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Technical Specification

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 e.r.p of up to 500 mW

Reference
DTS/ERM-TGDMR-056

Keywords
air interface, digital, FDMA, PMR, protocol, radio

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Contents

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

1 Scope

The present document covers digital private mobile radio equipment operating in peer-to- peer mode only and in accordance with ECC/DEC/(05)12 [2] on harmonized frequencies, technical characteristics, exemption from individual licensing and free carriage and use of digital PMR446 applications operating in the frequency band 446,100 MHz to 446,200 MHz.

The equipment shall comply with the technical requirements for Digital PMR 446 included in ECC/DEC/(05)12 [2].

NOTE: These requirements are: operation in the frequency range 446,100 MHz to 446,200 MHz, maximum e.r.p of 500 mW, and a maximum transmitter time-out-time of 180 seconds.

It covers only handportable equipment complying with EN 301 166-2 [1] and having an integral antenna.

The equipment is based on FDMA with channel spacing of 6,25 kHz supporting voice and data applications.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication and/or edition number or version number) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

[1] ETSI EN 301 166-2: "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 under article 3.2 of the R&TTE Directive".

[2] CEPT ECC/DEC/(05)12: "ECC Decision of 28 October 2005 on harmonised frequencies, technical characteristics, exemption from individual licensing and free carriage and use of digital PMR 446 applications operating in the frequency band 446.1-446.2 MHz".

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

bearer service: type of telecommunication service that provides the capability for the information transfer between user network interfaces, involving only low layer functions (layers 1 to 3 of the OSI model)

NOTE: Confirmed Data and Unconfirmed Data are examples of bearer services.

burst: smallest predefined block of continuous bits containing information or signalling

NOTE: The burst may include a guard time at the beginning and end of the burst used for power ramp-up and ramp-down.

call: complete sequence of related transactions between radios

NOTE: Transactions may be one or more bursts containing specific call related information.

Configured Services and Facilities (CSF): those functions available in the radio after re-programming

Control plane (C-plane): part of the protocol stack dedicated to control and data services

feature: attribute intrinsic to a station, e.g. MS has an address

Handportable Station (HS): physical grouping that contains all of the mobile equipment that is used to obtain dPMR mobile services and operating with an integral antenna

initial services and facilities: those functions available in the radio at point of sale (out-of-the box functions)

logical channel: distinct data path between logical endpoints

payload: bits in the information field

peer-to-peer mode: mode of operation where radios may communicate outside the control of a network

NOTE: This is communication technique where any radio unit may communicate with one or more other radio units without the need for any additional equipment (e.g. BS).

personalization: address and configuration information that characterizes a particular dPMR HS

NOTE: This information may be implanted by the installer before putting an HS into service.

physical channel: FDMA transmission

polite protocol: "Listen Before Transmit" (LBT) protocol

NOTE: This is a medium access protocol that implements a LBT function in order to ensure that the channel is free before transmitting.

prefix: most significant digit of a HS address in the user domain

Protocol Data Unit (PDU): unit of information consisting of protocol control information (signalling) and possibly user data exchanged between peer protocol layer entities

radio frequency channel: radio frequency carrier (RF carrier)

NOTE: This is a specified portion of the RF spectrum. The RF carrier separation is 6,25 kHz.

Received Signal Strength Indication (RSSI): root mean squared value of the signal received at the receiver antenna

signalling: exchange of information specifically concerned with the establishment and control of connections, and with management, in a telecommunication network

simplex: mode of working by which information can be transferred in both directions but not at the same time

NOTE: Simplex is also known as half duplex.

superframe: four concatenated FDMA frames

NOTE: A superframe has a length of 320 ms.

supplementary service: supplementary service modifies or supplements a tele-service or bearer service

NOTE: Consequently, it cannot be offered to a user as a standalone service. It must be offered together with or in association with a tele-service or bearer service. The same supplementary service may be common to a number of telecommunication services. Late entry is an example of supplementary service.

user numbering: decimal representation of dPMR air interface addresses, as seen by the user, i.e. user visible numbering

telecommunication service: offered by a dPMR entity in order to satisfy a specific telecommunication requirement

tele-service: type of telecommunication service that provides the complete capability, including terminal equipment functions, for communication between users

NOTE: Individual voice calls and group voice calls are examples of tele-services.

User plane (U-plane): part of the protocol stack dedicated to user voice services

vocoder socket: 216 bits vocoder payload

wildcard: character in the user domain that represents all digits 0 to 9

3.2 Symbols

For the purposes of the present document, the following symbols apply:

B_1	algorithm that converts HS dialable individual addresses between the User Interface and the Air Interface
B_2	algorithm that converts HS dialable talkgroup addresses between the User Interface and the Air Interface
B_3	algorithm that converts HS non-dialable individual addresses between the User Interface and the Air Interface
B_4	algorithm that converts HS non-dialable talkgroup addresses between the User Interface and the Air Interface
dBm	absolute power level relative to 1 mW, expressed in dB
dBp	Power relative to the average power transmitted over a burst in decibel
Eb	Energy per bit
No	Noise per Hz

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

4FSK	Four-level Frequency Shift Keying
AI	Air Interface
ARQ	Automatic Retransmission reQuest
CC	Colour Code
CCH	Control CHannel
CCL	Call Control Layer
CI	Call Information
Cont	Continuation flag
C-plane	Control-plane
CRC	Cyclic Redundancy Checksum for data error detection
CSF	Configured Services and Facilities
CTCSS	Continuous Tone Carrier Squelch System
Dibit	2 bits grouped together to represent a 4-level symbol
DLL	Data Link Layer
DP	Data Position
ET	End Type
FDMA	Frequency Division Multiple Access
FEC	Forward Error Correction
FN	Frame Numbering
HI	Header Information
HS	Handportable Station
HT	Header Type
ID	IDentifier
ISF	Initial Services and Facilities
LBT	Listen Before Transmit
MMI	Man Machine Interface
PDF	Packet Data Format
PDU	Protocol Data Unit

PL	Physical Layer
RF	Radio Frequency
RSSI	Received Signal Strength Indication
SLD	SLow Data
SYNC	SYNChronization
TCH	Traffic CHannel
U-plane	User-plane

4 Overview

The present document describes a narrow band Digital Private Mobile Radio system which employs a Frequency Division Multiple Access (FDMA) technology with an RF carrier bandwidth of 6,25 kHz.

The present document describes the Physical Layer (PL) and the Data Link Layer (DLL) of the Air Interface (AI) as well as the standardized services and facilities of the radio. Radio equipments which conform to the present document shall be interoperable at the PL and DLL with equipment from other manufacturers.

The present document describes 2 levels of functionality (services and facilities) that can be offered by the equipment. For the purposes of interoperability, a basic level of services and facilities (ISF) is defined along with a simplified mode of addressing such that all radios will be capable of interoperating without the need for any set-up or programming at the point of sale. An advanced level of services and facilities (CSF) is also defined for those equipments that can be re-programmed to offer a higher level of functionality.

The present document does not provide the specification or operational detail for system implementations which include but are not limited to, vocoder, security, data, other interfaces.

