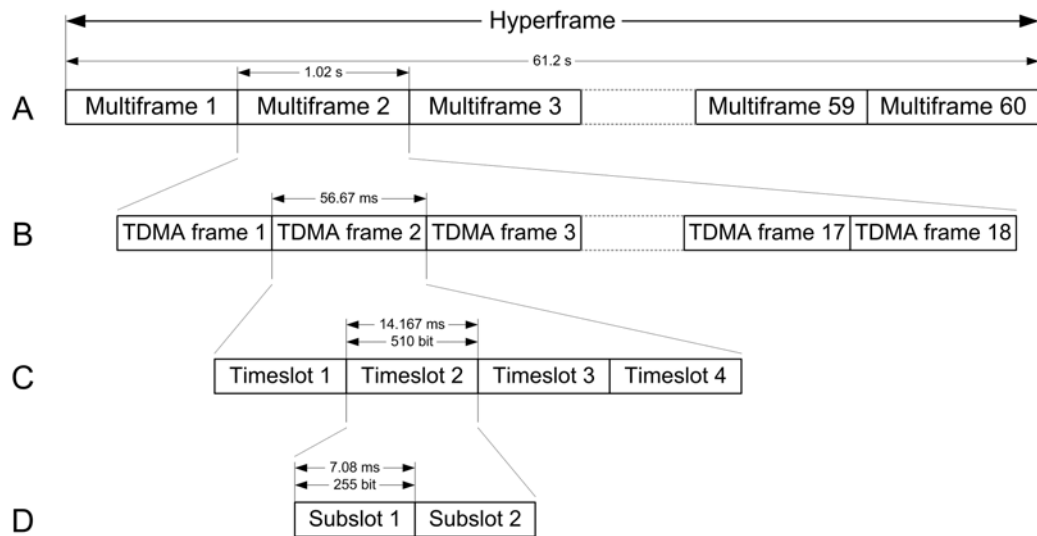


Fig. 3-98: TETRA frame structure.

A = Hyperframe
 B = Multiframe
 C = TDMA frame
 D = Timeslot

Uplink timeslots (figure 3-98, D) may be divided into two **subslots** of 7.08 ms each if necessary. Basically, four timeslots form a **TDMA frame** (C, 57.67 ms), i.e. four independent communication processes can be dealt with on one carrier frequency pair. A **multiframe** (B, 1.02 s) is arranged from 18 frames, the last (18th) of which is always used for control signaling (called control frame); voice or data information is conveyed in the remaining 17 frames. 60 multiframes set up a **hyperframe** (A, 61.2 s), they are in use for long-term (long repeat) purposes, e.g. synchronization of deciphering processes.

Bursts

A burst is a period of RF carrier modulated by a data stream. A burst therefore represents the physical content of a timeslot or subslot. Bursts are "patterns" being in use as required by the temporary traffic (no fixed mapping between bursts and physical channels).

The types of bursts in uplink direction are shown in figure 3-99; mind that all portions are modulated in PSK4B or PSK8B, respectively:

- **Control uplink burst 1 (CUB1) and 2 (CUB2)** (figure 3-99, A)
 Subslots (half slots) are applied to carry two independent bursts each; the 42 symbols (84 or 126 bits with PSK4B or PSK8B, 46 or 69 bits before channel coding) of control information are split into two areas by an extended training sequence of 15 symbols. Tail bits enclose this ensemble; also defined are guard periods of definite lengths.
- **Linearization uplink burst (B)**
 No information is transferred here, but MSs can transmit when tuning to a new frequency; again, the burst is conveyed during a half slot (Subslot 1 [SSN1] only).
- **Normal uplink burst (NUB) (C)**

Two independent blocks, BKN1 and BKN2, can carry separate logical channels (see 3.96.3.3, "Channels") with either control or traffic messages. Tail bits and training sequence again help sustaining or establishing bit synchronization.

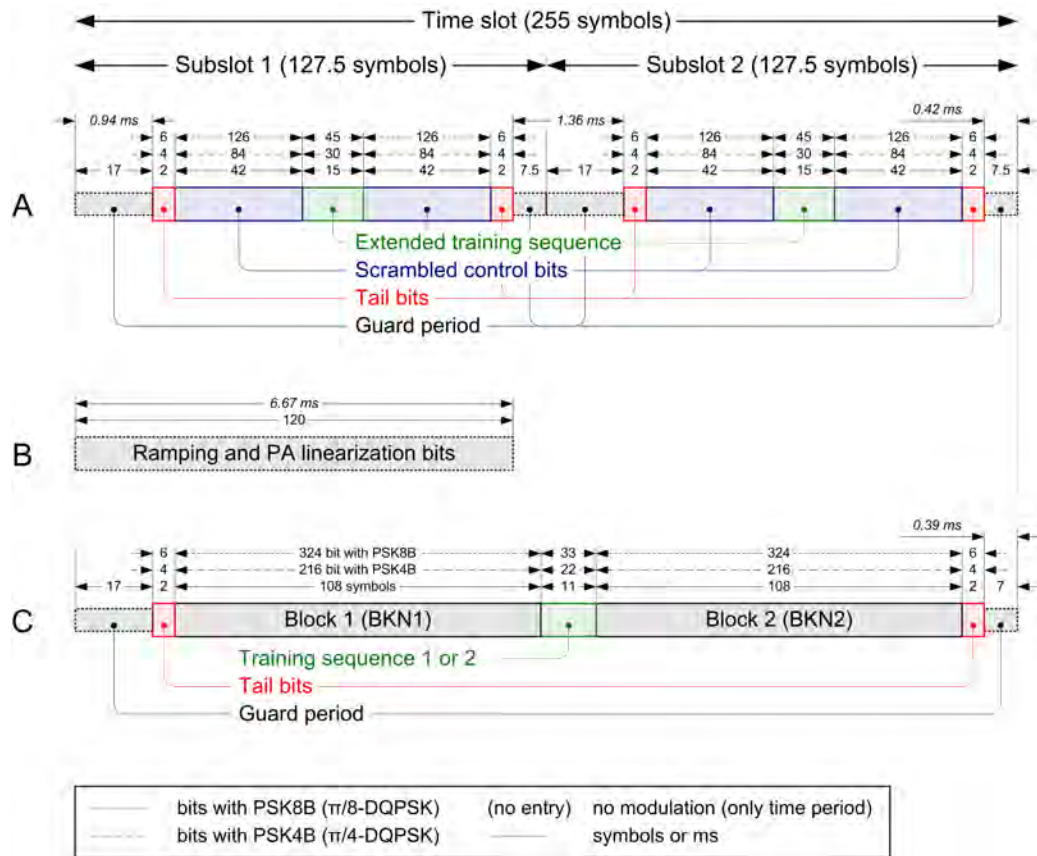


Fig. 3-99: TETRA types of uplink bursts for phase modulation.

A = Control uplink burst 1 (CUB1) in Subslot 1 (SSN1) and 2 (CUB2/SSN2)

B = Linearization uplink burst (in SSN1 only)

C = Normal uplink burst (NUB)

Bursts for downlink are given in figure 3-100. The two basic types "normal" and "synchronization" are additionally split into a "continuous" and a "discontinuous" variant:

- Normal continuous downlink burst (NDB) (figure 3-100, A)**
 The BS transmits control or traffic messages to the MS. Three blocks are available to carry the information, the BKN1 and BKN2 as with the uplink burst, and, in addition, a broadcast block (BBK) exclusively scheduled for the AACH (3.96.3.3, "Channels"). Training sequences surrounding or splitting the burst (and even the BBK), respectively, and phase adjustment bits exist for synchronization purposes. Use of continuous NDB is during continuous transmission mode.
- Normal discontinuous downlink burst (B)**
 Use is with timesharing transmission mode by a BS, from that, training sequence 3 is shortened and guard periods are provided at the start and end of the block.
- Synchronization continuous downlink burst (SB) (C)**
 Special type of NDB with the first half of the slot conveying a unique bit synchronization pattern. A further division is done into fields for frequency correction and

synchronization purposes. The other part of the burst may contain normal signaling messages.

- **Synchronization discontinuous downlink burst (D)**

Use is with timesharing transmission, see NDB (discontinuous).

- **Linearization downlink burst**

May be used by the BS to linearize its transmitter; if required, replaces BKN2 of a normal or synchronization continuous burst. No useful information is transferred here.

Note that with downlink bursts transmission of some fields is always done in PSK4B modulation, even if modulation mode selected is PSK8B (bit count marked in red in the figure).

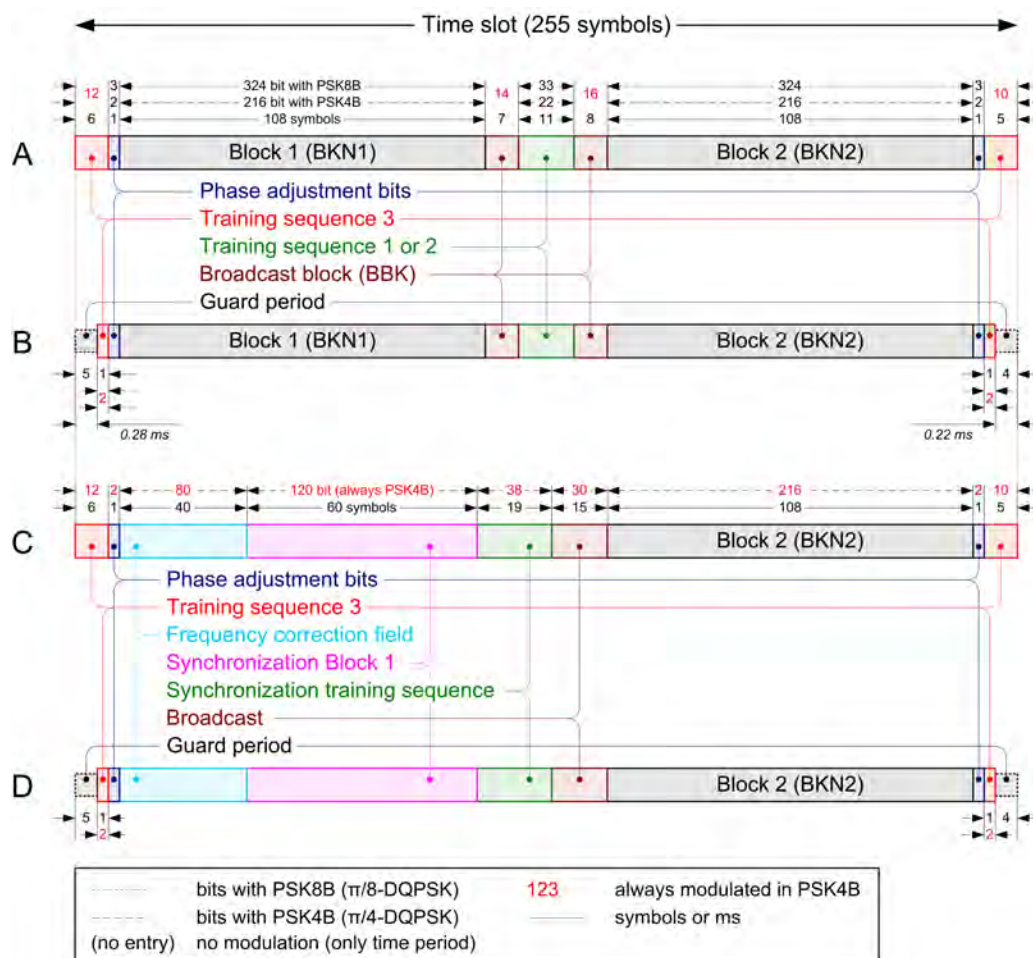


Fig. 3-100: TETRA types of downlink bursts for phase modulation.

- A = Normal continuous downlink burst (NDB)
B = Normal discontinuous downlink burst
C = Synchronization continuous downlink burst (SB)
D = Synchronization discontinuous downlink burst

3.97 TWINPLEX-BAUDOT

3.97.1 General

Transmission method	TWINPLEX-BAUDOT
Explanation of name	Fancy name for duplex (two [twin] channels multiplex), Baudot (correctly: ITA-2) code table
Other designations	BAUDOT/F7BBN Baudot ITA2 F7b two channels BF6 Baudot F7B ITA-2 Twin 2 channel ITA-2 RTTY (RadioTeleTYpe)
Variants existing	
Derived from method	TWINPLEX-SITOR
Typical users	
Kind of data	
Reference to standard	ITU-R Recommendation 346-1: " <i>Four-Frequency Diplex Systems – Section 3Ca – Radiotelegraph Circuits</i> " (January 1st, 1970) (withdrawn)
Frequency band	HF
Modulation method	FSK4
Shift/tone spacing	• 100 Hz - 100 Hz - 100 Hz • 200 Hz - 400 Hz - 200 Hz • 170 Hz - 170 Hz - 170 Hz • 115 Hz - 170 Hz - 115 Hz • 200 Hz - 200 Hz - 200 Hz • 115 Hz - 170 Hz - 515 Hz • 65 Hz - 170 Hz - 65 Hz • variable
Baud rate	100 Bd
Modulating subcarrier	(Defined as the mid-frequency between the two inner tones)
Bandwidth	1 kHz
Operating method	Simplex, asynchronous
Data protection	
Code table	ITA-2 (table 4-2 in chapter 4.1.2)

3.97.2 Description

TWINPLEX-BAUDOT is the same method as TWINPLEX-SITOR (see [chapter 3.98](#), "[TWINPLEX-SITOR](#)", on page 298), but uses the [ITA-2](#) alphabet, the originally only 5 characters per symbol are enlarged to 7 characters by a leading '0' bit (the start bit) and a trailing '1' bit (the stop bit).

3.98 TWINPLEX-SITOR

3.98.1 General

Transmission method	TWINPLEX-SITOR
Explanation of name	Fancy name for duplex (two [twin] channels multiplex), SITOR code table
Other designations	F7B1 to F7B6 (see 3.98.3, "Description") TWINPLEX TWINPLEX ARQ (F7B)
Variants existing	
Derived from method	
Typical users	Interpol United Nations Government diplomatic services
Kind of data	
Reference to standard	
Frequency band	HF
Modulation method	FSK4
Shift/tone spacing	• 100 Hz - 100 Hz - 100 Hz • 200 Hz - 400 Hz - 200 Hz • 170 Hz - 170 Hz - 170 Hz • 115 Hz - 170 Hz - 115 Hz • 200 Hz - 200 Hz - 200 Hz • 115 Hz - 170 Hz - 515 Hz • 65 Hz - 170 Hz - 65 Hz • variable
Baud rate	100.0 Bd, 200 Bd (rarely), 300 Bd (rarely)
Modulating subcarrier	(Defined as the mid-frequency between the two inner tones)
Bandwidth	720 Hz
Operating method	Half-duplex ("Simplex-ARQ")
Data protection	Mark to space ratio 3 to 4, ARQ
Code table	SITOR (CCIR 476-5) (table 4-7 in chapter 4.1.6)

3.98.2 History

TWINPLEX was developed by *Thrane & Thrane* of Denmark.

3.98.3 Description



Detecting of Correct Mode

Due to the many variations existing, an unambiguous detection of the correct one being present currently might be not possible. A way out is to display more than one data stream possibly decoded and let the user decide which one is the one whose contents make most sense.

Scope, Coding, Timing

TWINPLEX is a four-frequency transmission method. The signal to transmit commonly consists of two independent channels, the bit pairs of which are combined, each of the four possible bit combinations (dibits: 1-1, 1-0, 0-1, 0-0) representing one of the four frequencies. An example for frequency relationships is given in [figure 3-101](#) (Mode F7B-1, see [table 3-55](#)); among other things it can be seen that the **MSB** (transmission channel V1, explained below in this chapter) of a dibit selects the two "left" (lower) or the two "right" (upper) frequencies, i.e. in case of an empty channel 1 only two frequencies are used.

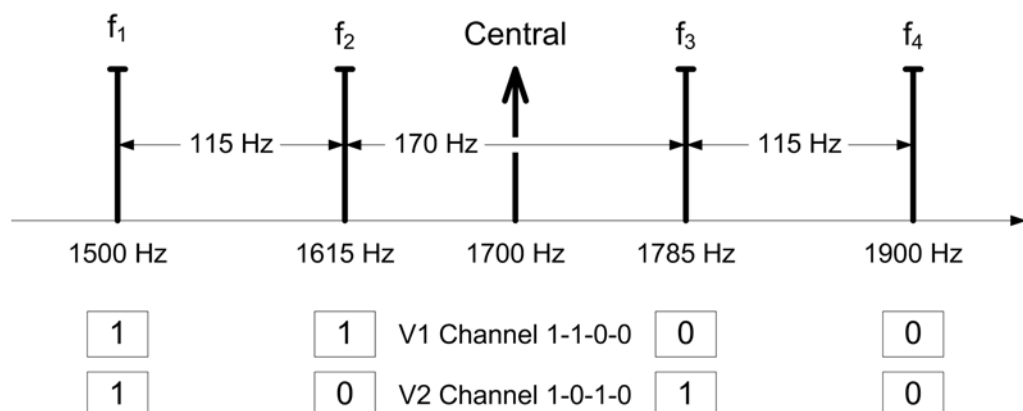


Fig. 3-101: Frequency example with TWINPLEX (Mode F7B-1).

"Conventional" TWINPLEX, also known as TWINPLEX-SITOR, uses the SITOR (CCIR 476-5) alphabet (each character 7-bit, always consisting of 3 '1' bits and 4 '0' bits, see [table 4-7](#) in [chapter 4.1.6, "SITOR Code Table"](#), on page 332). In contrast, TWINPLEX-BAUDOT (see [chapter 3.97, "TWINPLEX-BAUDOT"](#), on page 297) uses the ITA-2 alphabet, the originally only 5 characters per symbol are enlarged to 7 characters by a leading '0' bit (the start bit) and a trailing '1' bit (the stop bit).

Transmission of TWINPLEX signals is made in data blocks of 6 characters (3 in each channel, these together called a word) or 42 bits (21 dibits), consuming 210 ms and followed by a pause of 240 ms.

Constructing of the transmission parameters is widely variable:

Frequency Shift

The three shifts (frequency distances between the four frequencies) may be configured arbitrarily, they need not have the same value (equidistant frequencies) or even be symmetrical (the outer two shifts, f_1 to f_2 and f_3 to f_4 , equal). In any case the center frequency is defined as the distance of the inner two frequencies (f_2 and f_3 , regardless whether symmetrical relation or not). Standard combinations used more frequently are given in the table in 3.98.1, "General" (item "Shift/tone spacing").

Interleaving

Also, interleaving of the symbols from the two data channels 1 and 2 (figure 3-102, A) into the two transmission channels V1 and V2 may be Word (W, B), Character (C, C), Bit (B, D) interleaving or even not interleaved at all (E). W interleaving means that the first three characters to transmit are taken from channel 1 and the second three from channel 2, C interleaving splits the channels character by character, B interleaving alternately takes one bit from each channel. Not interleaved means just one channel to be transmitted (the bits extracted serially).



Fig. 3-102: Interleaving with TWINPLEX-SITOR.

- A = Two independent data channels 1 and 2
- B = Two transmission channels V1 and V2, word-interleaved
- C = character-interleaved
- D = bit-interleaved
- E = not interleaved (only one data channel)

Dibit-Frequency-Arrangement

Theoretically 24 combinations might be established to arrange the dibits to the four frequencies, most stations (cf [figure 3-101](#) example), however, work for channel V1 with the combination

- **Y-Y-B-B (1-1-0-0)**

and for channel V2 with the combination

- **Y-B-Y-B (1-0-1-0)** (erect) or
- **B-Y-B-Y (0-1-0-1)** (inverted).

Frequencies used for the dibits resulting from that can be seen from [table 3-54](#).

Table 3-54: Frequency allocation to dibit.

Channel		Allocation if channel V2 is							
		erect				inverted			
		f_1	f_2	f_3	f_4	f_1	f_2	f_3	f_4
V1	Y-Y-B-B (1-1-0-0)	Y (1)	Y (1)	B (0)	B (0)	Y (1)	Y (1)	B (0)	B (0)
V2	Y-B-Y-B (1-0-1-0)	Y (1)	B (0)	Y (1)	B (0)	B (0)	Y (1)	B (0)	Y (1)

In [table 3-55](#) the six basically different so-called modes (variations to combine the dibits with the modulation frequencies) are given together with the name of each mode. Note that all of the other 18 possible combinations emerge from the shown 6 by inverting one or both of the sidebands. The situation depicted in [table 3-54](#), thus, represents mode F7B-1.

Table 3-55: Frequency combinations.

Name of Mode	Channel V1	Channel V2	f_1	f_2	f_3	f_4
F7B-1	Y-Y-B-B	Y-B-Y-B	Y-Y	Y-B	B-Y	B-B
F7B-2	Y-Y-B-B	Y-B-B-Y	Y-Y	Y-B	B-B	B-Y
F7B-3	Y-B-Y-B	Y-Y-B-B	Y-Y	B-Y	Y-B	B-B
F7B-4	Y-B-Y-B	Y-B-B-Y	Y-Y	B-B	Y-B	B-Y
F7B-5	Y-B-B-Y	Y-Y-B-B	Y-Y	B-Y	B-B	Y-B
F7B-6	Y-B-B-Y	Y-B-Y-B	Y-Y	B-B	B-Y	Y-B

Idle State

In idle state (no traffic), TWINPLEX stations just key the two inner frequencies f_2 and f_3 (or during incorrect acknowledgment from the remote station).

3.99 UMTS

3.99.1 General

Transmission method	UMTS
Explanation of name	U niversal M obile T elecommunications S ystem
Other designations	
Variants existing	Open standard, subject to regular enhancement work
Derived from method	So-called 3rd generation standard for mobile telecommunications, thus derived from 2nd generation predecessors such as GSM
Typical users	
Kind of data	Services offered (examples only): • Telephone (audio and video) • Unified Messaging • Internet access • Personal navigation via GPS • Process management • E-Commerce, monitoring • Television (DVB-H)
Reference to standard	Plenty of separate standards; examples for getting started: ETSI TS (Technical Specification) 125 201: "<i>Universal Mobile Telecommunications System (UMTS); Physical layer - general description</i>" ETSI TS 125 213: "<i>Universal Mobile Telecommunications System (UMTS); Spreading and modulation (FDD)</i>" ETSI TS 125 223: "<i>Universal Mobile Telecommunications System (UMTS); Spreading and modulation (TDD)</i>"
Frequency band	UHF: e.g. in the EU • 1900 MHz to 1920 MHz (TDD) • 1920 MHz to 1980 MHz (FDD uplink) • 2010 MHz to 2025 MHz (TDD) • 2110 MHz to 2170 MHz (FDD downlink)
Modulation method	PSK 4, PSK 8, QAM 16, QAM 64
Shift/tone spacing	
Baud rate	Chip rate (due to CDMA technique): 3.84 Mchip/s (data rate 384 kbit/s max., even more with HSPA [High Speed Packet Access])
Modulating subcarrier	
Bandwidth	5 MHz for each carrier
Operating method	TDMA , FDMA , CDMA
Data protection	Intra and inter frame interleaving, channel coding (convolutional codes with code rate 1/2 or 1/3, turbo codes with code rate 1/3 or no channel coding)
Code table	

3.99.2 History

Originating from mobile communications systems like [GSM](#), the so-called 2nd generation ([2G](#)) systems, already in the eighties activities began, under the overall control of the [ITU](#), to develop and establish systems of a 3rd generation ([3G](#)). Requirements emerging with that were:

- worldwide harmonization of mobile communications standards
- operation in the same frequency band all over the world
- usage of applicable frequency band as efficient as possible
- universal options for use
- wide range of services (speech, data, multimedia, video)
- high data rates (up to 2 Mbit/s) and good quality of services
- compatibility to existing and, if possible, also future networks, especially fixed network, 2nd generation and competitive 3rd generation mobile networks.

In Europe, several research projects were initiated by the European Union which then generated various system proposals. These, in 1997, were presented to the [ETSI](#) to be audited; the ETSI selected two of the proposals to, after having elaborated and harmonized them, submit them to the ITU as the Universal Mobile Telecommunications System (UMTS).

Today, UMTS is subject to a continuous process of further development and enlargement; this is supervised and encouraged by the [3GPP](#) (the 3rd Generation Partnership Project), consisting of several organizational partners of the [EU](#), the [U.S.A.](#), Japan, Korea and China.

3.99.3 Description

UMTS, like [GSM](#), is a mobile telephone system, but, in contrast to it, is also capable to handle a variety of additional digital data or other services (like Internet or [TV](#)). A first, coarse division can be done into the

- **radio subsystem** and the
- **switching subsystem.**

The switching subsystem can be considered to follow similar concepts (architecture and protocols) as with GSM, whereas the radio subsystem introduces some completely new approaches, one of the most remarkable of which being the [CDMA](#) access method. Two discrete modes of transmission have been specified (due to the two proposals having been selected, see [3.99.2, "History"](#)), the

- **Frequency Division Duplex** (FDD) mode and the
- **Time Division Duplex** (TDD) mode.

Find more details about operating modes in [3.99.3.3, "Operating Modes"](#).

3.99.3.1 Architecture

In [figure 3-103](#) an overview of the basic architecture of UMTS is shown, together with a schematic of an imaginary GSM system. As known from there, a segmentation can be done into

- user equipment domain
- access network domain
- core network domain

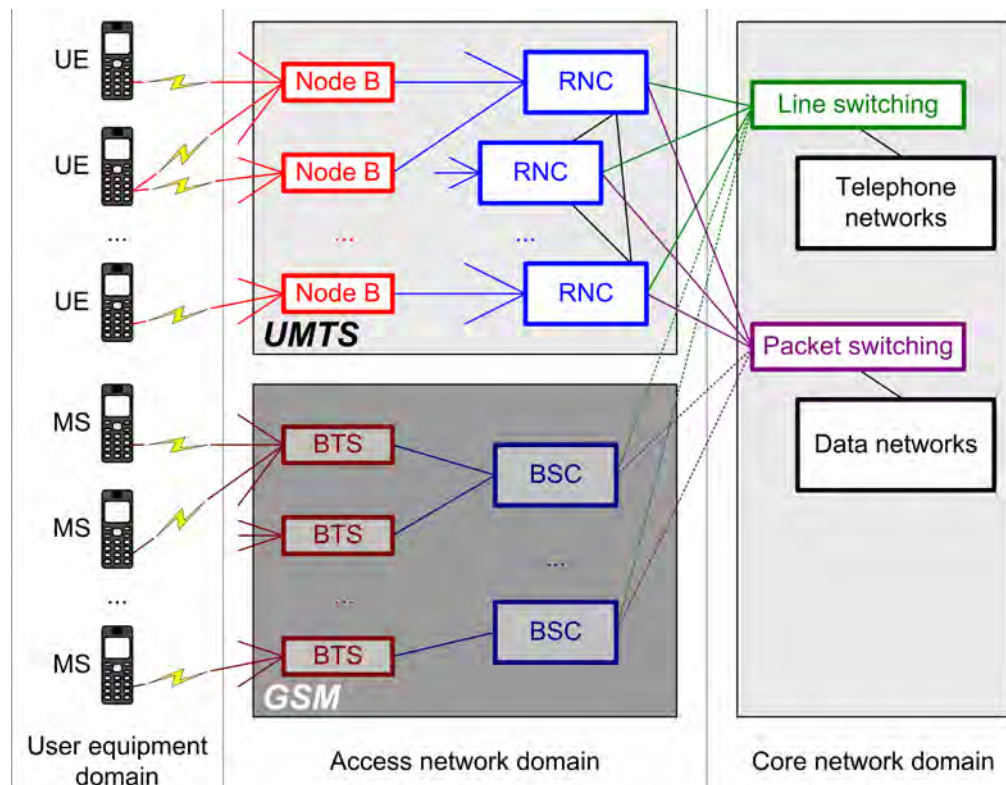


Fig. 3-103: Basic UMTS architecture compared to GSM.

UE = User Equipment
 MS = Mobile Station
 RNC = Radio Network Controller
 BTS = Base Transceiver Station
 BSC = Base Station Controller

Following the intention of this book to describe preferentially the radio aspects, a detailed examination of the core network will not be done here.

In order not to confuse items relating or corresponding to each other in the two systems, some new designations and acronyms have been introduced with UMTS. The "former" MS (Mobile Station) is now called UE (User Equipment) – mind in this context that both do not only consist of the mobile terminal itself but also of the [SIM](#) (Subscriber Identity Module), now USIM (UMTS SIM), inserted to it –, the BTS (Base Transceiver Station) "Node B" and the BSC (Base Station Controller) RNC (Radio Network Controller). A lot of other abbreviations exist not being dealt with in this short summary.

The two most notable differences in the access network are:

- A user mobile phone can be linked to more than one Node B (base station) at a time to be able to perform power measurements of concurrent cells at a specific location (only one BTS with GSM).
- The RNCs (BSCs) establish connection to ongoing services of the core network, making use of either line switching (for direct connections between users) or packet switching equipment (for exchange of data not in need of a direct connection).

As before, the RNCs (BSCs) establish connection to ongoing services of the core network, making use of either line switching (for direct connections between users) or packet switching equipment (for exchange of data not in need of a direct connection).

In [figure 3-104](#) another, compared to GSM, new feature of UMTS is depicted: Based on the CDMA technique, even neighbored network cells (called macro cells) may be fed with the same carrier frequency, and additionally, for locations (spots) with high emergence of data traffic, special sub-cells (micro cells) can be constructed to satisfy such needs. These micro cells have to be operated at a different carrier frequency in order not to cause perturbation to the traffic of the superordinate macro cell. Cells 1, 2 and 3, for example, are supplied by just one cell tower (and one frequency), whereas in cell 2 three micro cells *a1*, *a2* and *a3* exist that also can be operated at a frequency equal to each other, but different from the one of the macro cell.

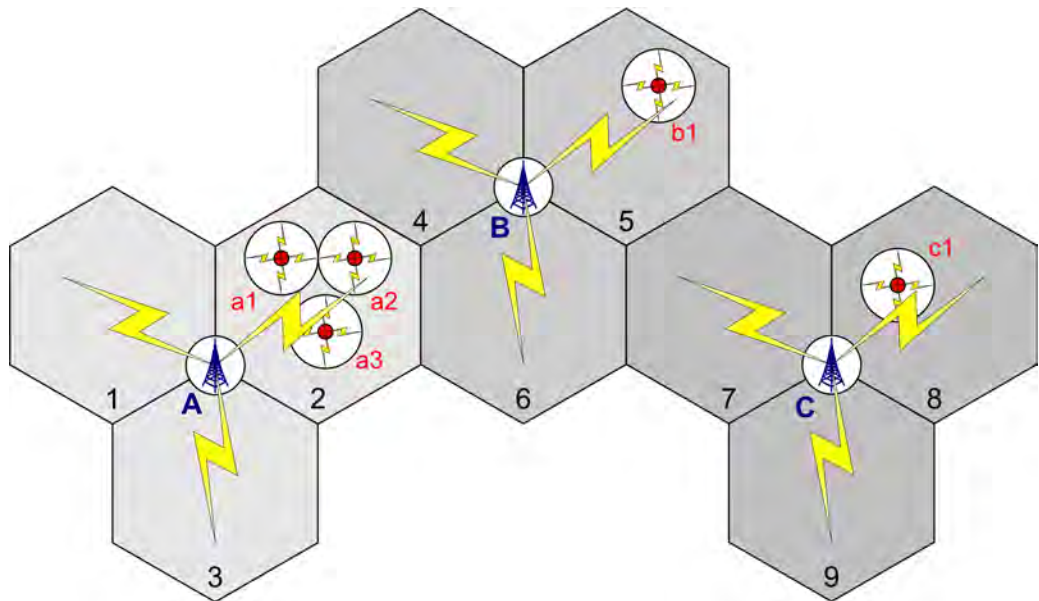


Fig. 3-104: Symbolic cell structure with UMTS.

1 to 9 = Macro cells
A, B, C = Cell towers feeding 3 macro cells each
a1, a2, a3, b1, c1 = Micro cells

3.99.3.2 Frequency Band

The situation concerning the frequency bands used for UMTS in the various countries of the world gives a rather confusing impression; frequencies used for GSM (2G) in one country may be in use for 3G in another country. In [figure 3-105](#) the situation in the EU is shown:

- The FDD operation mode rigorously separates in frequency the two directions of communicating, uplink (UE to Node B) and downlink (Node B to UE), as also known from GSM. A carrier frequency for uplink is strictly associated to one for downlink (paired carrier frequencies). The FDD uplink frequencies, bandwidth 5 MHz each, cover the frequency range from 1920 MHz to 1980 MHz, thus delivering a count of 12 frequencies. The corresponding downlink frequencies range from 2110 MHz to 2170 MHz, resulting in a duplex distance of 190 MHz each. FDD is a mode especially suitable for "symmetric" traffic (similar extent of data appearance in both directions like telephone conversations).
- Seven 5 MHz carriers are scheduled for TDD operation, i.e. no separation of uplink and downlink takes place, thus no pairing of frequencies is needed. Four of these carriers are placed from 1900 MHz to 1920 MHz, the remaining three from 2010 MHz to 2025 MHz. Because each individual TDD carrier can be arbitrarily partitioned into uplink and downlink portions, the mode is best suited for "asymmetric" traffic as Internet usage, mobile TV etc.



Fig. 3-105: UMTS frequency range.

3.99.3.3 Operating Modes

Frequency Spreading and CDMA

New with UMTS in comparison to 2G systems as GSM is the addition of the code multiplex (CDMA) technique to the frequency multiplex (FDMA) and time multiplex (TDMA) methods remaining still in use.

In simple words (find detailed information in relevant literature), the original data signal (ready to send anyway, this means, already stuffed with channel coding bits, interleaving performed etc.) is multiplied by a code signal of a strikingly higher bit rate, resulting in a target signal of this bit rate. The transmitting power will be spreaded over a far wider frequency range (called frequency spreading) and thus reduced by the same factor in the frequency range of the originating data signal. When using suitable code signals (so-called pseudo noise sequences, scrambling codes or orthogonal [OVSF] codes), several coded data signals can directly be added and emitted; the receivers can separate the signals (more precisely: select the one destined to them) by again multiplying the incoming signal by "their" individual code (having been told them in advance: the same as, for this signal, on the Tx side). A prerequisite for all that is that the individual signals to be added are present in alike amplitude levels.

To avoid confusions between the bits of the original data signal and the ones of the spreading/spreaded code signal, the latter are called chips; the chip rate with UMTS is 3.84 Mchip/s. Data rates achievable this way, due to Doppler shift, range from 2 Mbit/s

(quasi-stationary within buildings) over 384 kbit/s (urban surroundings with slow motion of users [pedestrians]) downward to 144 kbit/s (fast cars).

FDD

The FDD operation mode situation shows [figure 3-106](#): Two frames in time of 10 ms length each (see [3.99.3.4, "Frame Structure"](#)) are outlined from left to right, commonly furthermore divided in 15 time slots of therefore $10 \text{ ms}/15 = 666.667 \mu\text{s}$. Again mind in this context that time slots do not serve for housing (separating) individual connections (link channels) in a TDMA style as with GSM, but for a fast exchange of information (arranged in logical channels) for control of links established or to establish. The different link channels are represented by the "added" code signals, shown in the vertical dimension (see [section "Frequency Spreading and CDMA"](#)), and also by the individual carriers, i.e. frequency channels, from front to back. Everything shown in the picture describes either only downlink or only uplink data, due to frequency pairing with FDD.

As an example, the "yellow" signal might have ended with the first slot, whereas the "red" and "orange" ones vary in their original data rate, entailing that the frequency spreading factor and therefore the energy of the signal over the slots also vary.

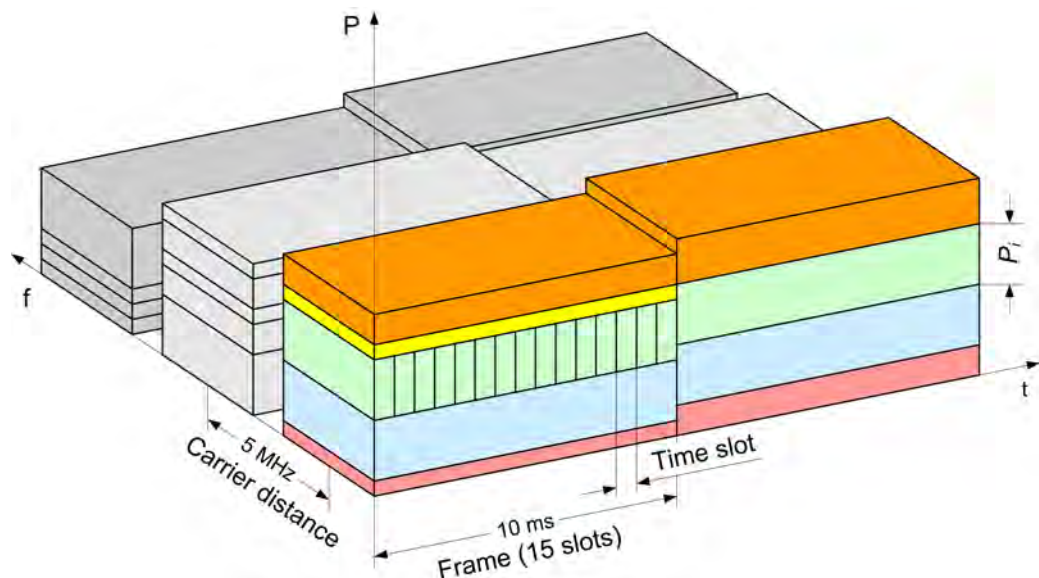


Fig. 3-106: Schematic of FDD operation mode.

P = Emitted power

P_i = Emitted power of individual CDMA channel

TDD

Find an example for a TDD scenario in [figure 3-107](#): Again, frames and slots in time as well as 5 MHz wide frequency carriers exist, but now no separating of uplink and downlink by distant frequency bands, this is, any time slot may arbitrarily be assigned to a discrete link connection in either uplink or downlink direction as required at the moment. This features a versatile handling of heavily asymmetric traffic (more to transmit in the one than in the other direction). Each time slot may accommodate 16 CDMA channels max.; the "red" channels (as an example) show, as in [section "FDD"](#), data streams of deviating bit rate. All other coloring has been done just to grant a better visi-

bility ("green" only to the optically "uppermost" channels, "blue" with no special significance).

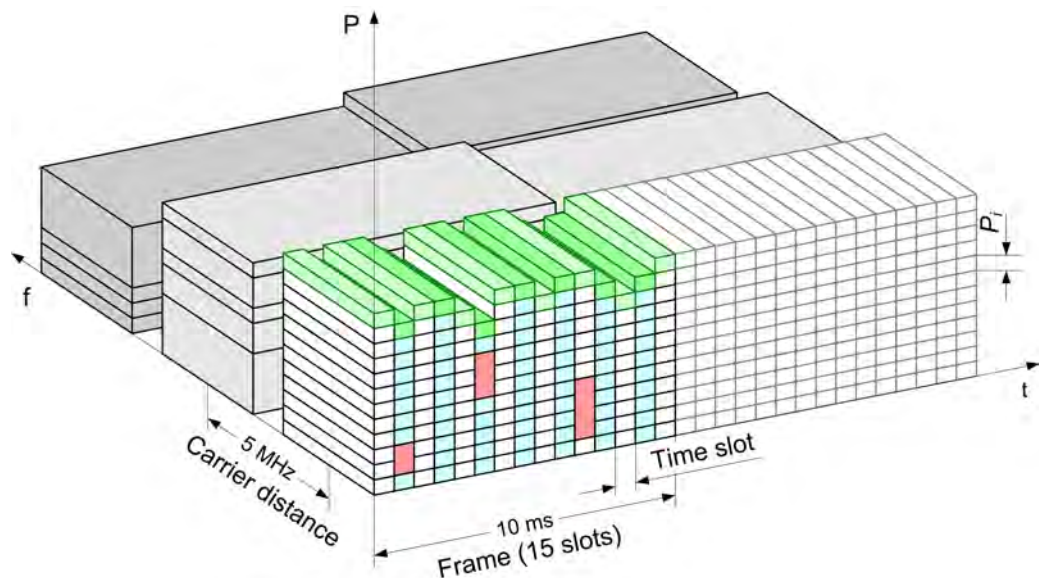


Fig. 3-107: Schematic of TDD operation mode.

3.99.3.4 Frame Structure

In figure 3-108 an example is given for the frame structure (again, detailed information can be looked up in relevant publications such as the basic standards). The basic frame of 10 ms (A) is structured into 15 timeslots each of which inalterably consists of 2560 chips (section "Frequency Spreading and CDMA"). It therefore depends on the originating data rate of the channel to transmit how deeply the data are to be spread.

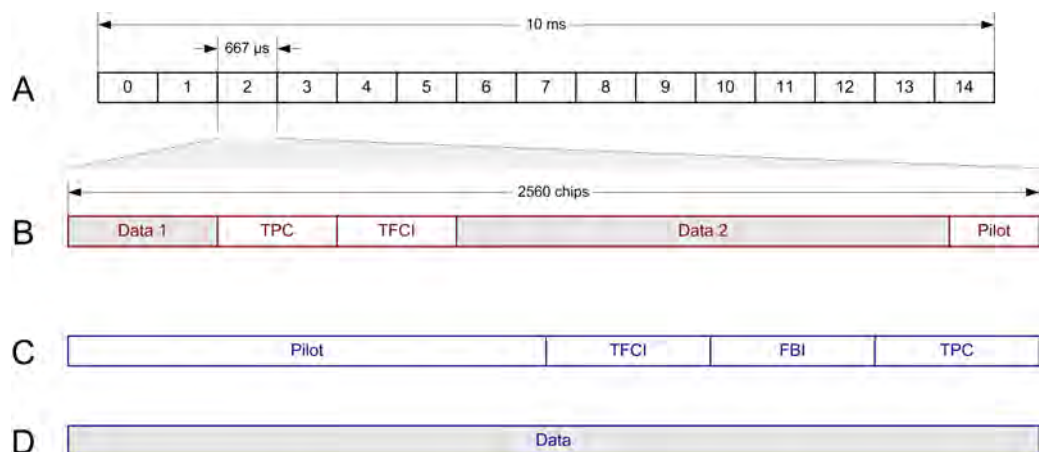


Fig. 3-108: Frame structure.

- A = Frame
- B = Timeslot with example Dedicated Channel (downlink) containing data and control information
- C = Timeslot with example Dedicated Channel (uplink) containing control information
- D = Timeslot with example Dedicated Channel (uplink) containing data information

TPC = Transmission Power Control
 TFCI = Transport Format Combination Indicator
 FBI = Feedback Information

Examples shown are for the so-called Dedicated Channel. In downlink direction (**B**) procedure to treat the data before transmitting is

1. Conflate 2 bits to 1 symbol.
2. Spread with an OVSF code specific to connection.
3. Spread with a scrambling code specific to cell.
4. Pulse forming and PSK4 modulation.

In uplink direction (**C** for control information word, **D** for plain data word)

1. Spread with an OVSF code specific to connection.
2. Spread with a scrambling code issued to UE.
3. Pulse forming and PSK4 modulation.

See the situation summarized in [table 3-56](#).

Table 3-56: Data rates and spreading factors in downlink and uplink.

Data rate [kbit/s]	Bits/slot	Downlink		Uplink
		Symbols/slot	Spreading factor	
15	10	5	512	256
30	20	10	256	128
60	40	20	128	64
120	80	40	64	32
240	160	80	32	16
480	320	160	16	8
960	640	320	8	4
1920	1280	640	4	(n.a.)

3.100 VDEW

3.100.1 General

Transmission method	VDEW
Explanation of name	German institution " V ereinigung D eutscher E lektrizitäts W erke e.V." (Union of German Power Companies)
Other designations	
Variants existing	
Derived from method	
Typical users	Selective call and data transmission in the non-public mobile land radio service
Kind of data	
Reference to standard	DIN (D eutsche I ndustrie N orm / German Industry Norm) 45013 (until 1992)
Frequency band	VHF/UHF
Modulation method	MSK (FFSK) (1200 Hz = '1', 1800 Hz = '0'), indirekt FM
Shift/tone spacing	600 Hz
Baud rate	1200 Bd (1200 bit/s)
Modulating subcarrier	1500 Hz
Bandwidth	12.5 kHz
Operating method	Simplex
Data protection	FEC (CRC)
Code table	BCD

3.100.2 Description

VDEW and ZVEI (see [chapter 3.102, "ZVEI"](#), on page 320) are digital selective calling systems defined for selective call and data transmission in the non-public mobile land radio service. On the physical layer (data telegrams, transmission speed, modulation method etc.), both systems are identical, but the VDEW system has added some special features to the ZVEI system due to extended requirements.

Data are transmitted in telegrams consisting of frames of 64 bits (32 bits user data):

- in VDEW, it is possible to convey longer call numbers by dividing the number into more than one frame
- in ZVEI, telegrams have a fixed length

Up to four telegrams can be concatenated (the basic telegram [Grundtelegramm] is followed by one or more follow-up telegrams [Folgetelegramm]), controlled by the BAK

frame (**B**etriebs**A**rten**K**ennung / operation mode key). By means of the BAK the decoder detects whether it is a VDEW message with follow-up telegrams or a ZVEI telegram without.

3.100.3 Channel Coding/Structure of Data Blocks

A data frame consists of 64 bits. After a carrier pre-keying, an 8-bit telegram preamble and a 15-bit Barker sequence follow. 32-bit user data is protected by 8-bit redundancy.