4.1 Protocol architecture

The purpose of this clause is to provide a model where the different functions and processes are identified and allocated to different layers in the protocol stack.

The protocol stack in this clause and all other related clauses describe and specify the interfaces, but this stack does not imply or restrict any implementation.

The protocol architecture which is defined herein follows the generic layered structure, which is accepted for reference description and specification of layered communication architectures.

The standard defines the protocols for the following 3 layered model as shown in figure 1.

The base of the protocol stack is the Physical Layer (PL) which is the layer 1.

The Data Link Layer (DLL), which is the layer 2, shall handle sharing of the medium by a number of users. At the DLL, the protocol stack shall be divided vertically into two parts, the User plane (U-plane), for transporting information without addressing capability (e.g. voice or data stream), and the Control plane (C-plane) for signalling with addressing capability, as illustrated by figure 1.

The Call Control Layer (CCL), which is layer 3, lies in the C-plane and is responsible for control of the call (addressing, facilities, etc.), provides the services supported by the radio, and supports the Data Service. U-plane access at layer 2 (DLL) supports voice service.

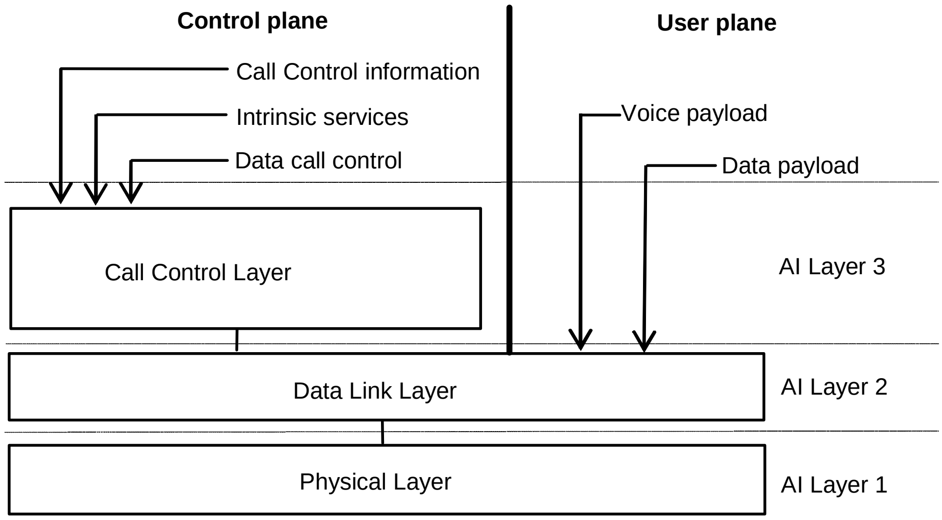


Figure 1: Protocol stack

4.1.1 Air Interface Physical Layer (layer 1)

The Air Interface layer 1 shall be the physical interface. It shall deal with the physical transmission or burst, composed of bits, which is to be sent and/or received. The Physical Layer is described in clause 12. The Air Interface layer 1 shall contain the following functions:

- modulation and demodulation;
- transmitter and receiver switching;
- RF characteristics;
- bits and symbol definition;
- frequency and symbol synchronization;
- transmission or burst building.

4.1.2 Air Interface Data Link Layer (layer 2)

The Air Interface layer 2 shall handle logical connections and shall hide the physical medium from the upper layers. The Data Link Layer is described in clauses 7 to 10.

The main functions are as follows:

- channel coding (FEC, CRC);
- interleaving, de-interleaving and bit ordering;
- acknowledgement and retry mechanism;
- media access control and channel management;
- framing, superframe building and synchronization;
- burst and parameter definition;
- link addressing (source and/or destination);
- interfacing of voice applications (vocoder data) with the PL;

- data bearer services;
- exchanging signalling and/or user data with the CCL.

4.1.3 Air Interface Call Control Layer (layer 3)

Air Interface layer 3 (CCL) is applicable only to the C-plane, and shall be an entity for the services and facilities supported by the radio on top of the layer 2 functionality.

The CCL provides the following functions:

- establishing, maintaining and terminating of calls;
- individual or group call transmission and reception;
- destination addressing;
- support of intrinsic services (late entry, call divert, etc.);
- data call control.

4.2 FDMA Structure

4.2.1 Overview of transmission and burst structure

The described solution is based on a FDMA structure.

All transmissions are asynchronous, since there is no entity to provide frame or slot timing.

The physical resource available to the radio system is an allocation of the radio spectrum.

A transmission or burst is a period of RF carrier that is modulated by a data stream. The physical channel of an FDMA transmission is required to support the logical channels.

A logical channel is defined as a logical communication pathway between two or more parties. The logical channels represent the interface between the protocol and the radio subsystem. The logical channels may be separated into two categories:

- the traffic channels carrying speech or data information; and
- control channels carrying signalling.

4.2.2 Transmission format

The FDMA transmission is made up of 80 ms frames, each comprising 384 bits.

Frame:

a	b	c	d	e	f

a: 24 bits FrameSync2 (FS2) or ColourCode (CC) bits
b: 72 bits Control Channel (CCH) data
c: 72 bits Traffic channel (TCH)
d: 72 bits TCH
e: 72 bits TCH
f: 72 bits TCH

Four 80 ms frames are concatenated to form a superframe of 320 ms.

Superframe:

FS2 CCH Payload	CC CCH Payload	FS2 CCH Payload	CC CCH Payload

The complete call sequence from a radio consists of a Header frame, a series of superframes and is terminated by an End frame.

The Header frame is of 80 ms (384 bits) in length.

Header:

P	FS1	HI0	CC	HI1

P: Preamble, minimum of 72 bits
FS1: 48 bit Frame Sync 1 sequence
HI0: Header Information 0, 120 bits
CC: Colour Code, 24 bits
HI1: Header Information 1, 120 bits

The End message is a shortened 96 bit frame.

End:

FS3	END

FS3: Frame sync, 24 bits
END: End data, 72 bits

4.2.3 Transmission sequences

Voice or data payload continuous transmission:

H	SF	SF	SF	SF	SF	E

H: Header frame
SF: Superframe
E: End frame

Call set up, service request, etc:

H	E

Acknowledgement:

H

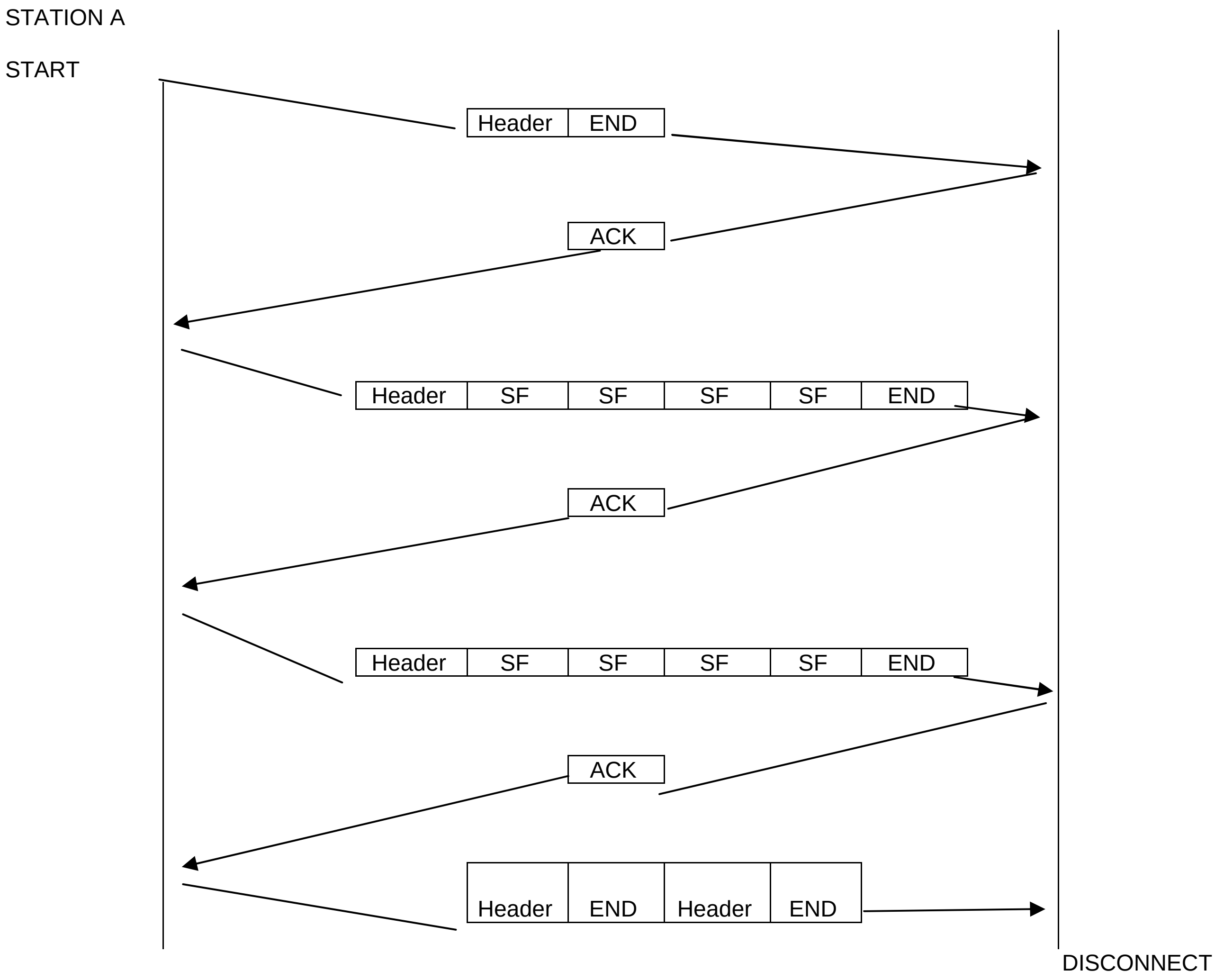


Figure 2: Communication exchanges

5 Frame coding

5.1 Superframe

Table 5.1a: Superframe content, frame 1

<table>
<tr><th></th><th>FRAME 1</th><th>Bits</th><th>FEC</th><th>Transfer</th><th>Rate</th></tr>
<tr><td>FS2</td><td>Frame Sync</td><td>24</td><td>None</td><td>24</td><td></td></tr>
<tr><td>CCH</td><td>Control Channel</td><td>(41)</td><td rowspan="7">CRC 7 bit
(12, 8)
Short
Hamming
Interleave
12 x 6
Scramble</td><td rowspan="7">72</td><td>513 bps</td></tr>
<tr><td>FN</td><td>Frame Number</td><td>2</td><td>25 bps</td></tr>
<tr><td>ID0</td><td>Called ID (upper 12 bits)</td><td>12</td><td>38 bps</td></tr>
<tr><td>M</td><td>Communications mode</td><td>3</td><td>38 bps</td></tr>
<tr><td>F</td><td>Comms format</td><td>4</td><td>50 bps</td></tr>
<tr><td>RES</td><td>Reserved</td><td>2</td><td>25 bps</td></tr>
<tr><td>SLD</td><td>Slow Data</td><td>18</td><td>225 bps</td></tr>
<tr><td>TCH</td><td>Payload</td><td>72 x 4</td><td></td><td>288</td><td></td></tr>
</table>

Table 5.1b: Superframe content, frame 2

	FRAME 2	Bits	FEC	Transfer	Rate
CC	Colour Code	12	Di-bit	24	
CCH	Control Channel	(41)	CRC 7 bit (12, 8) Short Hamming Interleave 12 x 6 Scramble	72	513 bps
FN	Frame Number	2			25 bps
ID1	Called ID (lower 12 bits)	12			38 bps
M	Communications mode	3			38 bps
F	Comms format	4			50 bps
RES	Reserved	2			25 bps
SLD	Slow Data	18			225 bps
TCH	Payload	72 x 4		288	

Table 5.1c: Superframe content, frame 3

	FRAME 3	Bits	FEC	Transfer	Rate
FS2	Frame Sync	24	None	24	
CCH	Control Channel	(41)	CRC 7 bit (12, 8) Short Hamming Interleave 12 x 6 Scramble	72	513 bps
FN	Frame Number	2			25 bps
ID2	Own ID (upper 12 bits)	12			38 bps
M	Communications mode	3			38 bps
F	Comms format	4			50 bps
RES	Reserved	2			25 bps
SLD	Slow Data	18			225 bps
TCH	Payload	72 x 4		288	

Table 5.1d: Superframe content, frame 4

	FRAME 4	Bits	FEC	Transfer	Rate
CC	Colour Code	12	Di-bit	24	
CCH	Control Channel	(41)	CRC 7 bit (12, 8) Short Hamming Interleave 12 x 6 Scramble	72	513 bps
FN	Frame Number	2			25 bps
ID3	Own ID (lower 12 bits)	12			38 bps
M	Communications mode	3			38 bps
F	Comms format	4			50 bps
RES	Reserved	2			25 bps
SLD	Slow Data	18			225 bps
TCH	Payload	72 x 4		288	