In VDEW, telegram length is open:

- [CRC](#)
- BAK (**B**etriebs**A**rten**K**ennung / operation mode key)
- EVU (**E**nergie**V**ersorgungs**U**nternehmen / electric utility)
- Data Count
- one or more frames (indicated by "Data Count") containing the Call Number; the Call Number is represented in [BCD](#) code

3.101 WLAN (IEEE 802.11)

3.101.1 General

Transmission method	WLAN		
Explanation of name	Wireless Local Area Network		
Other designations	Wi-Fi® (trademark name, not an acronym, but play on audiophile term <i>Hi-Fi</i> [High Fidelity]) IEEE 802.11 802.11		
Variants existing	0) IEEE 802.11 a) IEEE 802.11a	b) IEEE 802.11b g) IEEE 802.11g	n) IEEE 802.11n and others
Derived from method			
Typical users			
Kind of data			

Transmission method	WLAN
Reference to standard	0) IEEE Std 802.11: "IEEE Standard for Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications" a) IEEE Std 802.11a: "High-speed Physical Layer in the 5 GHz Band" b) IEEE Std 802.11b: "Higher-Speed Physical Layer Extension in the 2.4 GHz Band" g) IEEE Std 802.11g: "Amendment 4: Further Higher Data Rate Extension in the 2.4 GHz Band" n) IEEE Std 802.11n: "Amendment 5: Enhancements for Higher Throughput"
Frequency band	0), b), g), n) UHF: 2.4 GHz to 2.4835 GHz a), n) SHF: 5.15 GHz to 5.725 GHz
Modulation method	0) - FHSS variant: GFSK - DSSS variants: PSK: PSK2, PSK4 a) OFDM: PSK: PSK2, PSK4; QAM: QAM16, QAM64 b) DSSS (like 0)) g) - OFDM (like a)) - DSSS (like 0)) n) OFDM (like a))
Shift/tone spacing	0) FHSS: 110 kHz (all others: not defined)
Baud rate	Raw data rate (max.): 0) 2 Mbit/s: 1 and 2 b) 11 Mbit/s: 1, 2, 5.5 and 11 a) 54 Mbit/s: 6, 9, 12, 18, 24, 36, 48 and 54 g) 54 Mbit/s: like a) n) 150 Mbit/s per spatial stream (4 max., thus 600 Mbit/s) (Bw Bandwidth, GI Guard Interval): - Bw 20 MHz, GI 800 ns: 6.5, 13, 19.5, 26, 39, 52, 58.5, 65 - Bw 20 MHz, GI 400 ns: 7.2, 14.4, 21.7, 28.9, 43.3, 57.8, 65, 72.2 - Bw 40 MHz, GI 800 ns: 13.5, 27, 40.5, 54, 81, 108, 121.5, 135 - Bw 40 MHz, GI 400 ns: 15, 30, 45, 60, 90, 120, 135, 150
Modulating subcarrier	with OFDM (a), g), n)): 52 carriers, 312.5 kHz distance (20 MHz/64)
Bandwidth	0) 22 MHz b) 22 MHz n) 20 MHz, 40 MHz a) 20 MHz g) 20 MHz
Operating method	FHSS, DSSS, OFDM
Data protection	0), a) FEC (convolutional coding with code rate 1/2, 2/3, 3/4) b), g) CCK, optionally FEC (rate 1/2) n) FEC (rate 1/2, 2/3, 3/4, 5/6)
Code table	

3.101.2 History

The origin of IEEE 802.11 (in the following called 802.11) can be seen in an FCC ruling of 1985 that released the ISM bands for unlicensed use. As a predecessor, in 1991 NCR Corporation/AT&T (now Alcatel-Lucent and LSI Corporation) invented a wireless

technology intended to be used in cashier systems (then called WaveLAN and with data rates of 1 Mbit/s and 2 Mbit/s).

The IEEE in 1997 edited the first (today superordinate) standard 802.11 (3.101.3.4) specifying therein the MAC (Media Access Control) and PHY (physical) layers of the OSI model of abstraction layers. The PHY layer offered two spread spectrum methods, FHSS (Frequency-Hopping Spread Spectrum) and DSSS (Direct Sequence Spread Spectrum), for radio communications and a data transmission method for transfer by infrared light. Maximum gross (raw) bit rate to be achieved was 2 Mbit/s, the radio band to be used the (license-free) 2.4 GHz band. Two amendments followed in 1999: 802.11a (3.101.3.5) working with the 5 GHz band and facilitating a data rate of up to 54 Mbit/s, and 802.11b (3.101.3.6) getting along with the 2.4 GHz band already in use and enabling 11 Mbit/s. In 2003, 802.11g (3.101.3.7) raised the data rate to 54 Mbit/s, but in the 2.4 GHz band, and in 2009 802.11n (3.101.3.8) altered the frequency bands used and newly arranged the channels, thus promising data rates of up to 600 Mbit/s.

In 1999, the *Wi-Fi Alliance* was formed as a trade association to hold the *Wi-Fi*® trademark under which most products are sold.

3.101.3 Description

3.101.3.1 Overview

IEEE 802.11 is a class of standards defining a radio network to connect computers via Internet, similar to Ethernet for wired connections and based on that. It by now is the most widespread network of this type, simply said: for wireless applications the counterpart to Ethernet.



Nomenclature

Often the terms "WLAN" and "(IEEE) 802.11" are mixed. Mind that "WLAN" is the general hypernym for any kind of wireless local network, but "802.11" is a standard describing an individual technical solution – other solutions might also exist for that, even though 802.11 is the most common one.

Before 1997, the introduction of 802.11, a wide employment of wireless computer communication was inconceivable due to too slow data rates because of missing standardization. The various standards of 802.11, based on other 802 standards (e.g. 802.3: Ethernet), describe the physical layers of the OSI reference model in view of radio transmission, but without expecting particular protocols (protocol transparent), thus allowing to incorporate wireless network boards without further hindrance in any existing Ethernet, also, for example, to substitute wired applications by wireless ones.

As seen from the perspective of the user the most important item on that is the net data rate (the amount of user data – this is, excluding any additional expense for data protection – being transmitted in a definite time). The continually desired enhancement of this rate repeatedly raised amendments to the original standard 802.11, thereby having to respect as far as possible compatibility requirements to the standards/

amendments already existing. An overview of the standards covered here and the user data rates achievable by them can be found in [table 3-57](#). Mind that these data rates in practice commonly will not be reached, as both local conditions (quality of radio connection, walls, other networks concurrently active) set limits and, with multiple users, maximum rate will be partitioned to them. Other limitations arise by compatibility requirements (users active according to another standard can reduce the data rate actually possible with the current one).

Table 3-57: Frequency bands and data rates with 802.11.

Standard	802.11	802.11a	802.11b	802.11g	802.11n
Frequency band	2.4 GHz	5 GHz	2.4 GHz	2.4 GHz	2.4 GHz, 5 GHz
Gross data rate	2 Mbit/s	54 Mbit/s	11 Mbit/s	54 Mbit/s	150 to 600 Mbit/s
Net data rate	0,5 to 1 Mbit/s	up to 32 Mbit/s	1 to 5 Mbit/s	2 to 16 Mbit/s	up to 200 Mbit/s

3.101.3.2 Frequency Bands

Data transmission with 802.11 happens in two frequency bands both of which can be made use of without license, a band at 2.4 GHz (called **ISM** band: Industrial, Scientific, Medicine) and the other at 5 GHz. Fees therefore are not due for private use, but the bands, especially the 2.4 GHz band, are utilised rather intensively – not least the most common frequency of microwave ovens is situated at 2.455 GHz.

The situation for the 2.4 GHz band is shown in [figure 3-109](#). Originally the band is divided into 5 MHz wide channels (**A** in the figure; the illustration on the right highlights center and border frequencies of the leftmost channel in more detail, mind the overlapping of the 2.4 GHz frequency border). Channels eligible for WLAN use are shown in green, in grey the additionally presented.

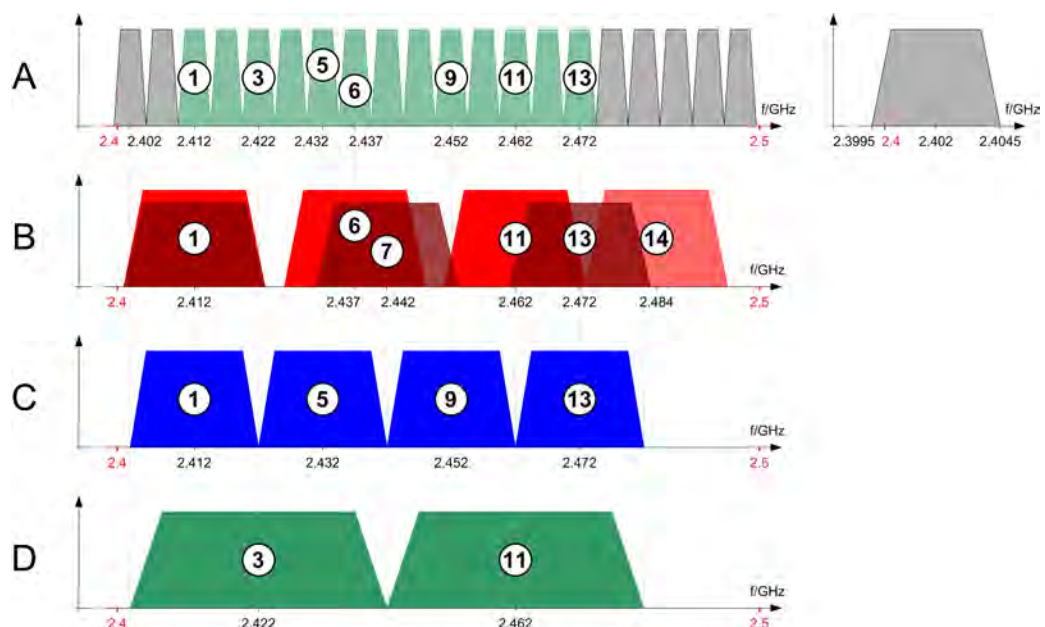


Fig. 3-109: Channel allocation in the 2.4 GHz band.

A = 5 MHz channels (green: defined and numbered [not all numbers shown]; grey: imaginary)
 B = 22 MHz channels (802.11b: DSSS)
 C = 20 MHz channels (802.11g, n: OFDM)
 D = 40 MHz channels (802.11n: OFDM)

Arrangement in 22 MHz wide channels for DSSS according to 802.11b (**B**, 3.101.3.6) can be done in two ways: channels 1–6–11 (light red, common in the U.S.A., as channels 12 and 13 are not opened to WLAN over there) or 1–7–13 (dark red, common in Europe), this is, 3 WLAN base stations may be operated in parallel in each case.

(Channel 14 being out of line is only relevant in Japan.) Operating mode OFDM with 802.11g (3.101.3.7) and 802.11n (3.101.3.8) uses a channel bandwidth of 20 MHz (**C**; see also figure 3-110, bottom), leading to arrangement 1–5–9–13 (4 WLAN stations), or, with 802.11n only, 40 MHz (**D**) with arrangement 3–11 (2 WLAN stations).

In the 5 GHz band (figure 3-110), originally also divided into 5 MHz wide channels, likewise always 4 channels are combined to one 20 MHz channel; an example is shown in the top left illustration for channel 48. On the right the channels approved (red) and excluded (grey) in Europe are depicted; numbering follows the original 5 MHz arrangement. Used for WLAN may be all 19 channels (36 to 64 and 100 to 140), but, for example, channels 120, 124 and 128 are used also by the weather Radar. Thus, all channels above channel 48 may only be included if the WLAN base station is capable to recognize channels occupied by other radio services at the moment and to avoid them by channel alteration (Dynamic Frequency Selection, DFS) and also to limit emitted power (Transmitter Power Control, TPC).

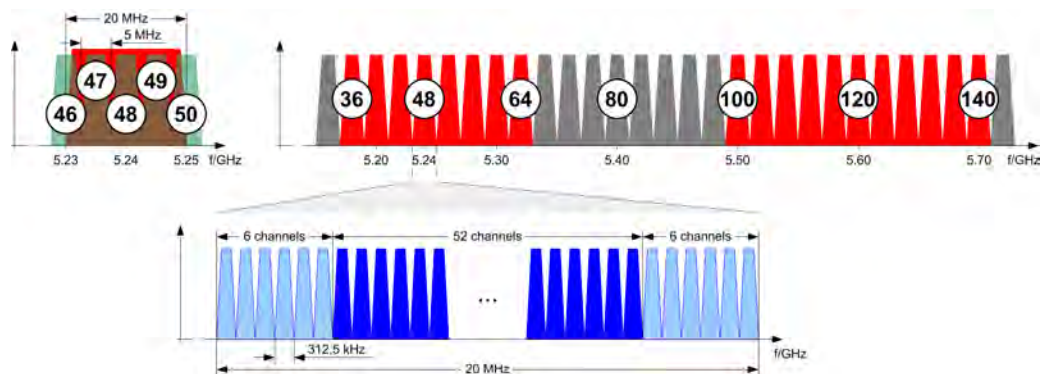


Fig. 3-110: Channel allocation in the 5 GHz band.

top, left = 20 MHz channel (channel #48 as an example) combined from four 5 MHz channels
 top, right = 20 MHz channels in use in the EU (shown in red)
 bottom = subcarriers within a 20 MHz channel: 52 used channels (center), 12 protection channels (left and right)

The bottom illustration depicts segmentation of each 20 MHz channel into 64 subcarriers (width $20 \text{ MHz}/64 = 312.5 \text{ kHz}$ each), the left and right 6 of which form the protective distance to the adjacent channel and the central 52 are utilized for data transmission.

3.101.3.3 Frame Structure

An overview of the frame structure can be seen from figure 3-111. Shown is an example with the surrounding PLCP (Physical Layer Convergence Protocol) overhead, but

be aware that, due to multitude of variants or compatibility to past versions, also differing formats may exist, a detailed description of which exceeds objective of this manual.

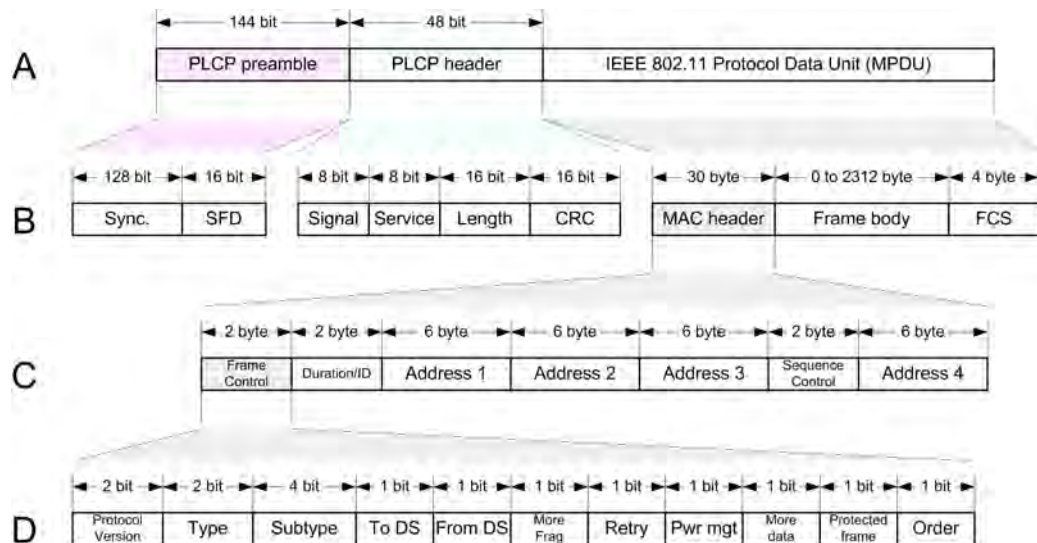


Fig. 3-111: IEEE 802.11 frame structure (example).

A = General PLCP frame architecture

B = PLCP preamble (left), PLCP header (center), MPDU (right)

C = MAC header

D = Frame Control field

The general PLCP frame (**A** in the figure) consists of the *PLCP preamble*, the *PLCP header* and the *MPDU* (Media access control Protocol Data Unit). PLCP preamble (**B**, left) and header (**B**, center) are emitted using a fixed bit rate, e.g. 1 Mbit/s or 2 Mbit/s. The PLCP preamble is composed of a synchronization signal (usually made up of alternating '1's and '0's) showing to the receiver that a Tx signal is present at all, followed by the *Start Frame Delimiter* (SFD) telling the start of the frame. The PLCP header gives the data rate of the MPDU (*Signal* field), some arbitrary information (*Service* field) and the length of the MPDU (*Length* field), a *CRC* field for error detection concludes the PLCP section.

The actual 802.11 data (frame) to exchange comes in the MPDU (right), consisting of the *MAC header*, the *frame body* containing the payload data (e.g. IEEE 802.3/Ethernet format for wired Internet) and again a *frame check sequence* (FCS) error detection field, but checking only the MAC header (not the frame body).

The MAC header (**C**) falls into the *Frame Control* field, a *Duration* field, the four *Address* fields 1 to 4 that can contain various address information, such as source and destination addresses or receiving and transmitting station addresses, and a *Sequence Control* field. Find detailed information on these fields and also on the individual fields of the Frame Control section (**D**) in the basic [standard](#).

3.101.3.4 IEEE 802.11

IEEE 802.11 (precisely: IEEE 802.11-1997 or IEEE 802.11-1999, respectively), sometimes also called legacy mode, is the original version of the IEEE 802.11 wireless net-

working standard. Most of the protocols described by this early version are rarely used today.

The two raw data rates of 1 Mbit/s and 2 Mbit/s had been specified, applying to transmissions, on the one hand, by infrared (IR) signals or, on the other hand, by either frequency hopping (FHSS) or direct-sequence spread spectrum (DSSS). The frequency band to be used was the 2.4 GHz band (ISM band, see 3.101.3.2). Today, 802.11 is considered obsolete and applications meanwhile replaced by advanced implementations according to the amendments (3.101.3.5 to 3.101.3.8). IR still remains a part of the standard but has no actual implementations known.

The original standard also defines a CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) feature as the medium access method. As a result, a significant portion of the available raw channel capacity is sacrificed to improving the transmission reliability under diverse, mainly adverse environmental conditions.

A weakness of the 802.11 original specification was the offer of many choices making interoperability turn out challenging to realize. Hence, it appears more a "beta" than a rigid specification, individual product vendors attained the flexibility to differentiate their products with it, but inter-vendor operability was not to be reached. Thus, the DSSS fraction of 802.11 was rapidly supplemented (and popularized) by the 802.11b amendment (3.101.3.6), which increased the bit rate to 11 Mbit/s; only after its release widespread adoption of 802.11 networks occurred, resulting in multiple interoperable products becoming available from multiple vendors. Before, comparatively few networks had been implemented on plain 802.11.

3.101.3.5 IEEE 802.11a

The IEEE 802.11a amendment (precisely: IEEE 802.11a-1999) to the original standard IEEE 802.11 (3.101.3.4) uses the same core protocol, but operates in the 5 GHz band with a 52-subcarrier orthogonal frequency-division multiplexing (OFDM) yielding a maximum raw data rate of 54 Mbit/s. Realistic net data throughput is about 20 Mbit/s.

Out of the 52 subcarriers available (see figure 3-110, bottom), 48 are used for data transmission and the remaining 4 as pilot signals, find count and numbering information in table 3-58. Modulation rate for each carrier is 250 kHz, delivering the raw rate of 6 Mbit/s over all 48 carriers (find details about calculating in the basic standard). All (raw) data rates defined and modulation and coding parameters of each rate can be seen from table 3-59.

Table 3-58: Subcarrier use in 802.11a.

Kind ¹⁾	D	P	D	P	D	P	D	P	D	
Number	-26 to -22	-21	-20 to -8	-7	-6 to -1	1 to 6	7	8 to 20	21	22 to 26
Count	5	1	13	1	12	1	13	1	5	

¹⁾ D data, P pilot

Table 3-59: Defined raw data rates.

Raw rate [Mbit/s]	6	9	12	18	24	36	48	54
Modulation (Bits/symbol)	PSK2 (1)		PSK4 (2)		QAM16 (4)		QAM64 (6)	
Bits per OFDM symbol	48		96		192		288	
Code rate	1/2	3/4	1/2	3/4	1/2	3/4	2/3	3/4
Usable data bits	24	36	48	72	96	144	192	216

Use of the 5 GHz band is a significant advantage of 802.11a due to the heavy usage of the 2.4 GHz band to the point of being crowded. Even though the effective overall range of 802.11a is slightly less than that of 2.4 GHz systems (signals are absorbed more readily by walls and path loss in signal strength is more rapid), the near absence of other interfering systems (microwave ovens, cordless phones, baby monitors) caused a wide spreading of 802.11a equipment.

3.101.3.6 IEEE 802.11b

The IEEE 802.11b amendment (precisely: IEEE 802.11b-1999) operates, as the IEEE 802.11 (3.101.3.4) original, in the 2.4 GHz band, but extends throughput up to 11 Mbit/s. (This specification is marketed as *Wi-Fi*® and has been implemented all over the world, compare 3.101.2.)

The higher rates are achieved by employing the modulation scheme 8-bit CCK (Complementary Code Keying); the chip rate of 11 Mchip/s is the same as with the DSSS system of 802.11, thus providing the same occupied channel bandwidth. The new capability arising from that is called HR/DSSS (High Rate DSSS). Other optional modes specified are

- CCK is replaced by HR/DSSS/PBCC (Packet Binary Convolutional Coding).
- A shorter PLCP preamble is used to significantly increase data throughput at the higher rates, this mode is called HR/DSSS/short or HR/DSSS/PBCC/short. This Short Preamble mode can coexist with DSSS, HR/DSSS or HR/DSSS/PBCC under limited circumstances.
- An optional capability for channel agility allows an implementation to overcome some inherent difficulty with static channel assignments.

Today, 802.11b is regarded obsolete due to insufficient data protection (too poor encryption). Additionally, data throughput lowers if an 802.11b device logs in to an 802.11g (3.101.3.7) or 802.11n (3.101.3.8) access point.

3.101.3.7 IEEE 802.11g

The IEEE 802.11g amendment (precisely: IEEE 802.11g-2003) to the original IEEE 802.11 (3.101.3.4), today also Clause 19 to both the standards IEEE 802.11-2007 and IEEE 802.11-2012, introduces the OFDM modulation scheme into the 2.4 GHz frequency band. It is fully backwards compatible to 802.11b (3.101.3.6) hardware, and details of making both standards work together took many efforts. However, presence of a 802.11b device will significantly reduce throughput of the overall network.

In use is the **CSMA/CA** (Carrier Sense Multiple Access/Collision Avoidance) transmission scheme; it reduces the maximum raw data rate of 54 Mbit/s to a net rate of 31.4 Mbit/s achievable at maximum (in case packets of 1500 byte are transmitted). Modulation is done, as said, in OFDM for data rates of 6 Mbit/s to 54 Mbit/s (cf [table 3-59](#)), for 5.5 Mbit/s and 11 Mbit/s it reverts to CCK and to DSSS for 1 Mbit/s and 2 Mbit/s.

Despite its major acceptance, 802.11g suffers from the same interference by devices operating in the already crowded 2.4 GHz range as 802.11b.

3.101.3.8 IEEE 802.11n

The IEEE 802.11n amendment (precisely: IEEE 802.11n-2009) to the original IEEE 802.11 ([3.101.3.4](#)) tries to unite the features of the past amendments and to add new ones in order to further increase the data rate (at least 100 Mbit/s intended), thereby maintaining backwards compatibility to 802.11a ([3.101.3.5](#)), 802.11b ([3.101.3.6](#)) and 802.11g ([3.101.3.7](#)). 802.11n operates in the 2.4 GHz as well as in the 5 GHz band.

Techniques to accomplish this goal are

- Use of 40 MHz channels (see [figure 3-109](#))
- Antenna groups with **MIMO** (Multiple Input Multiple Output), beamforming
- Spatial multiplexing by STBC (Space Time Block Coding)
- Antenna diversity (use signal of antenna of best reception)
- HT (high throughput) OFDM: improved OFDM to obtain 65 Mbit/s in a 20 MHz channel (802.11g: 54 Mbit/s)
- Frame aggregation (condense several Ethernet frames into one WLAN frame)
- Compressed block acknowledgment (normal block acknowledgment known from 802.11e)
- RIFS (Reduced Inter Frame Spacing)
- Guard interval reduced to 400 ns (other 802.11: 800 ns)
- Greenfield mode (deactivation of support of 802.11a, 802.11b and 802.11g)

Find some information on achievable raw data rates with the several *Modulation and Coding Schemes* defined in [table 3-60](#).

Table 3-60: Modulation and Coding Schemes and raw data rates¹⁾.

Spatial streams		1			2			3			4		
Mod.	Code rate	Data rate [Mbit/s] in case of bandwidth [MHz]; GI 800 ns (top), 400 ns (bottom)											
		<i>I.</i>	20	40	<i>I.</i>	20	40	<i>I.</i>	20	40	<i>I.</i>	20	40
PSK2	1/2	0	6.5	13.5	8	13	27	16	19.5	40.5	24	26	54
			7.2	15		14.4	30		21.7	45		28.8	60
PSK4	3/4	1	13	27	9	26	54	17	39	81	25	52	108
			14.4	30		28.9	60		43.3	90		57.6	120
		2	19.5	40.5	10	39	81	18	58.5	121.5	26	78	162
			21.7	45		43.3	90		65	135		86.8	180

Spatial streams		1			2			3			4		
Mod.	Code rate	Data rate [Mbit/s] in case of bandwidth [MHz]; GI 800 ns (top), 400 ns (bottom)											
		<i>l.</i>	20	40	<i>l.</i>	20	40	<i>l.</i>	20	40	<i>l.</i>	20	40
QAM16	1/2	3	26 28.9	54 60	11	52 57.8	108 120	19	78 86.7	162 180	27	104 115.6	216 240
	3/4	4	39 43.3	81 90	12	78 86.7	162 180	20	117 130	243 270	28	156 173.2	324 360
QAM64	2/3	5	52 57.8	108 120	13	104 115.6	216 240	21	156 173.3	324 360	29	208 231.2	432 480
	3/4	6	58.5 65	121.5 135	14	117 130	243 270	22	175.5 195	364.5 405	30	234 260	486 540
	5/6	7	65 72.2	135 150	15	130 144.4	270 300	23	195 216.7	405 450	31	260 288.8	540 600

¹⁾ MCS Modulation and Coding Scheme, *l.* MCS index, GI guard interval

3.102 ZVEI

3.102.1 General

Transmission method	ZVEI
Explanation of name	German institution " Z entral V erband E lektrotechnik und E lektronik I ndustrie e.V." (Central Association of Electrical and Electronic Industries)
Other designations	
Variants existing	
Derived from method	
Typical users	Selective call and data transmission in the non-public mobile land radio service
Kind of data	
Reference to standard	ZVEI Recommendation AK SRDS 87-3D
Frequency band	VHF/UHF
Modulation method	MSK (FFSK) (1200 Hz = '1', 1800 Hz = '0'), indirekt FM
Shift/tone spacing	600 Hz
Baud rate	1200 Bd (1200 bit/s)
Modulating subcarrier	1500 Hz

Transmission method	ZVEI
Bandwidth	12.5 kHz
Operating method	Simplex
Data protection	FEC (CRC)
Code table	BCD

3.102.2 Description

ZVEI and VDEW (see [chapter 3.100, "VDEW"](#), on page 310) are digital selective calling systems defined for selective call and data transmission in the non-public mobile land radio service. On the physical layer (data telegrams, transmission speed, modulation method etc.), both systems are identical, but the VDEW system has added some special features to the ZVEI system due to extended requirements.

Data are transmitted in telegrams consisting of frames of 64 bits (32 bits user data):

- in ZVEI, telegrams have a fixed length
- in VDEW, it is possible to convey longer call numbers by dividing the number into more than one frame

Up to four telegrams can be concatenated (the basic telegram [Grundtelegramm] is followed by one or more follow-up telegrams [Folgetelegramm]), controlled by the BAK frame (**B**etriebs**A**rten**K**ennung / operation mode key). By means of the BAK the decoder detects whether it is a VDEW message with follow-up telegrams or a ZVEI telegram without.

3.102.3 Channel Coding/Structure of Data Blocks

A data frame consists of 64 bits. After a carrier pre-keying, an 8-bit telegram preamble and a 15-bit Barker sequence follow. 32-bit user data is protected by 8-bit redundancy.

In the ZVEI system, the telegram is made up of 5 frames:

- [CRC](#) frame
- BAK (**B**etriebs**A**rten**K**ennung / operation mode key)
- Status
- EVU (**E**nergie**V**ersorgungs**U**nternehmen / electric utility)
- Call Number

4 Code and Tone Tables

4.1 Standard Code Tables

4.1.1 Scope

A summary and comparison of the standard alphabets in use and overview of some methods making use of them is shown in [table 4-1](#).

Table 4-1: Standard code tables, comparison.

Method designation			Baudot	ARQ-E3 ARQ-S FEC-S	POL-ARQ SITOR SWED-ARQ	ARQ-E ARQ-N FEC-A	
ISO designation			ITA-2	ITA-3		ITA-2P ARQ-1A	
ITU recommendation				CCIR 342-3	CCIR 476-5		
Combination No.	Level		5 bits	7 bits	7 bits	7 bits	7 bits
	Letter	Figure	12345	1234567	1234567	1234567	1234567
1	A	-	11000	0011010	0001110	0110001	0110000
2	B	?	10011	0011001	1011000	0100110	0100111
3	C	:	01110	1001100	0100011	0011100	0011101
4	D	@ (who?)	10010	0011100	0011010	0100101	0100100
5	E	3	10000	0111000	1001010	0100000	0100001
6	F	%	10110	0010011	0010011	0101100	0101101
7	G	(&)	01011	1100001	0101001	0010110	0010111
8	H	(#)	00101	1010010	0110100	0001011	0001010
9	I	8	01100	1110000	0100110	0011001	0011000
10	J	(\$)(bell)	11010	0100011	0001011	0110100	0110101
11	K	(	11110	0001011	1000011	0111101	0111100
12	L	)	01001	1100010	0101100	0010011	0010010
13	M	.	00111	1010001	0110001	0001110	0001111
14	N	,	00110	1010100	0110010	0001101	0001100
15	O	9	00011	1000110	0111000	0000111	0000110
16	P	0	01101	1001010	0100101	0011010	0011011
17	Q	1	11101	0001101	1000101	0111011	0111010

Method designation			Baudot	ARQ-E3 ARQ-S FEC-S	POL-ARQ SITOR SWED-ARQ	ARQ-E ARQ-N FEC-A	
ISO designation			ITA-2	ITA-3		ITA-2P ARQ-1A	
ITU recommendation				CCIR 342-3	CCIR 476-5		
Combination No.	Level		5 bits	7 bits	7 bits	7 bits	7 bits
	Letter	Figure	12345	1234567	1234567	1234567	1234567
18	R	4	01010	1100100	0101010	0010101	0010100
19	S	'	10100	0101010	0010110	0101001	0101000
20	T	5	00001	1000101	1101000	0000010	0000011
21	U	7	11100	0110010	1000110	0111000	0111001
22	V	=	01111	1001001	1100001	0011111	0011110
23	W	2	11001	0100101	0001101	0110010	0110011
24	X	/	10111	0010110	1010001	0101111	0101110
25	Y	6	10101	0010101	0010101	0101010	0101011
26	Z	+	10001	0110001	0011100	0100011	0100010
(Wildcards)							
27	(%) Carriage return		00010	1000011	1110000	0000100	0000101
28	(&) Line feed		01000	1011000	1100100	0010000	0010001
29	(@) Letter shift		11111	0001110	1010010	0111110	0111111
30	(#) Figure shift		11011	0100110	1001001	0110111	0110110
31	(\$) Gap		00100	1101000	1100010	0001000	0001001
32	(o) Blank		00000	0000111	1010100	0000001	0000000
	(r) Signal repetition request: RQ			0110100	1001100	1110000	1110001
	(a) Idle: a			0101001	0000111	1000110	1000111
	(b) Idle: b			0101100	0011001	1001001	1001000
	Control signal 1: CS1				0101100		
	Control signal 2: CS2				1010100		
	Control signal 3: CS3				0110010		
	Control signal 4: CS4				0101001		
	Control signal 5: CS5				0110100		

4.1.2 ITA-2 Code Table

The ITA-2 code is a standardized version of the Murray code (after the New Zealand journalist and inventor *Donald Murray*), which, on its part, had been derived from the Baudot code (after the french inventor *Jean-Maurice-Émile Baudot*). Although not correct, ITA-2 code is often simply called "Baudot code". Many variations of ITA-2 exist, one of the most common ones being the US TTY alphabet.

Both codes, ITA-2 and US TTY, are shown in [table 4-2](#) (sorted by their sequential number, code sequence normal and reversed, bits erect and inverted) and [table 4-3](#) (sorted by their code, both code sequences, only bit-erect case). Differences only occur in the *Figure* level, whereas the 26 characters of the *Letter* level agree fully.

The remaining 6 characters, completing the 26 (capital) letters of the Latin alphabet to the full set of $2^5 = 32$ combinations, are control signs (switch between the two levels, carriage and line control etc.). Due to the (historical) fact that both code variations (normal and reversed succession of bits or, as one could say, **MSB** first or **LSB** first, even though a decided MSB or LSB is not defined in this context) exist in reality, depending on the equipment manufacturer, these control signs own a bit pattern that is symmetrical, thus insensitive to reversing bit succession, or, in case of **CR** and **LF** characters, emerge from each other when reversed; the **CR-LF** sign order works the same as the **LF-CR** order on a teleprinter (page printer).

Table 4-2: ITA-2 and US TTY code tables, sorted by combination no. (and letter).

No.	Code				Letter	Level		Meaning
	normal		reversed			ITA-2	US TTY	
	Bit-							
	erect	inverted	erect	inverted				
1	11000	00111	00011	11100	A	-	-	Who are you?
2	10011	01100	11001	00110	B	?	?	
3	01110	10001	01110	10001	C	:	:	
4	10010	01101	01001	10110	D	WRU	\$	
5	10000	01111	00001	11110	E	3	3	
6	10110	01001	01101	10010	F	(undef)	!	Bell
7	01011	10100	11010	00101	G	(undef)	&	
8	00101	11010	10100	01011	H	(undef)	#	
9	01100	10011	00110	11001	I	8	8	
10	11010	00101	01011	10100	J	BEL	'	
11	11110	00001	01111	10000	K	(	(	
12	01001	10110	10010	01101	L	)	)	
13	00111	11000	11100	00011	M	.	.	
14	00110	11001	01100	10011	N	,	,	
15	00011	11100	11000	00111	O	9	9	

No.	Code				Letter	Level		Meaning
	normal		reversed			ITA-2	US TTY	
	erect	inverted	erect	inverted				
16	01101	10010	10110	01001	P	0	0	Bell
17	11101	00010	10111	01000	Q	1	1	
18	01010	10101	01010	10101	R	4	4	
19	10100	01011	00101	11010	S	'	BEL	
20	00001	11110	10000	01111	T	5	5	
21	11100	00011	00111	11000	U	7	7	
22	01111	10000	11110	00001	V	=	;	
23	11001	00110	10011	01100	W	2	2	
24	10111	01000	11101	00010	X	/	/	
25	10101	01010	10101	01010	Y	6	6	
26	10001	01110	10001	01110	Z	+	"	Carriage return Line feed Letter shift Figure shift
27	00010	11101	01000	10111		CR		
28	01000	10111	00010	11101		LF		
29	11111	00000	11111	00000		LTRS		
30	11011	00100	11011	00100		FIGS		
31	00100	11011	00100	11011		SPC		Space (gap)
32	00000	11111	00000	11111		BLK		Blank

Table 4-3: ITA-2 and US TTY code tables, sorted by code (normal and reversed, bit-erect only, cf table above).

No.	Code normal	Level			No.	Code reversed	Level		
		Letter	Figure				Letter	Figure	
			ITA-2	US TTY				ITA-2	US TTY
32	00000	BLK			32	00000	BLK		
20	00001	T	5	5	5	00001	E	3	3
27	00010	CR			28	00010	LF		
15	00011	O	9	9	1	00011	A	-	-
31	00100	SPC			31	00100	SPC		
8	00101	H	(undef)	#	19	00101	S	'	BEL
14	00110	N	,	,	9	00110	I	8	8
13	00111	M	.	.	21	00111	U	7	7
28	01000	LF			27	01000	CR		

No.	Code normal	Letter	Level		No.	Code reversed	Letter	Level	
			Figure					Figure	
			ITA-2	US TTY				ITA-2	US TTY
12	01001	L	)	)	4	01001	D	WRU	\$
18	01010	R	4	4	18	01010	R	4	4
7	01011	G	(undef)	&	10	01011	J	BEL	'
9	01100	I	8	8	14	01100	N	,	,
16	01101	P	0	0	6	01101	F	(undef)	!
3	01110	C	:	:	3	01110	C	:	:
22	01111	V	=	;	11	01111	K	(	(
5	10000	E	3	3	20	10000	T	5	5
26	10001	Z	+	"	26	10001	Z	+	"
4	10010	D	WRU	\$	12	10010	L	)	)
2	10011	B	?	?	23	10011	W	2	2
19	10100	S	'	BEL	8	10100	H	(undef)	#
25	10101	Y	6	6	25	10101	Y	6	6
6	10110	F	(undef)	!	16	10110	P	0	0
24	10111	X	/	/	17	10111	Q	1	1
1	11000	A	-	-	15	11000	O	9	9
23	11001	W	2	2	2	11001	B	?	?
10	11010	J	BEL	'	7	11010	G	(undef)	&
30	11011	FIGS			30	11011	FIGS		
21	11100	U	7	7	13	11100	M	.	.
17	11101	Q	1	1	24	11101	X	/	/
11	11110	K	(	(	22	11110	V	=	;
29	11111	LTRS			29	11111	LTRS		

4.1.3 MTK-2 Code Table

In countries or regions using differing alphabets (not the Latin one), like as Cyrillic, Greek, Arabic, Chinese etc., other variants of the [ITA-2/Murray code](#) ([chapter 4.1.2](#)) are used, the assignments of which of course are completely different. Thus, there is a Cyrillic variant (not described here) being in use in some Eastern European countries, but owning the disadvantage that solely Cyrillic emissions can be processed. The requirement to communicate with Cyrillic- and Latin-writing partners at a time then led to the Third-shift Cyrillic code or [MTK-2](#) (Russian equivalent to "International Teletype-writer Code", Cyrillic letters of abbreviation congruent with Latin). This code is given in [table 4-4](#), it adds a third level, resulting now in the three levels *Latin*, *Cyrillic* and *Fig-*

ure, and additionally accomodates the remaining four Cyrillic letters in the *Figure* level (the Cyrillic alphabet has 33 letters, one of them, the hard sign "Ъ", is not in use any longer and one, the "Ё", for this purpose is replaced by the "Е"). For shifting to *Cyrillic*, now the former *Blank* character is used; switching back is done by the normal *Letter shift* and *Figure shift* characters.

Table 4-4: MTK-2 code table.

No.	Code		Level			Meaning of ¹⁾		
	normal	reversed	Latin	Cyrillic	Figure	Cyrillic	Figure	
1	11000	00011	A	А	-	Tse	Che	
2	10011	11001	B	Б	?			
3	01110	01110	C	Ц	:			
4	10010	01001	D	Д	Ч			
5	10000	00001	E	Е	3			
6	10110	01101	F	Ф	Э		E	
7	01011	11010	G	Г	Ш		Sha	
8	00101	10100	H	Х	Щ		Shcha	
9	01100	00110	I	И	8		Yu	
10	11010	01011	J	Й	Ю			
11	11110	01111	K	К	(			
12	01001	10010	L	Л	)			
13	00111	11100	M	М	.			
14	00110	01100	N	Н	,			
15	00011	11000	O	О	9			
16	01101	10110	P	П	0	Ya		
17	11101	10111	Q	Я	1			
18	01010	01010	R	Р	4			
19	10100	00101	S	С	'			
20	00001	10000	T	Т	5			
21	11100	00111	U	У	7	Zhe		
22	01111	11110	V	Ж	=			
23	11001	10011	W	В	2			
24	10111	11101	X	Ь	1	Soft sign		
25	10101	10101	Y	Ы	6			
26	10001	10001	Z	З	+	Ze		
27	00010	01000	CR			Carriage return		
28	01000	00010	LF			Line feed		

No.	Code		Level			Meaning of ¹⁾	
	normal	reversed	Latin	Cyrillic	Figure	Cyrillic	Figure
29	11111	11111				Latin (letters) shift	
30	11011	11011				Figure shift	
31	00100	00100	SPC			Space (gap)	
32	00000	00000				Cyrillic (letters) shift	

¹⁾ (no notation if same meaning as Latin)

4.1.4 ITA-3 Code Table

The ITA-3 alphabet is the first alphabet introducing redundancy into the non-redundant ITA-2 alphabet ([chapter 4.1.2](#)), thus enabling ARQ operation. It is also known as the Moore ARQ code (or derived from it) or RCA code; it is said to have been invented by H. C. A. van Duuren (of Dutch PTT) in 1946 (or earlier). It was established as an international standard in 1956. The rule to compose it was to only use codes with strictly three '1's and four '0's, resulting in

$$\binom{7}{3} = \binom{7}{4} = \frac{7!}{3! \cdot 4!} = \frac{7 \cdot 6 \cdot 5}{3 \cdot 2 \cdot 1} = 35$$

(4 - 1)

different characters being able to arise – 3 more in comparison to the 32 of ITA-2. These 3 additional characters are used for control purposes. All other characteristics of the ITA-2 code are retained, especially the split-up into the two levels *Letter* and *Figure*.

The complete code is shown in [table 4-5](#).

Table 4-5: ITA-3 (CCIR 342-3) code table.

No.	Level		Code	
	Letter	Figure	ITA-2	ITA-3
1	A	-	11000	0011010
2	B	?	10011	0011001
3	C	:	01110	1001100
4	D	WRU	10010	0011100
5	E	3	10000	0111000
6	F	(undef)	10110	0010011
7	G	(undef)	01011	1100001
8	H	(undef)	00101	1010010
9	I	8	01100	1110000

No.	Level		Code	
	Letter	Figure	ITA-2	ITA-3
10	J	BEL	11010	0100011
11	K	(	11110	0001011
12	L	)	01001	1100010
13	M	.	00111	1010001
14	N	,	00110	1010100
15	O	9	00011	1000110
16	P	0	01101	1001010
17	Q	1	11101	0001101
18	R	4	01010	1100100
19	S	'	10100	0101010
20	T	5	00001	1000101
21	U	7	11100	0110010
22	V	=	01111	1001001
23	W	2	11001	0100101
24	X	/	10111	0010110
25	Y	6	10101	0010101
26	Z	+	10001	0110001
27	CR (Carriage return)		00010	1000011
28	LF (Line feed)		01000	1011000
29	LTRS (Letter shift)		11111	0001110
30	FIGS (Figure shift)		11011	0100110
31	SPC (Space/Gap)		00100	1101000
32	BLK (Blank)		00000	0000111
	RQ (Signal repetition request)			0110100
	α (Idle signal)			0101001
	β (Idle signal)			0101100

4.1.5 ITA-2P Code Table

ITA-2P (ITA-2 Parity, also called ARQ-1A) is just the normal ITA-2 code ([chapter 4.1.2](#)) supplemented by two additional bits: a leading bit which is always '0' for the normal 32 ITA-2 characters and always '1' for the 3 additional control characters known from ITA-3 ([chapter 4.1.4](#)), and a trailing bit forming an even or odd parity to the resulting 7-bit code word. Both variants can be seen in [table 4-6](#).

Table 4-6: ITA-2P (ARQ-1A) code table, odd and even parity.