5.2 Header frame

Table 5.2: Header frame content

<table>
<tr><th></th><th></th><th>Bits</th><th colspan="3">FEC</th><th>Transfer</th></tr>
<tr><td>P</td><td>Preamble</td><td>≥ 72</td><td colspan="3">none</td><td>72</td></tr>
<tr><td>FS1</td><td>Frame Sync</td><td>48</td><td colspan="3">none</td><td>48</td></tr>
<tr><td>HI0</td><td>Header Information</td><td>(72)</td><td rowspan="8">8 bit CRC
(12,8)
Short
Hamming</td><td rowspan="8">Interleave
12 x 10</td><td rowspan="8">Scramble</td><td rowspan="8">120</td></tr>
<tr><td>HT</td><td>Header type</td><td>4</td></tr>
<tr><td>ID0+1</td><td>Called station ID</td><td>24</td></tr>
<tr><td>ID2+3</td><td>Own ID</td><td>24</td></tr>
<tr><td>M</td><td>Communication mode</td><td>3</td></tr>
<tr><td>F</td><td>Comms format</td><td>4</td></tr>
<tr><td>Reserved</td><td>Reserved</td><td>2</td></tr>
<tr><td>CI</td><td>Call Information</td><td>11</td></tr>
<tr><td>CC</td><td>Colour Code</td><td>12</td><td>Di-bit</td><td></td><td></td><td>24</td></tr>
<tr><td>HI1</td><td>Header Information</td><td>(72)</td><td rowspan="8">8 bit CRC
(12,8)
Short
Hamming</td><td rowspan="8">Interleave
12 x 10</td><td rowspan="8">Scramble</td><td rowspan="8">120</td></tr>
<tr><td>HT</td><td>Header type</td><td>4</td></tr>
<tr><td>ID0+1</td><td>Called station ID</td><td>24</td></tr>
<tr><td>ID2+3</td><td>Own ID</td><td>24</td></tr>
<tr><td>M</td><td>Communication mode</td><td>3</td></tr>
<tr><td>F</td><td>Comms format</td><td>4</td></tr>
<tr><td>Reserved</td><td>Reserved</td><td>2</td></tr>
<tr><td>CI</td><td>Call Information</td><td>11</td></tr>
</table>

5.3 End frame

Table 5.3: End frame content

<table>
<tr><th></th><th></th><th>Bits</th><th colspan="3">FEC</th><th>Transfer</th></tr>
<tr><td>FS3</td><td>Frame Sync</td><td>24</td><td colspan="3">none</td><td>24</td></tr>
<tr><td>END0</td><td>End Information</td><td>(17)</td><td rowspan="6">7 bit CRC
(12,8)
Short
Hamming</td><td rowspan="12"></td><td rowspan="12">Scramble</td><td rowspan="12">72</td></tr>
<tr><td>ET</td><td>End type</td><td>2</td></tr>
<tr><td>ARQ</td><td>Ack request</td><td>2</td></tr>
<tr><td>WAIT</td><td>Tx wait</td><td>4</td></tr>
<tr><td>STAT</td><td>Status message</td><td>5</td></tr>
<tr><td>RES</td><td>Reserved</td><td>4</td></tr>
<tr><td>END1</td><td>End Information</td><td>(17)</td><td rowspan="6">7 bit CRC
(12,8)
Short
Hamming</td></tr>
<tr><td>ET</td><td>End type</td><td>2</td></tr>
<tr><td>ARQ</td><td>Ack request</td><td>2</td></tr>
<tr><td>WAIT</td><td>Tx wait</td><td>4</td></tr>
<tr><td>STAT</td><td>Status message</td><td>5</td></tr>
<tr><td>RES</td><td>Reserved</td><td>4</td></tr>
</table>

5.4 Packet data header

Table 5.4: Packet data header frame content

<table>
<tr><th></th><th></th><th>Bits</th><th colspan="3">FEC</th><th>Transfer</th></tr>
<tr><td>P</td><td>Preamble</td><td>≥ 72</td><td colspan="3">none</td><td>72</td></tr>
<tr><td>FS1</td><td>Frame Sync</td><td>48</td><td colspan="3">none</td><td>48</td></tr>
<tr><td>HI0</td><td>Header Information</td><td>(72)</td><td rowspan="8">8 bit CRC
(12,8)
Short
Hamming</td><td rowspan="8">Interleave
12 x 10</td><td rowspan="8">Scramble</td><td rowspan="8">120</td></tr>
<tr><td>HT</td><td>Header type</td><td>4</td></tr>
<tr><td>ID0+1</td><td>Called station ID</td><td>24</td></tr>
<tr><td>ID2+3</td><td>Own ID</td><td>24</td></tr>
<tr><td>M</td><td>Communication mode</td><td>3</td></tr>
<tr><td>F</td><td>Comms format</td><td>4</td></tr>
<tr><td>Reserved</td><td>Reserved</td><td>2</td></tr>
<tr><td>CI</td><td>Call Information</td><td>11</td></tr>
</table>

		Bits	FEC			Transfer
CC	Colour Code	12	Di-bit			24
HI1	Header Information	(72)	8 bit CRC (12,8) Short Hamming	Interleave 12 x 10	Scramble	120
HT	Header type	4				
ID0+1	Called station ID	24				
ID2+3	Own ID	24				
M	Communication mode	3				
F	Comms format	4				
Reserved	Reserved	2				
CI	Call Information	11				

5.5 ACK frame

The ACK frame has identical composition to the Header Frame. It is identified as an acknowledgement by the Header Type (HT) bits setting.

Table 5.5: Ack frame content

		Bits	FEC			Transfer
P	Preamble	≥ 72	none			72
FS1	Frame Sync	48	none			48
HI0	Header Information	(72)	8 bit CRC (12,8) Short Hamming	Interleave 12 x 10	Scramble	120
HT	Header type	4				
ID0+1	Called station ID	24				
ID2+3	Own ID	24				
M	Communication mode	3				
F	Comms format	4				
Reserved	Reserved	2				
CI	Call Information	11				
CC	Colour Code	12	Di-bit			24
HI1	Header Information	(72)	8 bit CRC (12,8) Short Hamming	Interleave 12 x 10	Scramble	120
HT	Header type	4				
ID0+1	Called station ID	24				
ID2+3	Own ID	24				
M	Communication mode	3				
F	Comms format	4				
Reserved	Reserved	2				
CI	Call Information	11				

5.6 Frame numbering

Frame used Comm Frame.

Data length 2 bits.

Two bits are allocated for frame numbering within each superframe.

Table 5.6: Frame numbering

00	1st frame
01	2nd frame
10	3rd frame
11	4th frame

5.7 Communication mode

Frame used Header Frame/Packet data Header Frame/Comm Frame.

Data length 3 bits.

Table 5.7: Communications mode

000	Voice communication (no user data in SLD field)
001	Voice + slow data (user data in SLD field)
010	Data communication type 1 (Payload is user data without FEC)
011	Data communication type 2 (Payload is user data with FEC)
100	Data communication type 3 (Packet data, ARQ method)
101	Voice and appended data (Type 2)
Other	Reserved

5.8 Communication format

Frame used Header Frame/Packet data Header Frame/Comm Frame.

Table 5.8: Communication format

0000	Call ALL
0001	Peer-to-peer communication
0010	Reserved
0011	Reserved
Other	Reserved

5.9 SLD format

Within the superframe there are 18 bits allocated in the CCH data for each frame for the transmission of slow data. Within the 18 bit allocation there are 2 flag bits and 16 bits of data.

Additionally, the SLD field is used during Type 1 and 2 data transmissions to indicate the type of data being transmitted as well as a flag to indicate if the data terminates after the current frame.

5.9.1 Slow data in the voice superframe

This is the normal use of the slow data field and 2 bytes of user data can be included within each frame of the voice superframe.

In this case the communication mode is set to 001 (clause 5.7).