No.	Level		ITA-2	Code	
	Letter	Figure		ITA-2P	
				Parity odd	Parity even
1	A	-	11000	0 11000 1	0 11000 0
2	B	?	10011	0 10011 0	0 10011 1
3	C	:	01110	0 01110 0	0 01110 1
4	D	WRU	10010	0 10010 1	0 10010 0
5	E	3	10000	0 10000 0	0 10000 1
6	F	(undef)	10110	0 10110 0	0 10110 1
7	G	(undef)	01011	0 01011 0	0 01011 1
8	H	(undef)	00101	0 00101 1	0 00101 0
9	I	8	01100	0 01100 1	0 01100 0
10	J	BEL	11010	0 11010 0	0 11010 1
11	K	(	11110	0 11110 1	0 11110 0
12	L	)	01001	0 01001 1	0 01001 0
13	M	.	00111	0 00111 0	0 00111 1
14	N	,	00110	0 00110 1	0 00110 0
15	O	9	00011	0 00011 1	0 00011 0
16	P	0	01101	0 01101 0	0 01101 1
17	Q	1	11101	0 11101 1	0 11101 0
18	R	4	01010	0 01010 1	0 01010 0
19	S	'	10100	0 10100 1	0 10100 0
20	T	5	00001	0 00001 0	0 00001 1
21	U	7	11100	0 11100 0	0 11100 1
22	V	=	01111	0 01111 1	0 01111 0
23	W	2	11001	0 11001 0	0 11001 1
24	X	/	10111	0 10111 1	0 10111 0
25	Y	6	10101	0 10101 0	0 10101 1
26	Z	+	10001	0 10001 1	0 10001 0
27	CR (Carriage return)		00010	0 00010 0	0 00010 1
28	LF (Line feed)		01000	0 01000 0	0 01000 1
29	LTRS (Letter shift)		11111	0 11111 0	0 11111 1
30	FIGS (Figure shift)		11011	0 11011 1	0 11011 0
31	SPC (Space/Gap)		00100	0 00100 0	0 00100 1

No.	Level		ITA-2	Code	
	Letter	Figure		ITA-2P	
				Parity odd	Parity even
32	BLK (Blank)		00000	0 00000 1	0 00000 0
	RQ (Signal repetition request)			1 11000 0	1 11000 1
	α (Idle signal)			1 00011 0	1 00011 1
	β (Idle signal)			1 00100 1	1 00100 0

4.1.6 SITOR Code Table

The **SITOR** alphabet (also called **CCIR 476-5** alphabet) is derived from **ITA-2** ([chapter 4.1.2](#)), as can be seen from [table 4-7](#), by inverting the bit polarity of the ITA-2 character and subsequently surrounding it with one leading and one trailing '0' and/or '1' bit in a way that the resulting code contains three '1's and four '0's. If not '0'/'0' or '1'/'1', but the '0'/'1' combination has to be added, the '0' forms the leading and the '1' the trailing bit, with the exception, however, that for "B" and "U" the '1'/'0' instead of the '0'/'1' combination is used. The codes that would have emerged if using '0'/'1' form the representations for the two "Idle" signs " α " and " β " instead.

An original ITA-2 code owning five '0's (one code: LTRS/"Letter shift"), five '1's (one code: BLK/"Blank") or four '1's and one '0' (five codes: "E", "T", CR/"Carriage return", LF/"Line feed" and SPC/"Space/gap") can evidently not be converted the way described. The SITOR codes in this case must be formed by taking the ITA-2 codes already used with the '0'/'1' combination (see above) and reusing them, but this time with the '1'/'0' combination.

In summary, the only codes concerned are

- "B" (combination no. 2)
- "E" (5)
- "T" (20)
- "U" (21)

the "wildcard" codes

- CR/"Carriage return" (27)
- LF/"Line feed" (28)
- LTRS/"Letter shift" (29)
- SPC/"Space/gap" (31)
- BLK/"Blank" (32)

and the "new" characters (not found in ITA-2)

- RQ/"Signal repetition request"
- " α "
- " β "

(The "ITA-2 portion" – inverted original ITA-2 code – of all according SITOR codes is shown in bold notation in the table.)

Be aware that the two levels *Letter* and *Figure* (switching between them two is done by the appropriate characters LTRS/"Letter shift" and FIGS/"Figure shift") are existing still.

Due to the strict three '1's to four '0's ratio, a minimum Hamming distance of 2 is obtained, meaning that a single bit error (but not more) can always be detected (but not corrected).

Some of the ordinary characters are reused as control signals because, as mentioned in [chapter 4.1.4](#), [equation 4-1](#), only 35 different codes can be created this way, but 40 are defined.

Table 4-7: SITOR (CCIR 476-5) code table.

No.	Level		Code		
	Letter	Figure	ITA-2 bit-erect	ITA-2 bit-inverted	SITOR
1	A	-	11000	00111	0 00111 0
2	B	?	10011	01100	1 01100 0 ¹⁾
3	C	:	01110	10001	0 10001 1
4	D	@ (who?)	10010	01101	0 01101 0
5	E	3	10000	01111	1 00101 0 ²⁾
6	F	%	10110	01001	0 01001 1
7	G	(&)	01011	10100	0 10100 1
8	H	(#)	00101	11010	0 11010 0
9	I	8	01100	10011	0 10011 0
10	J	(\$)(bell)	11010	00101	0 00101 1
11	K	(	11110	00001	1 00001 1
12	L	)	01001	10110	0 10110 0
13	M	.	00111	11000	0 11000 1
14	N	,	00110	11001	0 11001 0
15	O	9	00011	11100	0 11100 0
16	P	0	01101	10010	0 10010 1
17	Q	1	11101	00010	1 00010 1
18	R	4	01010	10101	0 10101 0
19	S	'	10100	01011	0 01011 0
20	T	5	00001	11110	1 10100 0 ²⁾
21	U	7	11100	00011	1 00011 0 ¹⁾
22	V	=	01111	10000	1 10000 1
23	W	2	11001	00110	0 00110 1
24	X	/	10111	01000	1 01000 1
25	Y	6	10101	01010	0 01010 1
26	Z	+	10001	01110	0 01110 0
27	CR (Carriage return)		00010	11101	1 11000 0 ²⁾

No.	Level		Code		
	Letter	Figure	ITA-2 bit-erect	ITA-2 bit-inverted	SITOR
28	LF (Line feed)		01000	10111	1 10010 0 ²⁾
29	LTRS (Letter shift)		11111	00000	1 01001 0 ²⁾
30	FIGS (Figure shift)		11011	00100	1 00100 1
31	SPC (Space/Gap)		00100	11011	1 10001 0 ²⁾
32	BLK (Blank)		00000	11111	1 01010 0 ²⁾
	RQ (Signal repetition request)				1 00110 0 ³⁾
	α (Idle signal)				0 00011 1 ⁴⁾
	β (Idle signal)				0 01100 1 ⁵⁾
	CS1 (Control signal 1)				0 10110 0 ⁶⁾
	CS2 (Control signal 2)				1 01010 0 ⁷⁾
	CS3 (Control signal 3)				0 11001 0 ⁸⁾
	CS4 (Control signal 3)				0 10100 1 ⁹⁾
	CS5 (Control signal 3)				0 11010 0 ¹⁰⁾

¹⁾ Leading '1', trailing '0'

²⁾ New code, not derived from ITA-2 code, leading '1', trailing '0'

^{3) to ¹⁰⁾} New code, not available in ITA-2:

³⁾ leading '1', trailing '0' (would otherwise equate to "W")

⁴⁾ leading '0', trailing '1' (would otherwise equate to "U")

⁵⁾ leading '0', trailing '1' (would otherwise equate to "B")

⁶⁾ (equates to "L")

⁷⁾ (equates to *BLK*/"Blank")

⁸⁾ (equates to "N")

⁹⁾ (equates to "G")

¹⁰⁾ (equates to "H")

4.1.7 Bauer Code Table

The Bauer code is a 10-bit code, the first 5 bits of which are the original ITA-2 bits ([chapter 4.1.2](#)) and the second 5 a repetition of the first 5 or the inverted first 5, respectively, depending on the parity of the original character code and the desired parity of the check bits. Constructing Bauer code words is described in detail in [chapter 3.19](#), "AUTOSPEC", on page 78. Attention has to be paid to the fact that "parity" describes

the process of gaining the check bits, but does not mean the parity of the arising over-all 10-bit code word.

A complete code table for the Odd and Even variants can be seen in [table 4-8](#); all cases where the original bits have to be inverted to form the check bits are given in bold notation.

Table 4-8: Bauer code table, odd and even parity.

No.	Level		ITA-2	Code	
	Letter	Figure		Bauer	
				Parity odd	Parity even
1	A	-	11000	11000 00111	11000 11000
2	B	?	10011	10011 10011	10011 01100
3	C	:	01110	01110 01110	01110 10001
4	D	WRU	10010	10010 01101	10010 10010
5	E	3	10000	10000 10000	10000 01111
6	F	(undef)	10110	10110 10110	10110 01001
7	G	(undef)	01011	01011 01011	01011 10100
8	H	(undef)	00101	00101 11010	00101 00101
9	I	8	01100	01100 10011	01100 01100
10	J	BEL	11010	11010 11010	11010 00101
11	K	(	11110	11110 00001	11110 11110
12	L	)	01001	01001 10110	01001 01001
13	M	.	00111	00111 00111	00111 11000
14	N	,	00110	00110 11001	00110 00110
15	O	9	00011	00011 11100	00011 00011
16	P	0	01101	01101 01101	01101 10010
17	Q	1	11101	11101 00010	11101 11101
18	R	4	01010	01010 10101	01010 01010
19	S	'	10100	10100 01011	10100 10100
20	T	5	00001	00001 00001	00001 11110
21	U	7	11100	11100 11100	11100 00011
22	V	=	01111	01111 10000	01111 01111
23	W	2	11001	11001 11001	11001 00110
24	X	/	10111	10111 01000	10111 10111
25	Y	6	10101	10101 10101	10101 01010
26	Z	+	10001	10001 01110	10001 10001
27	CR (Carriage return)		00010	00010 00010	00010 11101

No.	Level		Code		
	Letter	Figure	ITA-2	Bauer	
				Parity odd	Parity even
28	LF (Line feed)		01000	01000 01000	01000 10111
29	LTRS (Letter shift)		11111	11111 11111	11111 00000
30	FIGS (Figure shift)		11011	11011 00100	11011 11011
31	SPC (Space/Gap)		00100	00100 00100	00100 11011
32	BLK (Blank)		00000	00000 11111	00000 11111

4.2 ITA-5 (ASCII) Code Table

4.2.1 Standard Character Set

The ITA-5 or ASCII standard character set shown in [table 4-9](#) (control characters) and [table 4-10](#) (printable characters) contains the characters common to all national character sets; codes individual to these variants, on the other hand, are given in [table 4-11](#) ([chapter 4.2.2](#)). Characters varying in these sets are marked as "(var.)" in [table 4-10](#).

Table 4-9: ASCII standard character set, control characters.

h.	d.	binary	Ch.	Meaning	h.	d.	binary	Ch.	Meaning
0	0	0000000	NUL	Null	11	17	0010001	DC1	Device Control 1 (XON)
1	1	0000001	SOH	Start of Heading	12	18	0010010	DC2	Device Control 2
2	2	0000010	STX	Start of Text	13	19	0010011	DC3	Device Control 3 (XOFF)
3	3	0000011	ETX	End of Text	14	20	0010100	DC4	Device Control 4
4	4	0000100	EOT	End of Transmission	15	21	0010101	NAK	Negative Acknowledge
5	5	0000101	ENQ	Enquiry	16	22	0010110	SYN	Synchronous Idle
6	6	0000110	ACK	Acknowledge	17	23	0010111	ETB	End of Transmission Block
7	7	0000111	BEL	Bell	18	24	0011000	CAN	Cancel
8	8	0001000	BS	Backspace	19	25	0011001	EM	End of Medium
9	9	0001001	HT	Horizontal Tabulation	1A	26	0011010	SUB	Substitute
A	10	0001010	LF	Line Feed	1B	27	0011011	ESC	Escape
B	11	0001011	VT	Vertical Tabulation	1C	28	0011100	FS	File Separator
C	12	0001100	FF	Form Feed	1D	29	0011101	GS	Group Separator
D	13	0001101	CR	Carriage Return	1E	30	0011110	RS	Record Separator
E	14	0001110	SO	Shift Out	1F	31	0011111	US	Unit Separator

h.	d.	binary	Ch.	Meaning	h.	d.	binary	Ch.	Meaning
F	15	0001111	SI	Shift In	20	32	0100000	SPC	Space
10	16	0010000	DLE	Data Link Escape	7F	127	1111111	DEL	Delete

Table 4-10: ASCII standard character set, printable characters.

hex.	dec.	binary	Char.	hex.	dec.	binary	Char.	hex.	dec.	binary	Char.
21	33	0100001	!	41	65	1000001	A	61	97	1100001	a
22	34	0100010	"	42	66	1000010	B	62	98	1100010	b
23	35	0100011	(var.)	43	67	1000011	C	63	99	1100011	c
24	36	0100100	(var.)	44	68	1000100	D	64	100	1100100	d
25	37	0100101	%	45	69	1000101	E	65	101	1100101	e
26	38	0100110	&	46	70	1000110	F	66	102	1100110	f
27	39	0100111	'	47	71	1000111	G	67	103	1100111	g
28	40	0101000	(	48	72	1001000	H	68	104	1101000	h
29	41	0101001	)	49	73	1001001	I	69	105	1101001	i
2A	42	0101010	*	4A	74	1001010	J	6A	106	1101010	j
2B	43	0101011	+	4B	75	1001011	K	6B	107	1101011	k
2C	44	0101100	,	4C	76	1001100	L	6C	108	1101100	l
2D	45	0101101	-	4D	77	1001101	M	6D	109	1101101	m
2E	46	0101110	.	4E	78	1001110	N	6E	110	1101110	n
2F	47	0101111	/	4F	79	1001111	O	6F	111	1101111	o
30	48	0110000	0	50	80	1010000	P	70	112	1110000	p
31	49	0110001	1	51	81	1010001	Q	71	113	1110001	q
32	50	0110010	2	52	82	1010010	R	72	114	1110010	r
33	51	0110011	3	53	83	1010011	S	73	115	1110011	s
34	52	0110100	4	54	84	1010100	T	74	116	1110100	t
35	53	0110101	5	55	85	1010101	U	75	117	1110101	u
36	54	0110110	6	56	86	1010110	V	76	118	1110110	v
37	55	0110111	7	57	87	1010111	W	77	119	1110111	w
38	56	0111000	8	58	88	1011000	X	78	120	1111000	x
39	57	0111001	9	59	89	1011001	Y	79	121	1111001	y
3A	58	0111010	:	5A	90	1011010	Z	7A	122	1111010	z
3B	59	0111011	;	5B	91	1011011	(var.)	7B	123	1111011	(var.)
3C	60	0111100	<	5C	92	1011100	(var.)	7C	124	1111100	(var.)
3D	61	0111101	=	5D	93	1011101	(var.)	7D	125	1111101	(var.)

hex.	dec.	binary	Char.	hex.	dec.	binary	Char.	hex.	dec.	binary	Char.
3E	62	0111110	>	5E	94	1011110	(var.)	7E	126	1111110	(var.)
3F	63	0111111	?	5F	95	1011111	–				
40	64	1000000	(var.)	60	96	1100000	(var.)				

4.2.2 National Character Sets

In [table 4-11](#) some variants for national character set characters differing from set to set (country to country) – i.e. not uniform and thus not represented by the standard character set in [table 4-10](#) in [chapter 4.2.1](#) – are shown. The individual countries are identified by their international car signs. The "ISO 646-IRV" column marks the character set's International Reference Version standardized in the ISO 646 standard.

For more detailed information (character sets for additional countries or subvariants of the national character sets shown here) refer to relevant publications.

Table 4-11: ASCII national character sets.

No.			Character													
h.	d.	binary	ISO ¹⁾	Country-specific ²⁾												
				D	CH	USA	GB	F	CDN	FIN	N	S	I	NL	E	P
23	19	0100011	#	#	ù	#	£	£	#	#	#	#	£	£	£	#
24	20	0100100	¤	\$	\$	\$	\$	\$	\$	\$	\$	\$	\$	\$	\$	\$
40	64	1000000	@	§	à	@	@	à	à	@	@	É	§	¾	§	@
5B	91	1011011	[	Ä	é	[	[	°	â	Ä	Æ	Ä	°	ÿ	ı	Ã
5C	92	1011100	\	Ö	ç	\	\	ç	ç	Ö	Ø	Ö	ç	½	Ñ	Ç
5D	93	1011101	]	Ü	ê	]	]	§	ê	Å	Å	Å	é		¿	Ö
5E	94	1011110	^	^	î	^	^	^	î	Ü	^	Ü	^	^	^	^
60	96	1100000	`	`	ô	`	`	`	ô	é	`	é	ù	`	`	`
7B	123	1111011	{	ä	ä	{	{	é	é	ä	æ	ä	à	¨	°	ã
7C	124	1111100		ö	ö			ù	ù	ö	ø	ö	ò	f	ñ	¼
7D	125	1111101	}	ü	ü	}	}	è	è	â	â	â	è	¼	ç	õ
7E	126	1111110	~	ß	û	~	~	¨	û	ü	~	ü	ı	´	~	~

¹⁾ ISO 646-IRV

²⁾ **D** Germany **GB** Great Britain **FIN** Finland **I** Italy **P** Portugal
CH Switzerland **F** France **N** Norway **NL** Netherlands
USA U.S.A. **CDN** Canada **S** Sweden **E** Spain

4.3 CIS-36-50 Code Table

Data transmitted with CIS-36-50 ([chapter 3.27](#), "CIS-36-50", on page 94) is always encrypted, a special alphabet yielding readable text therefore cannot easily be told. However, the central sequence of a data block (apart from start and end sequences) is observed to always contain 7-bit characters with strictly three '0's and four '1's (or the opposite if a bit-inverted mode of observation has been selected). To make these characters distinguishable, an alphabet allocation should be done anyhow, assignment could be arbitrary in principle.

The way followed here is to use the ITA-3 alphabet ([chapter 4.1.4](#)): the original codes (*Letter* level only, *Figure* level is not considered) are bit-inverted and code reversed, so that the desired counts of four '1's and three '0's result, the related character is issued on reception of the corresponding bit pattern. If decoding would have revealed a control character, an alternative special character not being part of the *Letter* level of the ITA-3 alphabet is used instead. See [table 4-12](#) for details.

Table 4-12: CIS-36-50 code table.

No.	ITA-3		CIS-36-50		
	Letter	Code ¹⁾	Code ²⁾	decimal	Char.
1	A	0011010	1010011	83	A
2	B	0011001	0110011	51	B
3	C	1001100	1100110	102	C
4	D	0011100	1100011	99	D
5	E	0111000	1110001	113	E
6	F	0010011	0011011	27	F
7	G	1100001	0111100	60	G
8	H	1010010	1011010	90	H
9	I	1110000	1111000	120	I
10	J	0100011	0011101	29	J
11	K	0001011	0010111	23	K
12	L	1100010	1011100	92	L
13	M	1010001	0111010	58	M
14	N	1010100	1101010	106	N
15	O	1000110	1001110	78	O
16	P	1001010	1010110	86	P
17	Q	0001101	0100111	39	Q
18	R	1100100	1101100	108	R
19	S	0101010	1010101	85	S
20	T	1000101	0101110	46	T
21	U	0110010	1011001	89	U

No.	ITA-3		CIS-36-50		
	Letter	Code ¹⁾	Code ²⁾	decimal	Char.
22	V	1001001	0110110	54	V
23	W	0100101	0101101	45	W
24	X	0010110	1001011	75	X
25	Y	0010101	0101011	43	Y
26	Z	0110001	0111001	57	Z
27	CR (Carriage return)	1000011	0011110	30	&
28	LF (Line feed)	1011000	1110010	114	\
29	LTRS (Letter shift)	0001110	1000111	71	\$
30	FIGS (Figure shift)	0100110	1001101	77	@
31	SPC (Space/Gap)	1101000	1110100	116	!
32	BLK (Blank)	0000111	0001111	15	#
33	RQ (Repetition request)	0110100	1101001	105	>
34	α (Idle signal)	0101001	0110101	53	%
35	β (Idle signal)	0101100	1100101	101	<

¹⁾ code normal (not reversed), bit-erect

²⁾ ITA-3 code reversed, bit-inverted

4.4 Huffman Code Table

During normal text transmission in some systems, a data compression code, the Huffman code, is used; depending on frequency of occurrence of a character in a special (linguistic) environment, a differing count of code elements (bits) is spent to code it. Huffman codes commonly are constructed (coded and decoded) by tree structures; for details, refer to relevant publications. In [table 4-13](#), the Huffman code words used with PACTOR ([chapter 3.74, "PACTOR I"](#), on page 227, [chapter 3.76, "PACTOR II"](#), on page 232, [chapter 3.77, "PACTOR III"](#), on page 238) are shown in detail, in [table 4-14](#) the G-TOR ([chapter 3.50, "G-TOR"](#), on page 143) codes. Agreement between the two tables is wide, differences happen mainly for control characters of 15 bit of length. Note that for normal printable characters, the minimum count is 2 bits (for the SPC [space] sign: 10_H ["H" for "Huffman"], i.e., no other codings beginning with "10" may exist), the maximum count is 14 bits (e.g. "Q"). Control signs commonly incorporate 15 or 16 bits.

A distinction is done between the so-called Huffman-A code, comprising the lower and upper case character set, and the Huffman-B code, covering only upper case (more exactly: swapping the codes of lower and upper case characters, thus pretending a

larger frequency of upper case) and this way allowing a further reduction of transmission expense for texts consisting only of upper case letters.

4.4.1 PACTOR

Table 4-13: Huffman code table for PACTOR.

h.	Ch.	Huffman code	h.	Ch.	Huffman code	h.	Ch.	Huffman code
0	NUL	1111 0011 1000 110	2B	+	1111 0011 1110	56	V	1100 0110 00
1	SOH	1111 0011 1000 101	2C	,	1100 101	57	W	0001 0101 00
2	STX	1111 0011 1000 100	2D	-	0001 0101 111	58	X	0001 0101 1101 1
3	ETX	1111 0011 1000 011	2E	.	1100 100	59	Y	1111 0101 11
4	EOT	1111 0011 1000 010	2F	/	1111 0011 110	5A	Z	1100 0110 01
5	ENQ	1111 0011 1000 001	30	0	1100 0111	5B	(var.)	0010 1000 1101 000
6	ACK	1111 0011 1000 000	31	1	0010 1000 0	5C	(var.)	1111 0000 1101 01
7	BEL	1111 0000 1111 111	32	2	0001 0110 10	5D	(var.)	0010 1000 1101 000
8	BS	1111 0000 1111 110	33	3	0001 0110 11	5E	(var.)	1100 0110 1111 110
9	HT	1111 0000 1111 101	34	4	0001 0111 00	5F	—	1111 0000 1100
A	LF	0011 01	35	5	0001 0101 01	60	(var.)	1100 0110 1111 101
B	VT	1111 0000 1111 100	36	6	0001 0111 01	61	a	0100 0
C	FF	1111 0000 1111 011	37	7	0001 0111 10	62	b	0000 110
D	CR	0011 00	38	8	0001 0111 11	63	c	0100 11
E	SO	1111 0000 1111 010	39	9	0001 0100 10	64	d	0011 1
F	SI	1111 0000 1111 001	3A	:	0010 1000 111	65	e	011
10	DLE	1111 0000 1110 111	3B	;	1111 0000 1101 00	66	f	0000 111
11	DC1	1111 0000 1110 110	3C	<	0001 0101 1101 0	67	g	0001 11
12	DC2	1111 0000 1110 101	3D	=	1111 0000 10	68	h	0001 00
13	DC3	1111 0000 1110 100	3E	>	1111 0011 1111	69	i	1101
14	DC4	1111 0000 1110 011	3F	?	1100 1101 01	6A	j	0001 0100 110
15	NAK	1111 0000 1110 010	40	(var.)	0001 0101 1100 0	6B	k	0010 101
16	SYN	1111 0000 1110 001	41	A	0010 1001	6C	l	0000 10
17	ETB	1111 0000 1110 000	42	B	1100 1111	6D	m	0010 11
18	CAN	1111 0000 1101 111	43	C	1111 0001	6E	n	0101
19	EM	1111 0000 1101 110	44	D	1111 0100	6F	o	0100 10
1A	SUB	1111 0011 1000 111	45	E	1100 0000	70	p	1100 0010
1B	ESC	1111 0000 1101 101	46	F	1100 1100	71	q	1111 0101 10

h.	Ch.	Huffman code	h.	Ch.	Huffman code	h.	Ch.	Huffman code
1C	FS	1100 0110 01	47	G	0001 0100 111	72	r	1110
1D	GS	1111 0000 1101 100	48	H	0010 1000 10	73	s	0010 0
1E	RS	1111 0000 1111 000	49	I	1111 0010	74	t	0000 0
1F	US	1100 0110 1111 111	4A	J	1100 0001 10	75	u	1111 1
20	SPC	10	4B	K	1100 1101 00	76	v	1100 0011
21	!	1111 0011 101	4C	L	1100 1110 1	77	w	0001 100
22	"	1100 0110 1100	4D	M	1111 0101 0	78	x	1100 0110 10
23	(var.)	0010 1000 1101 1	4E	N	1111 0000 0	79	y	0001 0101 10
24	(var.)	0001 0101 1100 1	4F	O	0001 0100 0	7A	z	1100 010
25	%	1100 0110 1101	50	P	0001 0110 0	7B	(var.)	1100 0110 1111 100
26	&	1111 0111 001	51	Q	0010 1000 1101 01	7C	(var.)	1100 0110 1111 011
27	'	1100 0110 1110	52	R	1100 0001 0	7D	(var.)	1100 0110 1111 010
28	(	1100 1101 1	53	S	1111 011	7E	(var.)	1100 0110 1111 001
29	)	1100 1110 0	54	T	0001 101	7F	DEL	1100 0110 1111 000
2A	*	0010 1000 1100	55	U	1100 0001 11			

4.4.2 G-TOR

All codes differing from the ones of PACTOR (table 4-13) are shown in bold.