Each byte of user data is preceded by a continuation flag (Cont.) to inform the receiving party if the subsequent byte is the last.

Cont.	User data	Cont.	User data
1 bit	8 bits	1 bit	8 bits

Continuation Flag:

0	User data continues after the following byte.
1	User data is terminated by the following byte.

5.9.2 Slow data field use with Type 1 or 2 data

When Type 1 or 2 data is transmitted, the SLD field is used to convey information of data format, position and continuation, etc. The SLD field is also used when a voice transmission has data appended to the end of the transmission.

Reserved	DP	Format	Cont.	Data length (bytes)
5 bits	2 bits	4 bits	1 bit	6 bits

Data Position (DP):

Table 5.9a: DP coding

00	There is no data in this frame
01	Reserved
10	Reserved
11	This frame is the data frame

Format:

Table 5.9b: Format coding

0000	Radio generated data (short text message)
0001	User defined data 1 (GPS data)
0010	User defined data 2
- - - -	etc
0111	User defined data 7
Other	Reserved

Continuation flag:

0	Data continues after this frame.
1	Data finishes at this frame.

5.10 Call information

Frame used Header Frame/Packet Data Header Frame/ACK.

Data length 11 bits.

11 bits of the Header frame are allocated for Call Information (CI) data, three bits indicate the type of data and 8 bits contain the information:

Type	Information
3 bits	8 bits

Type (3 bits):

000	Normal Header
111	Extended wake-up Header

If the extended wake-up Header is used then the last 4 information bits will show how many Headers frames follow the current one (i.e. counting down to zero).

Table 5.10a: Extended wake up header coding

0000 0000	END Frame follows this header
0000 0001 ------ ↓ -------- 0000 1111	Header frame follows -- 15 Header frames follow
Other	Reserved

Data communications (types 1 and 2):

Type	Format	Reserved
001	4 bits	4 bits

Reserved bits are set to 0000.

Format:

Table 5.10b: Format coding

0000	Radio generated data (short text message)
0001	User defined data 1 (GPS data)
0010	User defined data 2
- - - -	etc
0111	User defined data 7
Other	Reserved

Information bits for Packet data format (Type 3):

Type	Information	
011	pdS 4 bits	pdM 4 bits

Data frame size (pdS):

Frame used Packet Data Frame (PDF).

Data length 16 bits.

Table 5.10c: Packet data frame sizes

pdS	Frame time (ms)	Data size bits
0	80	288
1	160	672
2	240	1 056
3	320	1 440
Other	Reserved	Reserved

Number of transmitted frames (pdM):

Table 5.10d: Packet data frame number

pdM	Number of Data frames
0	1 frame
1	2 frames
2	3 frames
3	4 frames
4	5 frames
5	6 frames
6	7 frames
7	8 frames
Other	Reserved

System request/answer/delivery header:

Table 5.10e: Header types

Type	Definition
000	
001	Dynamic group request/answer/delivery
010	Reserved
011	Reserved
100	ESN request/reply
101	MFID request/reply
110	Contact station address (via Interconnect, IP)
111	Reserved

Info.	
0	All bits set to zero (the data size is indicated in the CCH SLD field)

Acknowledgement:

Table 5.10f: Acknowledgement types

Type	Definition
000	
001	ACK (Rx OK)
010	NACK (data error, resend request)
011	NACK (request denied)
Other	Reserved

Info	
0	
1 to 255	ACK / NACK status (rejection reason defined by user)

5.11 Header type

Frame used Header Frame/Packet Data Header Frame.

Data length 4 bits.

Table 5.11: Header type

0000	Communication start header (a superframe follows)
0001	Connection request header (an END frame follows)
0010	Unconnect request header (an END frame follows)
0011	ACK (this a single frame, ACK or NACK is differentiated by the CI bits setting)
0100	System request header (an END frame follows)
0101	ACK header reply to a system request (a superframe follows)
0110	System delivery header (a superframe follows)
0111	Status response header
1000	Status request header
Other	Reserved

5.12 End type

Frame used END Frame.

Data length 2 bits.

Definition:

Table 5.12: End type

00	Normal end frame
01	End frame with status message
10	Reserved
11	Reserved

5.13 ARQ

Frame used END Frame.

Data length 2 bits.

Definition:

Table 5.13: ARQ

00	No ACK request to called station
01	ACK request to called station
10	Reserved
11	Reserved

5.14 Tx Wait

Frame used END.

Data length 4 bits.

Definition:

The Tx wait time will be implemented by the called station(s) such that other radios who have a break-in request pre-keyed by the user may transmit during the specified time.

Table 5.14: Tx wait time

0000	No specified time
0001	40 ms (half a frame)
0010	80 ms (one frame)
0011	160 ms (two frames)
0100	320 ms (one superframe)
Other	Reserved

5.15 Status

Frame used END Frame.

Data length 5 bits.

Definition:

0 to 31	Status message

6 Synchronization

6.1 Frame synchronization

6.1.1 FS1

The Frame sync 1 sequence contained in the non packet data header frame (Header 1) is a 48 bit sequence that shall have the following value:

Binary: 010101111111111110101111101110101110101010111011 1.

Hex: 57 FF 5F 75 D5 77.

6.1.2 FS2

The Frame sync 2 sequence contained in the superframe (frame 1) is a 24 bit sequence that shall have the following value:

Binary: 010111111111011101111101.

Hex: 5F F7 7D.

6.1.3 FS3

The Frame sync 3 sequence contained in the End frame is a 24 bit sequence that shall have the following value:

Binary: 011111011101111111110101.

Hex: 7D DF F5.

6.1.4 FS4

The Frame sync 4 sequence contained in the Packet Data header frame (Header 2) is a 48 bit sequence that shall have the following value:

Binary: 111111010101010111110101110111110111111111011101.

Hex: FD 55 F5 DF 7F DD.

6.1.5 Colour code

The Colour Code contained in the superframe (frames 2 and 4) and the header frame is a 12 bit code that is di-bit encoded into a 24 bit sequence.

Colour Code are attributed directly to the RF operating channel and are not freely selectable.

For the purposes of interoperability and to differentiate the different modes of addressing used, radios employing Initial Services and Facilities shall use the Group A colour codes only and radios employing Configured Services and Facilities shall use the Group B colour codes only.

Table 6.1: Colour code by RF channel

Group	Channel Frequency	Colour Code (Bit)	Colour Code (Hex)
A	446,103125	010101110111010101110111	577577
	446,109375	010101111101110101110101	57DD75
	446,115625	010101111111011101110101	57F775
	446,121875	010101010101011101111101	55577D
	446,128125	010101010111110101111101	557D7D
	446,134375	010101011101010101111111	55D57F
	446,140625	010101011111111101111111	55FF7F
	446,146875	010111110101010101011111	5F555F
	446,153125	010111110111111101011111	5F7F5F
	446,159375	010111111101011101011101	5FD75D
	446,165625	010111111111110101011101	5FFD5D
	446,171875	010111010101110101010101	5D5D55
	446,178125	010111010111011101010101	5D7755
	446,184375	010111011101111101010111	5DDF57
	446,190625	010111011111010101010111	5DF557
	446,196875	011101110101110111010111	775DD7
RESERVED	N/A	011101110111011111010111	7777D7
	N/A	011101111101111111010101	77DFD5
	N/A	011101111111010111010101	77F5D5
	N/A	011101010101010111011101	7555DD
	N/A	011101010111111111011101	757FDD
	N/A	011101011101011111011111	75D7DF
	N/A	011101011111110111011111	75FDDF
	N/A	011111110101011111111111	7F57FF
	N/A	011111110111110111111111	7F7DFF
	N/A	011111111101010111111101	7FD5FD
	N/A	011111111111111111111101	7FFFFD
	N/A	011111010101111111110101	7D5FF5
	N/A	011111010111010111110101	7D75F5
	N/A	011111011101110111110111	7DDDF7
	N/A	011111011111011111110111	7DF7F7
	N/A	110101110101010111110111	D755F7
	N/A	110101110111111111110111	D77FF7
	N/A	110101111101011111110101	D7D7F5
	N/A	110101111111110111110101	D7FDF5
	N/A	110101010101110111111101	D55DFD
	N/A	110101010111011111111101	D577FD
	N/A	110101011101111111111111	D5DFFF
	N/A	110101011111010111111111	D5F5FF
	N/A	110111110101111111011111	DF5FDF
	N/A	110111110111010111011111	DF75DF
	N/A	110111111101110111011101	DFDDDD
	N/A	110111111111011111011101	DFF7DD
	N/A	110111010101011111010101	DD57D5
	N/A	110111010111110111010101	DD7DD5
	N/A	110111011101010111010111	DDD5D7
	N/A	110111011111111111010111	DDFFD7

Group	Channel Frequency	Colour Code (Bit)	Colour Code (Hex)
B	446,103125	111101110101011101010111	F75757
	446,109375	111101110111110101010111	F77D57
	446,115625	111101111101010101010101	F7D555
	446,121875	111101111111111101010101	F7FF55
	446,128125	111101010101111101011101	F55F5D
	446,134375	111101010111010101011101	F5755D
	446,140625	111101011101110101011111	F5DD5F
	446,146875	111101011111011101011111	F5F75F
	446,153125	111111110101110101111111	FF5D7F
	446,159375	111111110111011101111111	FF777F
	446,165625	111111111101111101111101	FFDF7D
	446,171875	111111111111010101111101	FFF57D
	446,178125	111111010101010101110101	FD5575
	446,184375	111111010111111101110101	FD7F75
	446,190625	111111011101011101110111	FDD777
	446,196875	111111011111110101110111	FDFD77

7 Interleaving and FEC coding

7.1 Di-bit coding

This is coding scheme applicable to the Colour Code:

0 >	01
1>	11

7.2 CRC addition

Use	CRC	Polynomial
Frame (CCH)	CRC7	X^7 + X^3 + 1
Header (HI)	CRC8	X^8 + X^2 + X^1 + 1

7.3 Hamming code

A shortened Hamming code (12,8) is employed and the generator matrix is shown below:

X7,X6,X5,X4,X3,X2,X1,1 is Identity bit (8 bit): C3,C2,C1,C0 is Parity bit (4 bit).

Table 7.1: Generator matrix

	12	11	10	9	8	7	6	5	4	3	2	1
	X7	X6	X5	X4	X3	X2	X1	1	C3	C2	C1	C0
1	1	0	0	0	0	0	0	0	1	1	1	0
2	0	1	0	0	0	0	0	0	0	1	1	1
3	0	0	1	0	0	0	0	0	1	0	1	0
4	0	0	0	1	0	0	0	0	0	1	0	1
5	0	0	0	0	1	0	0	0	1	0	1	1
6	0	0	0	0	0	1	0	0	1	1	0	0
7	0	0	0	0	0	0	1	0	0	1	1	0
8	0	0	0	0	0	0	0	1	0	0	1	1

Shortened Hamming code (12,8) Polynomial: X^4 + X + 1.

7.4 Scrambling

The scrambling polynomial is X^9 + X^5 + 1 with an initial preset value of all "1"s.

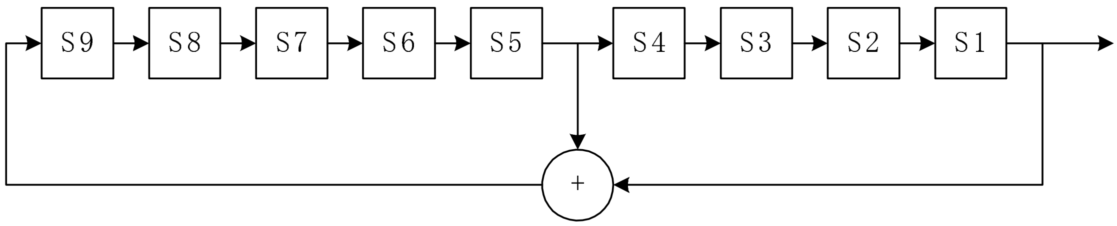


Figure 3: Scrambling format

7.5 Interleaving

There are two interleaving matrices, one for the TCH and one for the HI field.

TCH interleave structure matrix:

Table 7.2: TCH Interleaving matrix

	1	2	3	4	5	6
1	1	13	25	37	49	61
2	2	14	26	38	50	62
3	3	15	27	39	51	63
4	4	16	28	40	52	64
5	5	17	29	41	53	65
6	6	18	30	42	54	66
7	7	19	31	43	55	67
8	8	20	32	44	56	68
9	9	21	33	45	57	69
10	10	22	34	46	58	70
11	11	23	35	47	59	71
12	12	24	36	48	60	72

The Interleave Structure Matrix Map (Tx side: 12 bit x 10).

Table 7.3: HI field Interleaving matrix

	1	2	3	4	5	6	7	8	9	10
1	1	13	25	37	49	61	73	85	97	109
2	2	14	26	38	50	62	74	86	98	110
3	3	15	27	39	51	63	75	87	99	111
4	4	16	28	40	52	64	76	88	100	112
5	5	17	29	41	53	65	77	89	101	113
6	6	18	30	42	54	66	78	90	102	114
7	7	19	31	43	55	67	79	91	103	115
8	8	20	32	44	56	68	80	92	104	116
9	9	21	33	45	57	69	81	93	105	117
10	10	22	34	46	58	70	82	94	106	118
11	11	23	35	47	59	71	83	95	107	119
12	12	24	36	48	60	72	84	96	108	120
NOTE: Applied in the Header HI0/HI1.										

Use of interleaving matrices:

Transmit data is input to the matrix in vertical columns from top left to lower right. Data is output from the matrix in horizontal rows from top left to lower right.

Receive data is input to the matrix in horizontal rows from top left to lower right. Data is output from the matrix in vertical columns from top left to lower right.