Table 4-14: Huffman code table for G-TOR.

h.	Ch.	Huffman code	h.	Ch.	Huffman code	h.	Ch.	Huffman code
0	NUL	1111 0000 1111 1000	2B	+	1111 0011 1110	56	V	1100 0110 00
1	SOH	1111 0000 1111 1001	2C	,	1100 101	57	W	0001 0101 00
2	STX	1111 0000 1111 1010	2D	-	0001 0101 111	58	X	0001 0101 1101 1
3	ETX	1111 0000 1111 1011	2E	.	1100 100	59	Y	1111 0101 11
4	EOT	1111 0000 1111 1100	2F	/	1111 0011 110	5A	Z	1100 0110 01
5	ENQ	1111 0000 1111 1101	30	0	1100 0111	5B	(var.)	0010 1000 1101 00
6	ACK	1111 0000 1111 1110	31	1	0010 1000 0	5C	(var.)	1111 0000 1101 01
7	BEL	1111 0000 1111 1111	32	2	0001 0110 10	5D	(var.)	1111 0000 1101 11
8	BS	1111 0000 1111 0010	33	3	0001 0110 11	5E	(var.)	1100 0110 1111 11
9	HT	1111 0000 1111 0011	34	4	0001 0111 00	5F	—	1111 0000 1100
A	LF	0011 01	35	5	0001 0101 01	60	(var.)	1111 0000 1110 00
B	VT	1111 0000 1111 0100	36	6	0001 0111 01	61	a	0100 0
C	FF	1111 0000 1111 0101	37	7	0001 0111 10	62	b	0000 110

h.	Ch.	Huffman code	h.	Ch.	Huffman code	h.	Ch.	Huffman code
D	CR	0011 00	38	8	0001 0111 11	63	c	0100 11
E	SO	1111 0000 1111 0110	39	9	0001 0100 10	64	d	0011 1
F	SI	1111 0000 1111 0111	3A	:	0010 1000 111	65	e	011
10	DLE	1111 0011 1000 0000	3B	;	1111 0000 1101 00	66	f	0000 111
11	DC1	1111 0011 1000 0001	3C	<	0001 0101 1101 0	67	g	0001 11
12	DC2	1111 0011 1000 0010	3D	=	1111 0000 10	68	h	0001 00
13	DC3	1111 0011 1000 0011	3E	>	1111 0011 1111	69	i	1101
14	DC4	1111 0011 1000 0100	3F	?	1100 1101 01	6A	j	0001 0100 110
15	NAK	1111 0011 1000 0101	40	(var.)	0001 0101 1100 0	6B	k	0010 101
16	SYN	1111 0011 1000 0110	41	A	0010 1001	6C	l	0000 10
17	ETB	1111 0011 1000 0111	42	B	1100 1111	6D	m	0010 11
18	CAN	1111 0011 1000 1000	43	C	1111 0001	6E	n	0101
19	EM	1111 0011 1000 1001	44	D	1111 0100	6F	o	0100 10
1A	SUB	1111 0011 1000 1010	45	E	1100 0000	70	p	1100 0010
1B	ESC	1111 0011 1000 1011	46	F	1100 1100	71	q	1111 0101 10
1C	FS	1111 0011 1000 1100	47	G	0001 0100 111	72	r	1110
1D	GS	1111 0011 1000 1101	48	H	0010 1000 10	73	s	0010 0
1E	RS	1111 0011 1000 1110	49	I	1111 0010	74	t	0000 0
1F	US	1111 0011 1000 1111	4A	J	1100 0001 10	75	u	1111 1
20	SPC	10	4B	K	1100 1101 00	76	v	1100 0011
21	!	1111 0011 101	4C	L	1100 1110 1	77	w	0001 100
22	"	1100 0110 1100	4D	M	1111 0101 0	78	x	1100 0110 10
23	(var.)	0010 1000 1101 1	4E	N	1111 0000 0	79	y	0001 0101 10
24	(var.)	0001 0101 1100 1	4F	O	0001 0100 0	7A	z	1100 010
25	%	1100 0110 1101	50	P	0001 0110 0	7B	(var.)	1100 0110 1111 10
26	&	1111 0111 001	51	Q	0010 1000 1101 01	7C	(var.)	1111 0000 1101 10
27	'	1100 0110 1110	52	R	1100 0001 0	7D	(var.)	1100 0110 1111 01
28	(	1100 1101 1	53	S	1111 011	7E	(var.)	1100 0110 1111 00
29	)	1100 1110 0	54	T	0001 101	7F	DEL	1111 0000 1111 0001
2A	*	0010 1000 1100	55	U	1100 0001 11			

Upper ASCII	1111 0011 0xxx xxxx		
80	1111 0010 0000 0000 0	IDLE	1111 0000 1111 0000

81		1111 0010 0000 0000 1	RLE	1111 0000 1110 01
82		1111 0010 0000 0001 0 etc.	UNUSED	1111 0000 1110 1

4.5 MORSE Code Table

For general informations about Morse code, refer to [chapter 3.68, "MORSE"](#), on page 208.

Table 4-15: Morse code table: letters.

Char	Code	Char	Code	Char	Code	Char	Code	Char	Code	Char	Code
A	• –	F	• • • •	K	– • –	P	• – • •	U	• • –	Z	– • • •
B	– • • •	G	– • •	L	• – • •	Q	– • • –	V	• • • –		
C	– • • •	H	• • • •	M	– –	R	• • •	W	• • –		
D	– • •	I	• •	N	– •	S	• • •	X	– • • –		
E	•	J	• – • •	O	– • •	T	–	Y	– • • •		

Table 4-16: Morse code table: numbers.

Char	Code	Char	Code	Char	Code	Char	Code	Char	Code
0	– • • • •	2	• • • • –	4	• • • • –	6	– • • • •	8	– • • • •
1	• • • • •	3	• • • • –	5	• • • • •	7	– • • • •	9	– • • • •

Table 4-17: Morse code table: punctuation.

Char	Meaning	Code	Char	Meaning	Char
.	(AAA) Period	• • • • •	:	Colon	– • • • •
,	(MIM) Comma	– • • • •	;	Semicolon	– • • • •
?	(IMI) Question mark	• • • • •	=	Double dash, Equals sign	– • • • –
'	Apostrophe	• • • • •	+	Plus	• • • • •
!	Exclamation mark	– • • • •	-	Hyphen, Minus	– • • • •
/	Slash, Fraction bar	– • • • •	_	Underscore	• • • • •
(	Open Paranthesis	– • • • •	"	Quotation mark	• • • • •
)	Close Paranthesis	– • • • •	\$	Dollar sign	• • • • •
&	Ampersand, Wait	• • • • •	@ (AC)	At sign	• • • • •

Table 4-18: Morse code table: non-english letters.

Char	Code	Char	Code	Char	Code
ä, æ, å	• • • •	è, ì	• • • •	ñ, ñ	– • • •
à, â	• • • •	é, ð, ë	• • • •	ö, ø, ó	– • • •
ç, ç, ç	– • • •	ô	– • • •	š	• • • •

Char	Code	Char	Code	Char	Code
ch, š	----	ĥ	- (obsolete) - - - - (new)	þ ("Thorn")	. - - . .
Ð ("Eth")	. . - . .	ĵ	. - - . .	ü, ŭ	. . - -
ś	. . . - . . .	ž	- - - . . .	ž	- - . . -

Table 4-19: Morse code table: prosigns.

Char	Code	Char	Code	Char	Code
Wait		Understood		Starting signal	- . . . -
Invitation to transmit	- - -	Error		Pause	- . . . -
SOS	. . . - -	End of work	. . . - -	Stopping signal	

4.6 HNG-FEC Code Table

The HNG-FEC (see [chapter 3.58, "HNG-FEC"](#), on page 161) alphabet consists of the 32 characters of the normal ITA-2 alphabet and is shown in [table 4-20](#). Each code comprises 15 bits, the first 5 of which (if grouped in three 5-bit sequences) are the ITA-2 code itself, but with the first and last bit (**MSB** and **LSB**) inverted. It can easily be recognized that each of the other two sets of 5-bit sequences (second and third) also consists of 32 different bit combinations (i.e., each possible combination exists exactly once per sequence set). Combination of the elements of the sequence sets is done the way that a 15-bit code results with a Hamming distance of 7 or 8, hence a minimum distance of 7, so that the complete code is suited to correct up to 3 transmission errors in a code word.

Example: Code 11011₂ appears in the first 5-bit column only with HNG-FEC combination 11 ("R" or "4"), in the second only with combination 9 (**LF**) and in the third only with combination 7 ("N" or ";").

Each code has a complementary code, i.e. inverting all bits of a valid code leads to another valid code, thus, an indication of the bit polarity (normal or inversed) of a received signal cannot be made. Both possibilities have to be displayed and the operator has to decide which one is correct.

Two additional codes exceeding the 32-character ITA-2 table (but also complying with the minimum Hamming distance of 7) are the **IDLE** and the **UT** (Unperforated Tape) code.

Table 4-20: HNG-FEC code table.

Combination		Binary code		Level	
HNG-FEC	ITA-2	ITA-2	HNG-FEC	Letter	Figure
1	32	00000	10001 00101 11110	BLK	
2	20	00001	10000 01100 01001	T	5
3	27	00010	10011 10110 10000	CR	

HNG-FEC Code Table

Combination		Binary code		Level	
HNG-FEC	ITA-2	ITA-2	HNG-FEC	Letter	Figure
4	15	00011	10010 11111 00111	O	9
5	31	00100	10101 01010 10101	SPC	
6	8	00101	10100 00011 00010	H	(undef)
7	14	00110	10111 11001 11011	N	,
8	13	00111	10110 10000 01100	M	.
9	28	01000	11001 11011 01000	LF	
10	12	01001	11000 10010 11111	L	)
11	18	01010	11011 01000 00110	R	4
12	7	01011	11010 00001 10001	G	(undef)
13	9	01100	11101 10100 00011	I	8
14	16	01101	11100 11101 10100	P	0
15	3	01110	11111 00111 01101	C	:
16	22	01111	11110 01110 11010	V	=
17	5	10000	00001 10001 00101	E	3
18	26	10001	00000 11000 10010	Z	+
19	4	10010	00011 00010 01011	D	WRU
20	2	10011	00010 01011 11100	B	?
21	19	10100	00101 11110 01110	S	'
22	25	10101	00100 10111 11001	Y	6
23	6	10110	00111 01101 00000	F	(undef)
24	24	10111	00110 00100 10111	X	/
25	1	11000	01001 01111 10011	A	-
26	23	11001	01000 00110 00100	W	2
27	10	11010	01011 11100 11101	J	BEL
28	30	11011	01010 10101 01010	FIGS	
29	21	11100	01101 00000 11000	U	7
30	17	11101	01100 01001 01111	Q	1
31	11	11110	01111 10011 10110	K	(
32	29	11111	01110 11010 00001	LTRS	
			11010 01100 10011	IDLE	
			00101 10011 01100	UT	

4.7 RUM-FEC Code Table

Similar to HNG-FEC (see [chapter 4.6](#)), the RUM-FEC (see [chapter 3.85, "RUM-FEC"](#), on page 256) alphabet follows the one of ITA-2 and therefore consists of 32 codes, they are made up of 16 bits each. The complete set is shown in [table 4-21](#). It can be seen that both in "horizontal" and in "vertical" direction the code falls in groups of 4, i.e. horizontally in elements of 4 bits and vertically in groups of 4 codes being very similar to each other (only differing in the status "erect" or "inverted" of each corresponding 4-bit group). All 4-bit elements are odd parity (odd count of '1's), they are formed from the bits of the original ITA-2 code bits and are combined in a way giving a code with a minimum Hamming distance of 8, again (like as HNG-FEC code) being able to correct any (up to) 3-bit error.

Example: The second 4-bit element of RUM-FEC combinations 2, 6, 10 (and so on) is always 0001_2 or its inverted value 1110_2 .

The "complementary code" feature also exists here (a code being inverted in all bits leads to another existing code), so that polarity of a received signal cannot be determined. The user must select from both alternatives displayed which is the correct one.

Table 4-21: RUM-FEC code table.

Combination		Binary code		Level	
RUM-FEC	ITA-2	ITA-2	RUM-FEC	Letter	Figure
1	32	00000	0010 0100 1110 0001	BLK	
2	20	00001	0111 0001 1011 0100	T	5
3	27	00010	0001 0111 1101 0010	CR	
4	15	00011	1011 1101 0111 1000	O	9
5	31	00100	0010 1011 1110 1110	SPC	
6	8	00101	1000 0001 0100 0100	H	(undef)
7	14	00110	1110 0111 0010 0010	N	,
8	13	00111	0100 1101 1000 1000	M	.
9	28	01000	0010 0100 0001 1110	LF	
10	12	01001	1000 1110 1011 0100	L	)
11	18	01010	1110 1000 1101 0010	R	4
12	7	01011	0100 0010 0111 1000	G	(undef)
13	9	01100	1101 0100 1110 1110	I	8
14	16	01101	0111 1110 0100 0100	P	0
15	3	01110	0001 1000 0010 0010	C	:
16	22	01111	1011 0010 1000 1000	V	=
17	5	10000	1101 1011 1110 0001	E	3
18	26	10001	0111 0001 0100 1011	Z	+

Combination		Binary code		Level	
RUM-FEC	ITA-2	ITA-2	RUM-FEC	Letter	Figure
19	4	10010	0001 0111 0010 1101	D	WRU
20	2	10011	1011 1101 1000 0111	B	?
21	19	10100	0010 1011 0001 0001	S	'
22	25	10101	1000 0001 1011 1011	Y	6
23	6	10110	1110 0111 1101 1101	F	(undef)
24	24	10111	0100 1101 0111 0111	X	/
25	1	11000	1101 1011 0001 1110	A	-
26	23	11001	1000 1110 0100 1011	W	2
27	10	11010	1110 1000 0010 1101	J	BEL
28	30	11011	0100 0010 1000 0111	FIGS	
29	21	11100	1101 0100 0001 0001	U	7
30	17	11101	0111 1110 1011 1011	Q	1
31	11	11110	0001 1000 1101 1101	K	(
32	29	11111	1011 0010 0111 0111	LTRS	

4.8 GMDSS/DSC Code Table

The GMDSS/DSC (see [chapter 3.48, "GMDSS/DSC-HF"](#), on page 138 and [chapter 3.49, "GMDSS/DSC-VHF"](#), on page 142) 10-bit error-detecting code is shown in [table 4-22](#). It is constructed from 7 bits representing the No. of the symbol in dual notation (but **MSB** right) and 3 control bits indicating the count of '0' bits in the first 7 bits. The minimum Hamming distance achieved this way is 2 and therefore single bit errors can be detected (but not corrected).

Table 4-22: GMDSS/DSC code table.

Symbol No.	Emitted signal	Symbol No.	Emitted signal	Symbol No.	Emitted signal
00	0000000 111	43	1101010 011	86	0110101 011
01	1000000 110	44	0011010 100	87	1110101 010
02	0100000 110	45	1011010 011	88	0001101 100
03	1100000 101	46	0111010 011	89	1001101 011
04	0010000 110	47	1111010 010	90	0101101 011
05	1010000 101	48	0000110 101	91	1101101 010
06	0110000 101	49	1000110 100	92	0011101 011
07	1110000 100	50	0100110 100	93	1011101 010

Symbol No.	Emitted signal	Symbol No.	Emitted signal	Symbol No.	Emitted signal
08	0001000 110	51	1100110 011	94	0111101 010
09	1001000 101	52	0010110 100	95	1111101 001
10	0101000 101	53	1010110 011	96	0000011 101
11	1101000 100	54	0110110 011	97	1000011 100
12	0011000 101	55	1110110 010	98	0100011 100
13	1011000 100	56	0001110 100	99	1100011 011
14	0111000 100	57	1001110 011	100	0010011 100
15	1111000 011	58	0101110 011	101	1010011 011
16	0000100 110	59	1101110 010	102	0110011 011
17	1000100 101	60	0011110 011	103	1110011 010
18	0100100 101	61	1011110 010	104	0001011 100
19	1100100 100	62	0111110 010	105	1001011 011
20	0010100 101	63	1111110 001	106	0101011 011
21	1010100 100	64	0000001 110	107	1101011 010
22	0110100 100	65	1000001 101	108	0011011 011
23	1110100 011	66	0100001 101	109	1011011 010
24	0001100 101	67	1100001 100	110	0111011 010
25	1001100 100	68	0010001 101	111	1111011 001
26	0101100 100	69	1010001 100	112	0000111 100
27	1101100 011	70	0110001 100	113	1000111 011
28	0011100 100	71	1110001 011	114	0100111 011
29	1011100 011	72	0001001 101	115	1100111 010
30	0111100 011	73	1001001 100	116	0010111 011
31	1111100 010	74	0101001 100	117	1010111 010
32	0000010 110	75	1101001 011	118	0110111 010
33	1000010 101	76	0011001 100	119	1110111 001
34	0100010 101	77	1011001 011	120	0001111 011
35	1100010 100	78	0111001 011	121	1001111 010
36	0010010 101	79	1111001 010	122	0101111 010
37	1010010 100	80	0000101 101	123	1101111 001
38	0110010 100	81	1000101 100	124	0011111 010
39	1110010 011	82	0100101 100	125	1011111 001
40	0001010 101	83	1100101 011	126	0111111 001

Symbol No.	Emitted signal	Symbol No.	Emitted signal	Symbol No.	Emitted signal
41	1001010 100	84	0010101 100	127	1111111 000
42	0101010 100	85	1010101 011		

4.9 Varicode Code Table

Varicode is an entropy coding method, i.e., the codes of frequently occurring characters are shorter (less bits to represent) than the ones of rare characters – similarly to Morse code ([chapter 4.5](#)) or Huffman code ([chapter 4.4](#)). It was developed by *Peter Martinez* in 1997 to improve transmission speed of SLOWBPSK. He investigated large amounts of English text for frequency of the individual letters.

The further properties of Varicode are

- Minimum code length is 1 bit, maximum 10 bits
- Each code starts and terminates with a '1' bit
- Only single (no consecutive) '0' bits exist within a code
- The "00" sequence serves as separating sign between the characters
- The original character set to assign new codes to was [ASCII \(chapter 4.2\)](#). Originally only regular ASCII characters had been supported (i.e., for example, no umlauts in languages other than English), but since 1998 also the upper 128 characters were used (but not sorted by frequency)
- Due to dependence on English language, in other languages compression rates might be weaker

The character considered to be the most frequent one is `SPC` (ASCII 20₁₆), thus it is represented by a single 1_V (the starting and terminating '1's coinciding; "V" meaning "Varicode"); the next characters are "e" (65₁₆, only consisting of these two '1's: 11_V), "t" (74₁₆, 101_V) and "o" (6F₁₆, 111_V), followed mainly by small letters ("a", 61₁₆; "i", 69₁₆; "n", 6E₁₆, ...) and the two control characters `LF` and `CR`, then capital letters, digits, special and the remaining control characters. The complete code table is given in [table 4-23](#).

Table 4-23: Varicode code table.

hex.	Char.	Varicode code	hex.	Char.	Varicode code	hex.	Char.	Varicode code
0	NUL	1 0101 0101 1	2B	+	1 110 1111 1	56	V	1 101 1010 1
1	SOH	1 0110 1101 1	2C	,	1 1 1010 1	57	W	1 010 1110 1
2	STX	1 0111 0110 1	2D	-	1 1010 1	58	X	1 011 1010 1
3	ETX	1 1011 1011 1	2E	.	1 0 1011 1	59	Y	1 011 1101 1
4	EOT	1 0111 0101 1	2F	/	1 101 0111 1	5A	Z	1 0101 0110 1
5	ENQ	1 1010 1111 1	30	0	1 01 1011 1	5B	(var.)	1 111 1011 1
6	ACK	1 0111 0111 1	31	1	1 01 1110 1	5C	(var.)	1 111 0111 1

Varicode Code Table

hex.	Char.	Varicode code	hex.	Char.	Varicode code	hex.	Char.	Varicode code
7	BEL	1 0111 1110 1	32	2	1 11 0110 1	5D	(var.)	1 111 1101 1
8	BS	1 0111 1111 1	33	3	1 11 1111 1	5E	(var.)	1 0101 1111 1
9	HT	1 11 0111 1	34	4	1 011 1011 1	5F	—	1 011 0110 1
A	LF	1 110 1	35	5	1 010 1101 1	60	(var.)	1 0110 1111 1
B	VT	1 1011 0111 1	36	6	1 011 0101 1	61	a	1 01 1
C	FF	1 0110 1110 1	37	7	1 101 0110 1	62	b	1 0 1111 1
D	CR	1 111 1	38	8	1 101 0101 1	63	c	1 0111 1
E	SO	1 1011 1010 1	39	9	1 101 1011 1	64	d	1 0110 1
F	SI	1 1101 0101 1	3A	:	1 11 1010 1	65	e	1 1
10	DLE	1 0111 1011 1	3B	;	1 101 1110 1	66	f	1 1110 1
11	DC1	1 0111 1010 1	3C	<	1 111 0110 1	67	g	1 0 1101 1
12	DC2	1 1101 0110 1	3D	=	1 0 1010 1	68	h	1 0101 1
13	DC3	1 1101 0111 1	3E	>	1 110 1011 1	69	i	1 10 1
14	DC4	1 1010 1101 1	3F	?	1 0101 0111 1	6A	j	1 111 0101 1
15	NAK	1 1011 0101 1	40	(var.)	1 0101 1110 1	6B	k	1 01 1111 1
16	SYN	1 1011 0110 1	41	A	1 1 1110 1	6C	l	1 101 1
17	ETB	1 1010 1011 1	42	B	1 11 0101 1	6D	m	1 1101 1
18	CAN	1 1011 1101 1	43	C	1 01 0110 1	6E	n	1 11 1
19	EM	1 1011 1110 1	44	D	1 01 1010 1	6F	o	1 1 1
1A	SUB	1 1101 1011 1	45	E	1 1 1011 1	70	p	1 1111 1
1B	ESC	1 1010 1010 1	46	F	1 10 1101 1	71	q	1 101 1111 1
1C	FS	1 1010 1110 1	47	G	1 11 1110 1	72	r	1 010 1
1D	GS	1 1101 1101 1	48	H	1 010 1010 1	73	s	1 011 1
1E	RS	1 0111 1101 1	49	I	1 1 1111 1	74	t	1 0 1
1F	US	1 1011 1111 1	4A	J	1 111 1110 1	75	u	1 1011 1
20	SPC	1	4B	K	1 011 1110 1	76	v	1 1 1101 1
21	!	1 111 1111 1	4C	L	1 10 1011 1	77	w	1 1 0101 1
22	"	1 010 1111 1	4D	M	1 01 1101 1	78	x	1 10 1111 1
23	(var.)	1 111 1010 1	4E	N	1 10 1110 1	79	y	1 0 1110 1
24	(var.)	1 110 1101 1	4F	O	1 01 0101 1	7A	z	1 110 1010 1
25	%	1 0110 1010 1	50	P	1 10 1010 1	7B	(var.)	1 0101 1011 1
26	&	1 0101 1101 1	51	Q	1 110 1110 1	7C	(var.)	1 101 1101 1
27	'	1 011 1111 1	52	R	1 01 0111 1	7D	(var.)	1 0101 1010 1

hex.	Char.	Varicode code	hex.	Char.	Varicode code	hex.	Char.	Varicode code
28	(	1 11 1101 1	53	S	1 1 0111 1	7E	(var.)	1 0110 1011 1
29	)	1 11 1011 1	54	T	1 1 0110 1	7F	DEL	1 1101 1010 1
2A	*	1 011 0111 1	55	U	1 010 1011 1			

4.10 MFSK Varicode Code Table

Another entropy code to a certain degree different from Varicode ([table 4-23](#) in [chapter 4.9](#)) is MFSK Varicode (see [chapter 3.84](#), "PSK63F, PSK125F, PSK220F", on page 255). It was invented by *Nino Porcino* and *Murray Greenman* in 2000 and is shown in [table 4-24](#). Also deviant is the probability distribution of characters and the different handling of the idle condition. Therewith, in this code also successive '0's occur, but only terminating (not inside) the character concerned; the '1' introducing each character also exists here.

The maximum length of 12 bits at first glance seems to be more than 10 bits in Varicode, but be aware that the two '0' bits separating the characters are shown as already part of each code, so maximum code length is the same in both alphabets. Tests with standard text files revealed a speed increase of about 13 % (only uppercase letters used) up to 20 % (also lowercase letters).

The table shows only the lower half of the [ASCII](#) characters 0 to $7F_{16}$ (127_{10}); codes also exist for ASCII characters 80_{16} (128_{10}) to FF_{16} (255_{10}), they can be looked up in relevant publications.

Table 4-24: MFSK Varicode code table.

hex.	Char.	Varicode code	hex.	Char.	Varicode code	hex.	Char.	Varicode code
0	NUL	1 1101 0111 00	2B	+	1 11 1000 00	56	V	1 10 1010 00
1	SOH	1 1101 1000 00	2C	,	1 0 1000 00	57	W	1 01 1010 00
2	STX	1 1101 1010 00	2D	-	1 11 0110 00	58	X	1 01 1100 00
3	ETX	1 1101 1011 00	2E	.	1 11 0101 00	59	Y	1 01 1110 00
4	EOT	1 1101 1100 00	2F	/	1 11 1010 00	5A	Z	1 10 1110 00
5	ENQ	1 1101 1101 00	30	0	1 1 1000 00	5B	(var.)	1 011 1010 00
6	ACK	1 1101 1110 00	31	1	1 1 1100 00	5C	(var.)	1 011 0100 00
7	BEL	1 1101 1111 00	32	2	1 01 0000 00	5D	(var.)	1 011 1011 00
8	BS	1 0 1010 00	33	3	1 01 0101 00	5E	(var.)	1 011 0101 00
9	HT	1 1110 0000 00	34	4	1 01 1101 00	5F	—	1 010 1100 00
A	LF	1 1110 1000 00	35	5	1 01 1000 00	60	(var.)	1 010 1011 00
B	VT	1 1110 1010 00	36	6	1 01 1011 00	61	a	1 01 00
C	FF	1 1110 1011 00	37	7	1 10 1000 00	62	b	1 1000 00
D	CR	1 0 1011 00	38	8	1 10 0000 00	63	c	1 110 00

MFSK Varicode Code Table

hex.	Char.	Varicode code	hex.	Char.	Varicode code	hex.	Char.	Varicode code
E	SO	1 1110 1100 00	39	9	1 10 1011 00	64	d	1 101 00
F	SI	1 1110 1101 00	3A	:	1 11 1011 00	65	e	1 0 00
10	DLE	1 1110 1110 00	3B	;	1 11 1110 00	66	f	1 0100 00
11	DC1	1 1110 1111 00	3C	<	1 011 0000 00	67	g	1 0110 00
12	DC2	1 1111 0000 00	3D	=	1 11 0111 00	68	h	1 100 00
13	DC3	1 1111 0100 00	3E	>	1 010 1111 00	69	i	1 10 00
14	DC4	1 1111 0101 00	3F	?	1 11 0100 00	6A	j	1 0 0000 00
15	NAK	1 1111 0110 00	40	(var.)	1 010 0000 00	6B	k	1 1100 00
16	SYN	1 1111 0111 00	41	A	1 0 1111 00	6C	l	1 011 00
17	ETB	1 1111 1000 00	42	B	1 00 0000 00	6D	m	1 0000 00
18	CAN	1 1111 1010 00	43	C	1 1 0101 00	6E	n	1 11 00
19	EM	1 1111 1011 00	44	D	1 1 0111 00	6F	o	1 00 00
1A	SUB	1 1111 1100 00	45	E	1 0 1110 00	70	p	1 0101 00
1B	ESC	1 1111 1101 00	46	F	1 1 1110 00	71	q	1 1110 00
1C	FS	1 1111 1110 00	47	G	1 01 0100 00	72	r	1 000 00
1D	GS	1 1111 1111 00	48	H	1 01 0110 00	73	s	1 010 00
1E	RS	1 0 0000 0000 00	49	I	1 1 0000 00	74	t	1 1 00
1F	US	1 0 1000 0000 00	4A	J	1 10 1101 00	75	u	1 111 00
20	SPC	1 00	4B	K	1 01 1111 00	76	v	1 1011 00
21	!	1 11 0000 00	4C	L	1 1 1101 00	77	w	1 1010 00
22	"	1 11 1111 00	4D	M	1 1 1010 00	78	x	1 1101 00
23	(var.)	1 011 0110 00	4E	N	1 1 1111 00	79	y	1 0111 00
24	(var.)	1 010 1010 00	4F	O	1 1 0100 00	7A	z	1 1111 00
25	%	1 010 1000 00	50	P	1 1 1011 00	7B	(var.)	1 011 0111 00
26	&	1 000 0000 00	51	Q	1 10 1100 00	7C	(var.)	1 010 1110 00
27	'	1 10 1111 00	52	R	1 1 0110 00	7D	(var.)	1 011 1000 00
28	(	1 11 1101 00	53	S	1 0 1101 00	7E	(var.)	1 011 1100 00
29	)	1 11 1100 00	54	T	1 0 1100 00	7F	DEL	1 0 1010 0000 00
2A	*	1 010 1101 00	55	U	1 01 0111 00			

4.11 COQUELET-8 Tone Table

See [chapter 3.33, "COQUELET-8"](#), on page 104 and [chapter 3.35, "COQUELET-80"](#), on page 108.

Table 4-25: COQUELET-8 tone and code table, sorted by tones (and also code bits).

Tone n		Meaning in level		Bits	Tone n		Meaning in level		Bits
1st	2nd	Letter	Figure		1st	2nd	Letter	Figure	
0	4	Space		00000	4	4	E	3	10000
0	5	T	5	00001	4	5	Z	+	10001
0	6	Carriage return		00010	4	6	D	#	10010
0	7	O	9	00011	4	7	B	?	10011
1	4	Gap		00100	5	4	S	'	10100
1	5	H	[	00101	5	5	Y	6	10101
1	6	N	,	00110	5	6	F	"	10110
1	7	M	.	00111	5	7	X	/	10111
2	4	Line feed		01000	6	4	A	-	11000
2	5	L	)	01001	6	5	W	2	11001
2	6	R	4	01010	6	6	J	%	11010
2	7	G	]	01011	6	7	Figure shift		11011
3	4	I	8	01100	7	4	U	7	11100
3	5	P	0	01101	7	5	Q	1	11101
3	6	C	:	01110	7	6	K	(	11110
3	7	V	=	01111	7	7	Letter shift		11111

Table 4-26: COQUELET-8 tone and code table, sorted by characters.

Tone n		Meaning in level		Bits	Tone n		Meaning in level		Bits
1st	2nd	Letter	Figure		1st	2nd	Letter	Figure	
6	4	A	-	11000	7	5	Q	1	11101
4	7	B	?	10011	2	6	R	4	01010
3	6	C	:	01110	5	4	S	'	10100
4	6	D	#	10010	0	5	T	5	00001
4	4	E	3	10000	7	4	U	7	11100
5	6	F	"	10110	3	7	V	=	01111
2	7	G	]	01011	6	5	W	2	11001
1	5	H	[	00101	5	7	X	/	10111
3	4	I	8	01100	5	5	Y	6	10101

Tone n		Meaning in level		Bits	Tone n		Meaning in level		Bits
1st	2nd	Letter	Figure		1st	2nd	Letter	Figure	
6	6	J	%	11010	4	5	Z	+	10001
7	6	K	(	11110	0	6	Carriage return		00010
2	5	L	)	01001	2	4	Line feed		01000
1	7	M	.	00111	1	4	Gap		00100
1	6	N	,	00110	6	7	Figure shift		11011
0	7	O	9	00011	7	7	Letter shift		11111
3	5	P	0	01101	0	4	Space		00000

4.12 COQUELET-13 Tone Table

See [chapter 3.34, "COQUELET-13"](#), on page 106.

Table 4-27: COQUELET-13 (Table 0 and 1) tone and code table, sorted by code bits.

Table		Table		Table		Table		Table		Table		Table		Table	
0		1		0		1		0		1		0		1	
Tone n		Tone n		Tone n		Tone n		Tone n		Tone n		Tone n		Tone n	
1st	2nd	1st	2nd	Letter	Figure	Bits	1st	2nd	1st	2nd	Letter	Figure	Bits	1st	2nd
7	12	7	9	ZERO		00000	7	10	7	12	E	3	10000	7	10
2	12	3	9	T	5	00001	2	10	3	12	Z	+	10001	2	10
6	12	2	9	Carriage return		00010	6	10	2	12	D		10010	6	10
1	12	5	9	O	9	00011	1	10	5	12	B	?	10011	1	10
3	12	4	9	Gap		00100	3	10	4	12	S		10100	3	10
4	12	6	9	H		00101	4	10	6	12	Y	6	10101	4	10
5	12	1	9	N	,	00110	5	10	1	12	F		10110	5	10
0	12	0	9	M	.	00111	0	10	0	12	X	/	10111	0	10
7	11	7	11	Line feed		01000	7	9	7	10	A	-	11000	7	9
2	11	3	11	L	)	01001	2	9	3	10	W	2	11001	2	9
6	11	2	11	R	4	01010	6	9	2	10	J	BEL	11010	6	9
1	11	5	11	G		01011	1	9	5	10	Figure shift		11011	1	9
3	11	4	11	I	8	01100	3	9	4	10	U	7	11100	3	9
4	11	6	11	P	0	01101	4	9	6	10	Q	1	11101	4	9
5	11	1	11	C	:	01110	5	9	1	10	K	(	11110	5	9
0	11	0	11	V	=	01111	0	9	0	10	Letter shift		11111	0	9
							8	8	8	8	Start/idle				

Table 4-28: COQUELET-13 (Table 0 and 1) tone and code table, sorted by characters.

Table				Meaning in level		Bits	Table				Meaning in level		Bits	
0		1					0		1					
Tone n							Tone n							
1st	2nd	1st	2nd	Letter	Figure		1st	2nd	1st	2nd	Letter	Figure		
7	9	7	10	A	-	11000	6	11	2	11	R	4	01010	
1	10	5	12	B	?	10011	3	10	4	12	S		10100	
5	11	1	11	C	:	01110	2	12	3	9	T	5	00001	
6	10	2	12	D		10010	3	9	4	10	U	7	11100	
7	10	7	12	E	3	10000	0	11	0	11	V	=	01111	
5	10	1	12	F		10110	2	9	3	10	W	2	11001	
1	11	5	11	G		01011	0	10	0	12	X	/	10111	
4	12	6	9	H		00101	4	10	6	12	Y	6	10101	
3	11	4	11	I	8	01100	2	10	3	12	Z	+	10001	
6	9	2	10	J	BEL	11010	6	12	2	9	Carriage return		00010	
5	9	1	10	K	(	11110	7	11	7	11	Line feed		01000	
2	11	3	11	L	)	01001	3	12	4	9	Gap		00100	
0	12	0	9	M	.	00111	1	9	5	10	Figure shift		11011	
5	12	1	9	N	,	00110	0	9	0	10	Letter shift		11111	
1	12	5	9	O	9	00011	7	12	7	9	ZERO		00000	
4	11	6	11	P	0	01101	8	8	8	8	Start/idle			
4	9	6	10	Q	1	11101								

Table 4-29: COQUELET-13 (Table 0) tone and code table, sorted by tones.

Tone n		Meaning in level		Bits	Tone n		Meaning in level		Bits
1st	2nd	Letter	Figure		1st	2nd	Letter	Figure	
0	9	Letter shift		11111	4	9	Q	1	11101
0	10	X	/	10111	4	10	Y	6	10101
0	11	V	=	01111	4	11	P	0	01101
0	12	M	.	00111	4	12	H		00101
1	9	Figure shift		11011	5	9	K	(	11110
1	10	B	?	10011	5	10	F		10110
1	11	G	:	01011	5	11	C	:	01110
1	12	O	9	00011	5	12	N	,	00110
2	9	W	2	11001	6	9	J	BEL	11010
2	10	Z	+	10001	6	10	D		10010

Tone n		Meaning in level			Tone n		Meaning in level		
1st	2nd	Letter	Figure	Bits	1st	2nd	Letter	Figure	Bits
2	11	L	)	01001	6	11	R	4	01010
2	12	T	5	00001	6	12	Carriage return		00010
3	9	U	7	11100	7	9	A	-	11000
3	10	S		10100	7	10	E	3	10000
3	11	I	8	01100	7	11	Line feed		01000
3	12	Gap		00100	7	12	ZERO		00000
					8	8	Start/idle		

Table 4-30: COQUELET-13 (Table 1) tone and code table, sorted by tones.

Tone n		Meaning in level		Bits	Tone n		Meaning in level		Bits
1st	2nd	Letter	Figure		1st	2nd	Letter	Figure	
0	9	M	.	00111	4	9	Gap		00100
0	10	Letter shift		11111	4	10	U	7	11100
0	11	V	=	01111	4	11	I	8	01100
0	12	X	/	10111	4	12	S		10100
1	9	N	,	00110	5	9	O	9	00011
1	10	K	(	11110	5	10	Figure shift		11011
1	11	C	:	01110	5	11	G		01011
1	12	F		10110	5	12	B	?	10011
2	9	Carriage return		00010	6	9	H		00101
2	10	J	BEL	11010	6	10	Q	1	11101
2	11	R	4	01010	6	11	P	0	01101
2	12	D		10010	6	12	Y	6	10101
3	9	T	5	00001	7	9	ZERO		00000
3	10	W	2	11001	7	10	A	-	11000
3	11	L	)	01001	7	11	Line feed		01000
3	12	Z	+	10001	7	12	E	3	10000
					8	8	Start/idle		

4.13 Piccolo-6 (MK 6) Tone Table

See [chapter 3.78, "Piccolo-6 \(MK 6\)"](#), on page 242.

Table 4-31: Mapping between tone combination and ITA-2 character (inverted shift is equivalent to substituting Tone i by Tone 5-i).

Tone n		Shift normal		Shift inverted		Tone n		Shift normal		Shift inverted	
1st	2nd	Letter	Figure	Letter	Figure	1st	2nd	Letter	Figure	Letter	Figure
0	0	Q	1	K	(	3	0	E	3	B	?
0	1	Y	6	F	!	3	1	ZERO		O	9
0	2	W	2	J	BEL	3	2			IDL	
0	3	FS		A	-	3	3				
0	4	X	/	S	'	3	4	CR		T	5
0	5	LS		U	7	3	5	D	\$	Z	+
1	0	P	0	C	:	4	0	I	8	V	:
1	1	H	#	N	,	4	1	SP		M	.
1	2	L	)	R	4	4	2	LF		G	&
1	3	G	&	LF		4	3	R	4	L	)
1	4	M	.	SP		4	4	N	,	H	#
1	5	V	=	I	8	4	5	C	:	P	0
2	0	Z	+	D	\$	5	0	U	7	LS	
2	1	T	5	CR		5	1	S	'	X	/
2	2	SBY		ZERO		5	2	A	-	A	-
2	3					5	3	J	BEL	W	2
2	4					5	4	F	!	Y	6
2	5	B	?	E	3	5	5	K	(	Q	1

4.14 Piccolo-12 (MK 6) Tone Table

See [chapter 3.79, "Piccolo-12 \(MK 6\)"](#), on page 246.

Table 4-32: Mapping between tone combination and ITA-5 (ASCII) character.

Tone n		2nd Tone											
1st Tone		0	1	2	3	4	5	6	7	8	9	10	11
0			DLE	DC4	4	0			8	<	FS	CAN	
1		DC2	DC1	DC3	3	1	2	:	9	;	ESC	EM	SUB
2		SYN	NAK	ETB	7	5	6	>	=	?	US	GS	RS
3		V	U	W	w	u	v	~	}	DEL	_	]	^
4		R	Q	S	s	q	r	z	y	{	[	Y	Z
5			P	T	t				x		\	X	

Tone n	2nd Tone											
1st Tone	0	1	2	3	4	5	6	7	8	9	10	11
6		@	D	d	`			l	h	L	H	
7	B	A	C	c	a	b	j	i	k	K	I	J
8	F	E	G	g	e	f	n	m	o	O	M	N
9	ACK	ENQ	BEL	'	%	&	.	-	/	SI	CR	SO
10	STX	SOH	ETX	#	!	"	*	)	+	VT	HT	LF
11		ZERO	EOT	\$	SPC			(	,	FF	BS	

Table 4-33: Explanation of control character designations.

ACK	Acknowledge	EM	End of Medium	RS	Record Separator
BEL	Bell	EOT	End of Transmission	SI	Shift In
BS	Backspace	ESC	Escape	SO	Shift Out
CAN	Cancel	ETB	End of Block	SOH	Start of Header
CR	Carriage Return	ETX	End of Text	SPC	Space
DC1	Device Control 1	FF	Form Feed	STX	Start of Text
DC2	Device Control 2	FS	File Separator	SUB	Substitute
DC3	Device Control 3	GS	Group Separator	SYN	Synchronous Idle
DC4	Device Control 4	HT	Horizontal Tab	US	Unit Separator
DEL	Delete	LF	Line Feed	VT	Vertical Tab
DLE	Data Link Escape	NAK	Negative Acknowledge		
ENQ	Enquiry or WRU	ZERO	Zero		

Table 4-34: Mapping between tone combination and ITA-5 (ASCII) or ITA-2 (the central 6x6 matrix shown in bold letters) code, respectively. X = non-valid character (tone combination not existing).

Tone n	2nd Tone											
1st Tone	0	1	2	3	4	5	6	7	8	9	10	11
0	X	0010	0010	0110	0110	X	X	0111	0111	0011	0011	X
		000	100	100	000			000	100	100	000	
1	0010	0010	0010	0110	0110	0110	0111	0111	0111	0011	0011	0011
	010	001	011	011	001	010	010	001	011	011	001	010
2	0010	0010	0010	0110	0110	0110	0111	0111	0111	0011	0011	0011
	110	101	111	111	101	110	110	101	111	111	101	110
3	1010	1010	1010	1110	1110	1110	1111	1111	1111	1011	1011	1011
	110	101	111	111	101	110	110	101	111	111	101	110
4	1010	1010	1010	1110	1110	1110	1111	1111	1111	1011	1011	1011
	010	001	011	011	001	010	010	001	011	011	001	010

Tone n		2nd Tone											
1st Tone		0	1	2	3	4	5	6	7	8	9	10	11
5	X	1010	1010	1110	1110	X	stand by	1111	1111	1011	1011	X	
		000	100	100	000								
6	X	1000	1000	1100	1100	X	X	1101	1101	1001	1001	X	
		000	100	100	000								
7		1000	1000	1000	1100	1100	1100	1101	1101	1101	1001	1001	1001
		010	001	011	011	001	010	010	001	011	011	001	010
8		1000	1000	1000	1100	1100	1100	1101	1101	1101	1001	1001	1001
		110	101	111	111	101	110	110	101	111	111	101	110
9		0000	0000	0000	0100	0100	0100	0101	0101	0101	0001	0001	0001
		110	101	111	111	101	110	110	101	111	111	101	110
10		0000	0000	0000	0100	0100	0100	0101	0101	0101	0001	0001	0001
		010	001	011	011	001	010	010	001	011	011	001	010
11	X	0000	0000	0100	0100	X	X	0101	0101	0001	0001	X	
		000	100	100	000								



Cross-reference glossary

The cross-reference glossary is only intended to direct a user, knowing a certain (alternative) name of a demodulation/decoding method, to the correct chapter in which this method is described. Any additional statements are not made here (in the glossary or when telling these alternative names) – e.g. if different names call only parts of a particular method, telling these names in parallel does not comprise that also the described method parts coincide.