8 Bearer services, tele-services and supplementary services

8.1 Initial mode

Table 8.1

Bearer services	Tele-services	Supplementary services
Voice	Group Call	Late Entry
		All Call
		PTT Call
		Talking Party Identification
Type 2 data	IP over dPMR	-
	Group Short Data Message	Status Message
		Precoded Message
		Free Text Message
		Short file transfer
Type 1 data	IP over dPMR	-
	Group Short Data Message	Status Message
		Precoded Message
		Free Text Message
		Short file transfer

8.1.1 Initial addressing

The ISF addressing is based on an allocation of 24 bits. This address space is subdivided into two parts.

For the purposes of interoperability "out of the box", radios employing Initial Services and Facilities shall operate with simplified addressing scheme. Of the 24 bit address space, 16 bits are fixed and only the 8 bit Common ID is selectable by the user. This results in 254 selectable codes which operate indiscriminately as both individual and group addresses.

8.1.1.1 Common ID

The 8 bit Common ID field may be considered as similar to CTCSS/DTCS as used in analogue PMR radio.

Selectable values (decimal) are as follows:

Table 8.2: Common ID addressing

Com ID	
0	Reserved
1 to 254	Applicable
255	All call

8.1.1.2 Fixed part of address

The 16 bits following the common ID field shall all be set to 1.

8.1.2 ISF colour codes

Radios shall use only the Group A C.

8.2 Configured mode

Table 8.3

Bearer services	Tele-services	Supplementary services
Voice	Individual Call	Late Entry
		OACSU
		Cancel call set-up
		Call divert
		PTT call
		Slow user data
		Short appended data
		Talking Party Identification
	Group Call	Late Entry
		All Call
		Call divert
		PTT Call
		Slow user data
		Short appended data
		Broadcast Call
		Talking Party Identification
Type 3 data	IP over dPMR	-
	Individual Short Data Message	Status Message
		Precoded Message
		Free Text Message
		Short file transfer
Type 2 data	IP over dPMR	-
	Individual Short Data Message	Status Message
		Precoded Message
		Free Text Message
		Short file transfer
	Group Short Data Message	Status Message
		Precoded Message
		Free Text Message
		Short file transfer
Type 1 data	IP over dPMR	-
	Individual Short Data Message	Status Message
		Precoded Message
		Free Text Message
		Short file transfer
	Group Short Data Message	Status Message
		Precoded Message
		Free Text Message
		Short file transfer

8.2.1 Call types

8.2.1.1 Individual call

An individual call is a call made to a dialable address as defined in clause A.2.1.1.1 that does not contain any "wildcard" characters as defined in clause A.2.1.2.1.

8.2.1.2 Group call

A group call is a call made to a dialable address as defined in clause A.2.1.2.1 using "wildcard" characters to define talkgroups.

8.2.2 Addressing

The addressing is based on an allocation of 24 bits.

Radios shall use a 7 digit addressing scheme that is encoded into the 24 bit address field as detailed in annex A.

8.2.3 CSF colour codes

Radios shall use only the Group B CC.

8.3 Packet data format

Packet data uses a different format to the normal communications frame format. The use of frame sync 4 (FS4) indicates that the frames following will be in PDF format.

Basic PDF format:

Header 2	Data frames	END

Total length of data frames = 80 ms x (pdS + 1)

The value of pdS transmitted will indicate the number of 80 ms frames.

Concatenated PDF frames:

Header 2	PDF 1	PDF 2	PDF 3	PDF 4	PDF 5	END

The value of pdM transmitted will indicate the number of 320 ms frames.

The maximum transmission time of a single packet will be when pdS = 3 and pdM = 7

i.e. Header + (PDF max X pdM max) + END

= 80 + (320 X8) + 20 ms

= 2 660 ms

ACK

Individual transmissions will be acknowledged (or NACK'ed) according to the decoded data. The information bits in the NACK frame will denote the number of the last PDF frame received without error.

Example of NACK Call information:

Table 8.4: NACK retransmit values

Type	Information	
010	0	Retransmit from frame 1
	1	Retransmit from frame 2
	2	Retransmit from frame 3
	3	Retransmit from frame 4
	4	Retransmit from frame 5
	5	Retransmit from frame 6
	6	Retransmit from frame 7
	7	Retransmit from frame 8
	Other	Reserved

Packet Data Frame format:

CC	PAR	DATA
24 bits	72 bits	288 bits (pdS = 0), 672 (pdS = 1), 1 056 (pdS=2), 1 440 (pdS = 3)

Table 8.5: Packet data frame coding

		Tx frame	Info bits	FEC		Transfer bits
CC	Colour Code	ALL	12	Di-bit		24
PAR	Parameter		(41)	CRC 7 bit (12, 8) Short Hamming Interleave 12 x 6	Scramble	72
N	No packet frames sent	ALL	3			
LEN	Data length (BYTE) *1	ALL	8			
DUMMY	DUMMY BITS	ALL	14			
CRC-D	CRC for DATA field	ALL	16			
DATA	User data pdS = 0	ALL	288	NONE		288
	pdS = 1	ALL	672			672
	pdS = 2	ALL	1 056			1056
	pdS = 3	ALL	1 440			1440

N (Packet Frame Number: PDF Number)

Data length 3 bit

Definition:

0 to 7	(dec)	Frame Number

The number attached when the PDF is transmitted interconnected.

LEN (Data length (BYTE): DATA Frame)

Frame used Packet Data Frame (PDF)

Data length 8 bits

Definition:

0 to 36	(dec)	Data length (BYTE)	36 byte = 288 bit, for pdS = 0
0 to 84	(dec)		84 byte = 672 bit,for pdS = 1
0 to 132	(dec)	Data length (BYTE)	132 byte = 1 056 bit, for pdS = 2
0 to 180	(dec)	Data length (BYTE)	180 byte = 1 440 bit, for pdS = 3
Other	(dec)	reserved	

1 The valid data length within the Data is indicated in bytes, with the left over area filled with zeros.

Dummy (DATA Frame)

Data length 14 bit

Definition All"0"
Reserved

CRC_D (CRC for DATA field: DATA Frame)

Data length 16 bit

Definition:

Indicated the CRC of the Data area.

The Generated Polynomial uses X^16 + X^12 + X^5 + 1.

CRC_D Data

Data (Data: DATA field)

Data length 288 - 1440 bit (36 - 180 byte)

Definition:

The frame size is declared in the Header frame CI field pdS.