Glossary: Aliases and Variants

Symbols

2 channel ITA-2 RTTY: [TWINPLEX-BAUDOT](#) (chapter 3.97 on page 297)

2-PSK: [PSK_n](#) (chapter 2.3 on page 14)

2G ALE: [MIL-STD-188-141A](#) (chapter 3.66 on page 198)

4-PSK: [PSK_n](#)

8-PSK: [PSK_n](#)

96-TDM: [ARQ-M](#) (chapter 3.13 on page 64)

125-ARTRAC: [DUP-ARQ](#) (chapter 3.39 on page 122)

192-TDM: [ARQ-M](#)

250-ARTRAC: [DUP-ARQ2](#) (chapter 3.40 on page 125)

802.11: [WLAN](#) (IEEE 802.11) (chapter 3.101 on page 311)

6028: [BARRIE 6028](#) (chapter 3.20 on page 83)

$\pi/2$ -(D)BPSK: [PSK_n](#)

$\pi/4$ -(D)QPSK: [PSK_n](#)

$\pi/8$ -(D)MPSK: [PSK_n](#)

A

ACARS: [ACARS-VUHF](#) (chapter 3.2 on page 34)

ACARS ARINC: [ACARS-VUHF](#)

ACARS SITA: [ACARS-VUHF](#)

ALE :: [MIL-STD-188-141A](#) (chapter 3.66 on page 198)

ALE 2G: [MIL-STD-188-141A](#)

ALE 3G: [MIL-STD-188-141B](#) (Appendix C) (chapter 3.67 on page 206)

ALIS-2000: [ALIS-2](#) (chapter 3.5 on page 44)

AMOR: [CIS-14](#) (chapter 3.25 on page 90)

AMOR 96: [CIS-14](#)

AMTOR: [SITOR-B](#) (chapter 3.88 on page 268)

AMTOR-ARQ: [SITOR-A](#) (chapter 3.87 on page 262)

AMTOR-FEC: [SITOR-B](#)

APCO-25: [APCO P25](#) (chapter 3.6 on page 45)

ARINC 618: [ACARS-VUHF](#)

ARINC 635: [ACARS-HF](#) (chapter 3.1 on page 31)

ARINC ANNEX 10 SELCAL: [ICAO-SELCAL](#) (chapter 3.59 on page 164)

ARQ :: [SITOR-A](#)

ARQ 625: [SITOR-A](#)

ARQ 1000S: [ARQ-S](#) (chapter 3.15 on page 69)

ARQ DUPLEX: [DUP-ARQ](#) (chapter 3.39 on page 122)

ARQ-28: [ARQ-M](#) (chapter 3.13 on page 64)

ARQ-56: [ARQ-M](#)

ARQ-1000: [ARQ-N](#) (chapter 3.14 on page 68)

ARQ-1000 D: [ARQ-E](#) (chapter 3.11 on page 61)

ARQ-1000 Duplex: [ARQ-E](#)

ARQ-M2-242: [ARQ-M](#)

ARQ-M2-342: [ARQ-M](#)

ARQ-M4-242: [ARQ-M](#)

ARQ-M4-342: [ARQ-M](#)

ARQ-POL: [POL-ARQ](#) (chapter 3.81 on page 251)

ARQ-SWE: [SWED-ARQ](#) (chapter 3.95 on page 285)

ARQ-SWED: [SWED-ARQ](#)

ARQ-TDM-242: [ARQ-M](#)

ARQ-TDM-342: [ARQ-M](#)

ARQM 2: [ARQ-M](#)

ARQM 4: [ARQ-M](#)

ARTRAC: [DUP-ARQ](#)

ARTRAC II: [DUP-ARQ2](#) (chapter 3.40 on page 125)

ASK-n: [ASKn](#) (chapter 2.1 on page 11)

AUM-13: [MTONE](#) (chapter 2.7 on page 28)

AUTOSPEC Mark II: [SPREAD-11](#), [SPREAD-21](#), [SPREAD-51](#) (chapter 3.90 on page 273)

AUTOSPEC MK 2: [SPREAD-11](#), [SPREAD-21](#), [SPREAD-51](#)

AUTOSPEC-BAUER: [AUTOSPEC](#) (chapter 3.19 on page 78)

B

BARRIE: [BARRIE 6028](#) (chapter 3.20 on page 83)

Baudot ITA2 F7b two channels: [TWINPLEX-BAUDOT](#) (chapter 3.97 on page 297)

BAUDOT/F7BBN: [TWINPLEX-BAUDOT](#)

BAUER: [AUTOSPEC](#) (chapter 3.19 on page 78)

BEE: [CIS-36-50](#) (chapter 3.27 on page 94) | [CIS-50-50](#) (chapter 3.28 on page 97)

BEE-36: [CIS-36-50](#)

BF6 Baudot F7B: [TWINPLEX-BAUDOT](#)

BPSK :: [PSKn](#) (chapter 2.3 on page 14) | [PSK31](#) (chapter 3.82, "PSK31, PSK63, PSK125, PSK220, PSK250 (BPSK)", on page 252)

BPSK31: [PSK31](#)

BR 6028: [BARRIE 6028](#)

C

CCIR 342-2: [ARQ-M](#) (chapter 3.13 on page 64)

CCIR 476 variant: [ARQ 6-70](#) (chapter 3.8 on page 57) | [ARQ 6-90](#) (chapter 3.9 on page 59) | [ARQ 6-98](#) (chapter 3.10 on page 60) | [POL-ARQ](#) (chapter 3.81 on page 251)

CCIR 519 variant: [ARQ-E3](#) (chapter 3.12 on page 63)

CCIR 584: [POCSAG](#) (chapter 3.80 on page 249)

CCIR M493-4 compatible: [CODAN 8580](#) (chapter 3.32 on page 103)

CCIR1: [SELCAL-5T](#) (chapter 3.86 on page 259)

CCIR2: [SELCAL-5T](#)

CCITT :: [SELCAL-5T](#)

CIS 10-11-11 MFSK: [CIS-36](#) (chapter 3.26 on page 93)

CIS AT-3104 Modem: [CIS-12](#) (chapter 3.24 on page 89)

CIS-96: [CIS-14](#) (chapter 3.25 on page 90)

CIS-Navy: [CIS-36-50](#) (chapter 3.27 on page 94)

CIS/Russian Piccolo: [CIS-36](#)

Cityruf: [POCSAG](#)

CLOVER: [CLOVER-II](#) (chapter 3.29 on page 98)

CLOVER-2: [CLOVER-II](#)

CODAN: [CODAN 3012](#) (chapter 3.31 on page 101)

CODAN 16 tone: [CODAN 3012](#)

CODAN 8580-SELCAL: [CODAN 8580](#)

CODAN 9001: [CODAN 3012](#)

CODAN 9002: [CODAN 3012](#)

CODAN-Selcall: [CODAN 8580](#)

COQ-8: [COQUELET-8](#) (chapter 3.33 on page 104)

COQ-8 FEC: [COQUELET-80](#) (chapter 3.35 on page 108)

COQ-13: [COQUELET-13](#) (chapter 3.34 on page 106)

COQUELET Mk I: [COQUELET-13](#)

COQUELET Mk II: [COQUELET-8](#)

COQUELET-8 FEC: [COQUELET-80](#)

COQUELET-80S: [COQUELET-80](#)

COQUELET-82S: [COQUELET-80](#)

CROWD-36: [CIS-36](#)

D

dPMR Tier 1/2: [DPMR](#) (chapter 3.37 on page 112)

dPMR446: [DPMR](#)

DSC :: [GMDSS/DSC-HF](#) (chapter 3.48 on page 138)

DUP-FEC: [DUP-FEC2](#) (chapter 3.41 on page 126)

E

E3: [ARQ-E3](#) (chapter 3.12 on page 63)

EEA: [SELCAL-5T](#) (chapter 3.86 on page 259)

EIA: [SELCAL-5T](#)

EURO: [SELCAL-5T](#)

F

F7B1 to F7B6: [TWINPLEX-SITOR](#) (chapter 3.98 on page 298)

FEC :: [SITOR-B](#) (chapter 3.88 on page 268)

FEC 625: [SITOR-B](#)

FEC B: [SITOR-B](#)

FEC-100: [FEC-A](#) (chapter 3.44 on page 130)

FEC-100A: [FEC-A](#)

FEC-101: [FEC-A](#)

FEC-1000 Simplex: [FEC-S](#) (chapter 3.45 on page 134)

FEC-1000S: [FEC-S](#)

FED-STD 1045A: [MIL-STD-188-141A](#) (chapter 3.66 on page 198)

FELDHELL: [HELLSCHREIBER AM](#) (chapter 3.54 on page 155)

FFSK :: [FSKn](#) (chapter 2.2 on page 12)

Fire: [CIS-12](#) (chapter 3.24 on page 89)

FMHELL: [HELLSCHREIBER FM](#) (chapter 3.55 on page 157)

FSK PACTOR: [PACTOR I](#) (chapter 3.74 on page 227)

FSK-n: [FSKn](#)

G

GMDSS-HF: [GMDSS/DSC-HF](#) (chapter 3.48 on page 138)

GMSK :: [FSKn](#) (chapter 2.2 on page 12)

H

Hagelin Crypto ARQ: [HC-ARQ](#) (chapter 3.53 on page 154)

HELL: [HELLSCHREIBER AM](#) (chapter 3.54 on page 155)

HELLSCHREIBER: [HELLSCHREIBER AM](#)

HFDL: [ACARS-HF](#) (chapter 3.1 on page 31)

I

ICRC-PACTOR: [PACTOR I](#) (chapter 3.74 on page 227)

IDAS: [NXDN](#) (chapter 3.70 on page 211)

IEEE 802.11: [WLAN \(IEEE 802.11\)](#) (chapter 3.101 on page 311)

IFRC-PACTOR: [PACTOR I](#)

IRA-ARQ: [ASCII](#) (chapter 3.16 on page 72)

ITA-2 Twin: [TWINPLEX-BAUDOT](#) (chapter 3.97 on page 297)

ITA2: [BAUDOT](#) (chapter 3.21 on page 84)

ITA5: [ASCII](#)

ITU-R M493-4 compatible: [CODAN 8580](#) (chapter 3.32 on page 103)

J

Javelin: [SkyFax](#) (chapter 3.89 on page 271)

M

METEOSAT: [METEOSAT-WEFAX](#) (chapter 3.61 on page 175)

MF4: [DTMF](#) (chapter 3.38 on page 121)

MFC: [DTMF](#)

MFSK :: [MTONE](#) (chapter 2.7 on page 28)

MFSK-8: [MTONE](#)

MFSK-16: [MTONE](#)

MFSK-20: [MTONE](#)

MFSK188: [MIL-STD-188-141A](#) (chapter 3.66 on page 198)

MFV: [DTMF](#)

MIL-188-141 ALE: [MIL-STD-188-141A](#)

MIL-STD-188-110 16 Tone: [MIL-STD-188-110A](#) (Appendix A) (chapter 3.63 on page 182)

MIL-STD-188-110 39 Tone: [MIL-STD-188-110A](#) (Appendix B) (chapter 3.64 on page 186)

MIL-STD-188-110A Parallel Tone: [MIL-STD-188-110A](#) (Appendix A) | [MIL-STD-188-110A](#) (Appendix B)

MIL-STD-188-110A serial: [MIL-STD-188-110A](#) (chapter 3.62 on page 176)

MIL-STD-188-110B (Appendix A): [MIL-STD-188-110A](#) (Appendix A)

MIL-STD-188-110B (Appendix B): [MIL-STD-188-110A](#) (Appendix B)

MIL-STD-188-141 (ALE): [MIL-STD-188-141A](#)

MIL-STD-188-141A/ALE : [MIL-STD-188-141A](#)

MIL188: [MIL-STD-188-141A](#)

MPSK :: [PSKn](#) (chapter 2.3 on page 14)

MS5: [CIS-12](#) (chapter 3.24 on page 89)

MSK :: [FSKn](#) (chapter 2.2 on page 12)

N

n-ASK: [ASKn](#) (chapter 2.1 on page 11)

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U

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Glossary: Abbreviations

Symbols

°: Degree

°C: Degree Celsius

2G: 2nd Generation

3G: 3rd Generation

3GPP: 3rd Generation Partnership Project

λ : Wavelength

μ s: Microsecond (10^{-6} s)

A

ACK: Acknowledge

AFSK: Audio [FSK](#)

ALE: Automatic Link Establishment

AM: Amplitude Modulation

AMTOR: Amateur Microprocessing Teleprinting over Radio

ANSI: American National Standards Institute (formerly [ASA](#))

APRS: Automatic Packet Reporting System

ARQ: Automatic Repeat/Repetition Request

ASA: American Standards Association (now [ANSI](#))

ASCII: American Standard Code for Information Interchange

ASK: Amplitude Shift Keying

ATC: Air Traffic Control

ATU: Arabic Telecommunication Union

B

B: Radio circuit state: data level 0, space, higher frequency

BCD: Binary Coded Decimal

BCH: Bose-Chaudhuri-Hocquenghem

Bd: Baud (symbols/s)

bit: Binary Digit (also used as a unit)

BPSK: Binary (2-ary) PSK

C

CB: Citizens' Band (11-m-band), Germany: 26.565 MHz to 27.405 MHz (80 channels), Europe: 26.965 MHz to 27.405 MHz (40 channels)

CCIR: (*French*) Comité Consultatif International des Radiocommunications (International Consultative Committee on Radio) (now ITU-R)

CCITT: (*French*) Comité Consultatif International Téléphonique et Télégraphique (International Telegraph and Telephone Consultative Committee) (now ITU-T)

CCK: Complementary Code Keying

CDMA: Code Division Multiple Access

CEPT: (*French*) Conférence Européenne des Administrations des Postes et des Télécommunications (European Conference of Postal and Telecommunications Administrations)

chip: (no abbreviation, but term for data element with CDMA, also used as a unit)

CIS: Commonwealth of Independent States

cm: Centimeter (10^{-2} m)

CRC: Character Repetition Cycle | Cyclic Redundancy Check/Code

CSMA/CA: Carrier Sense Multiple Access/Collision Avoidance

CW: Continuous Wave

D

D8PSK: Differential 8-ary PSK

dB: Dezibel

DBPSK: Differential Binary (2-ary) [PSK](#)

DCF77: D: Deutschland (Germany), C: long wave, F: Frankfurt, 77: 77.5 [kHz](#) (call sign of German standard-frequency radio station)

DFS: Dynamic Frequency Selection

DFT: Discrete Fourier Transformation

DPSK: Differential [PSK](#)

DQPSK: Differential Quaternary (4-ary) [PSK](#)

DSC: Digital Selective Calling

DSP: Digital Signal Processor/Processing

DSSS: Direct-Sequence Spread Spectrum

DVB-H: Digital Video Broadcasting for Handhelds

DX: Direct Transmission (level)

E

EFR: Enhanced Full Rate

EHR: Enhanced Half Rate

EN: (*German*) Europäische Norm (European standard) (or Euronorm)

EOM: End of Message

EPIRB: Emergency Position-Indicating Radio Beacon

ERP: Effective Radiated Power

ETSI: European Telecommunications Standards Institute

EU: European Union

EUMETSAT: European Organisation for the Exploitation of Meteorological Satellites

F

f: Frequency

FAX: Facsimile

FCC: Federal Communications Commission

FCO: (United Kingdom) Foreign and Commonwealth Office

FDM: Frequency Division Multiplex

FDMA: Frequency Division Multiple Access

FEC: Forward Error Correction

FFSK: Fast **FSK** (same as **MSK**)

FFT: Discrete Fourier Transformation

FHSS: Frequency-Hopping Spread Spectrum

FIR: Finite Impulse Response

FM: Frequency Modulation

FOT: Frequency for Optimum Traffic

FSK: Frequency Shift Keying

ft: Foot/Feet

G

GHz: Gigahertz (10^9 **Hz**)

GMSK: Gaussian Minimum Shift Keying, a special kind of **MSK**

GPS: Global Positioning System

GSM: Global System for Mobile Communications (formerly [*French*] Groupe Spécial Mobile [study group four mobile communications])

H

HAM: (Nickname for) Amateur Radio Operator (derived from the call sign of one of the first amateur radio stations: *Albert Hyman*, *Bob Almay* and *Peggy Murray*, Harvard Radio Club, 1908)

HDL: High-Rate Data Link

HDLC: High Level Data Link Control

HF: High Frequency ($f = 3 \text{ MHz}$ to 30 MHz , $\lambda = 10 \text{ m}$ to 200 m)

hPa: Hectopascal (10^2 Pascal)

Hz: Hertz

I

I: In-Phase

IALA: International Association of Marine Aids to Navigation and Lighthouse Authorities

ICAO: International Civil Aviation Organization

ICI: Interchannel Interference

ID: Identifier

IDFT: Inverse [DFT](#)

IEC: International Electrotechnical Commission

IEEE: Institute of Electrical and Electronics Engineers

IIR: Infinite Impulse Response

IMO: International Maritime Organization

IOC: Index of Cooperation

IP: Internet Protocol

IR: Infrared

IRA: International Reference Alphabet

IRS: Information Receiving Station

IRV: International Reference Version

ISDN: Integrated Services Digital Network

ISI: Intersymbol Interference

ISM: Industrial, Scientific and Medical (radio bands: several discrete bands from [center frequency] 6.78 MHz to 245 GHz)

ISO: International Organization for Standardization, from (*Greek*) "isos" ("equal")

ISS: Information Sending Station

ITA: International Telegraph Alphabet

ITU: International Telecommunication Union

ITU-R: ITU, Radiocommunication Sector (formerly CCIR)

ITU-T: ITU, Telecommunication Standardization Sector (formerly CCITT)

K

kBd: Kilobaud (10^3 Bd)

kHz: Kiloherertz (10^3 Hz)

km: Kilometer (10^3 m)

kn: Knot(s)

L

LDL: Low-Latency Data Link

LF: Low Frequency (30 kHz to 300 kHz, 1 km to 10 km)

LMR: Land Mobile Radio

LPC: Linear Predictive Coding

LSB: Least Significant Bit | Lower Side Band

LSByte: Least Significant Byte

LW: Long Wave (30 kHz to 300 kHz, 1000 m to 10000 m)

M

m: Meter

MAC: Medium/Media Access Control

MAYDAY: (*French*) "Venez m'aider" ("Come help me", distress call)

Meteosat: Meteorological Satellite

MF: Medium Frequency (300 kHz to 3 MHz, 10 m to 200 m)

MFSK: Multi-FSK

MHz: Megahertz (10^6 Hz)

MID: Maritime Identification Digit

MIMO: Multiple Input Multiple Output

min: Minute

mm: Millimeter (10^{-3} m)

MMSI: Maritime Mobile Service Identity

MoU: Memorandum of Understanding

MPDU: MAC Protocol Data Unit

MPSK: Multiple PSK

MPT: Ministry of Postal Service and Telecommunications (UK)

ms: Millisecond (10^{-3} s)

MSB: Most Significant Bit

MSByte: Most Significant Byte

MSK: Minimum Shift Keying, a special kind of FSK: frequency shift is half the baud rate (same as FFSK)

MTK: (*Russian*) международный телеграфный код / "Meshdunarodnyi telegrafnyi kod" (International Teletypewriter Code)

MUF: Maximum Usable Frequency

mW: Milliwatt (10^{-3} W)

N

NAK: Negative Acknowledge

NASA: National Aeronautics and Space Administration

NATO: North Atlantic Treaty Organization

NAVTEX: Navigational Telex

NGO: Non-Government Organization

NRZI: Non Return to Zero Invert

ns: Nanosecond (10^{-9} s)

O

OFDM: Orthogonal Frequency Division Multiplex

OOK: On-Off Keying

OQPSK: Offset Quadrature PSK

OSI: Open Systems Interconnection

OVSF: Orthogonal Variable Spreading Factor

OWF: Optimum Working Frequency

P

PC: Personal Computer

PDU: Protocol Data Unit

PHY: Physical Layer

PLCP: Physical Layer Convergence Protocol

PM: Phase Modulation

PMR: Private Mobile Radio

PN: Pseudo-Random Noise

PSK: Phase Shift Keying

PTT: Post, Telephone and Telegraph | Push to Talk

Q

Q: Quadrature

QAM: Quadrature Amplitude Modulation

QPSK: Quadrature [PSK](#)

R

Radar: Radio Detection and Ranging | Radio Aircraft Detection and Ranging

RAINWAT: Regional Arrangement concerning the Radiotelephone Service on Inland Waterways

RCA: Radio Corporation of America

RCC: Rescue Coordination Center

RF: Radio Frequency

RLE: Run-Length Encoding

rpm: Rotations per Minute

RQ: Repeat/Repetition Request

RS: Reed-Solomon

RTCM: Radio Technical Commission for Maritime Services

RTTE: Radio and Telecommunications Terminal Equipment (also R&TTE)

RTTY: Radioteletype

Rx: Receive

RX: Repeated Transmission (level)

S

s: Second

SAR: Search and Rescue | International Convention on Maritime Search and Rescue

SATCOM: Satellite Communications

SELCAL: Selective Calling

SHF: Super High Frequency ($f = 3 \text{ GHz}$ to 30 GHz , $\lambda = 1 \text{ cm}$ to 10 cm)

SIM: Subscriber Identity Module

SITOR: Simplex Teleprinting over Radio

SMS: Short Message Service

SNR: Signal-to-Noise Ratio

SOLAS: Safety of Life at Sea

SOS: Distress call (not an abbreviation or acronym, but easy to transmit in Morse code; commonly associated with phrases as "save our ship", "save our souls", "send out succor")

SSB: Single Side Band

T

TCP/IP: Transmission Control Protocol / Internet Protocol

TDM: Time Division Multiplex

TDMA: Time Division Multiple Access

TPC: Transmitter Power Control

TTY: Teletype

TV: Television

Tx: Transmit

U

U.S.: United States (of America)

U.S.A.: United States of America

UHF: Ultra High Frequency ($f = 300$ MHz to 3 GHz, $\lambda = 10$ cm to 1 m)

UI: Unit Identifier

UK: United Kingdom

UN: United Nations

US: U.S.

USB: Upper Side Band

V

VFT: Voice-Frequency Telegraphy

VHF: Very High Frequency ($f = 30$ MHz to 300 MHz, $\lambda = 1$ m to 10 m)

VLF: Very Low Frequency (3 kHz to 30 kHz, 10 km to 100 km)

VSC: Vertical Service Code

W

W: Watt

WLAN: Wireless Local Area Network

WPM: Words per Minute

Y

Y: Radio circuit state: data level 1, mark, lower frequency

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