80 ms / 384 bit

pdS = 0

CC	PAR	Data
		288 bit (36 byte)

160 ms / 768 bit

pdS = 1

CC	PAR	Data
		672 bit (84 byte)

pdS = 2

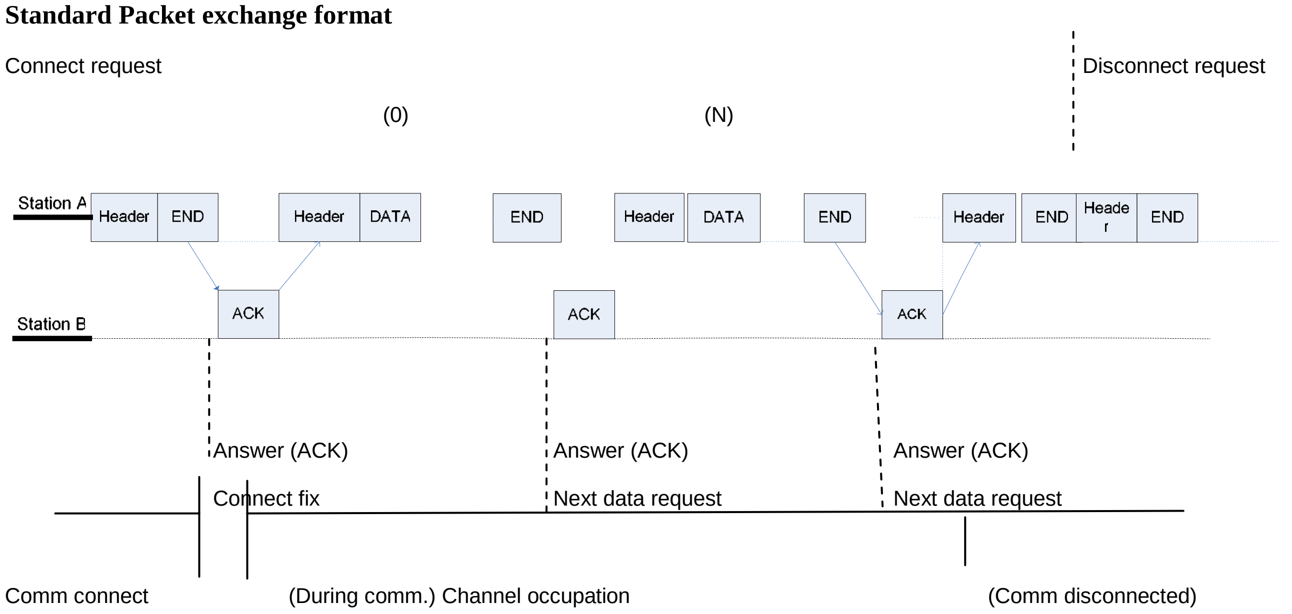
240 ms / 1 152 bit

CC	PAR	Data
		1 056 bit (132 byte)

pdS = 3

320 ms / 1 536 bit

CC	PAR	Data
		1 440 bit (180 byte)



NOTE: (0) to (7) or (N) indicates the Send packet frame number.

Figure 4: Packet exchanges

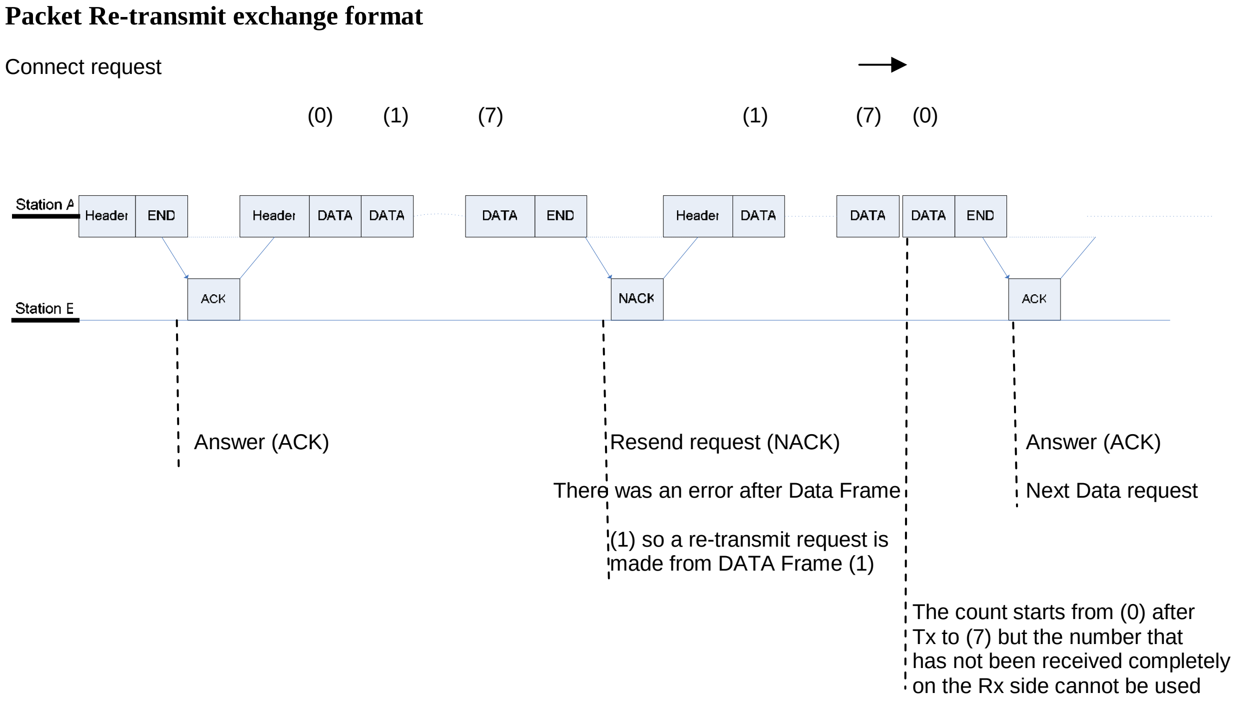


Figure 5: Packet retransmissions

9 Channel coding process

9.1 Voice superframe

Construction of the voice superframe starts with CCH control channel data.

Frame Numbering (FN) is from 00 to 11 (1 to 4).

FN is followed by 12 bits of the called station address or own ID as follows:

The called station ID and own ID make a total of 48 bits. These bits are split into 12 bit blocks and one block is included in each of the 4 frames of the superframe.

- FN 00 will include the upper 12 bits of the called station ID.
- FN 01 will include the lower 12 bits of the called station ID.
- FN 10 will include the upper 12 bits of the own ID.
- FN 11 will include the lower 12 bits of the own ID.

The communications mode value is added according to the table in clause 5.7. For example, if slow data (SLD) is being included within the voice superframe then communications mode value is set to 001.

The communications format bits are now added according to clause 5.8. Generally these will be set to 0001 (peer-to-peer call). Occasionally they may be set to 0000 (all call) but this is a special case, similar to a broadcast.

The next 2 bits are set to 00 (reserved bits):

- If the communications mode is set to 000 the 18 bits of slow user data (SLD) field are set to zero and added.
- If the communications mode is set to 001 the 18 bits of slow user data (SLD) are added (clause 5.9.1).
- If the communications mode is set to 101 the slow user data (SLD) field is assembled according to clause 5.9.2 and appended.

This gives the total of 41 bits of CCH data.

The 7 bit CRC checksum is added using the polynomial given in clause 7.2 giving a total of 48 bits.

These 48 bits are now separated into 6 bytes. Each byte is now coded by a shortened 12,8 Hamming Code (clause 7.3) giving 6 x 12 bit blocks.

To protect against burst interference, these 6 x 12 bit blocks are now interleaved using the 12 x 6 TCH interleaving matrix given in clause 7.6.

Finally the interleaved TCH data is scrambled using the polynomial given in clause 7.5.

The frame is completed by prefixing with either the 24 bits of FS2 (frame numbers 00 or 10) or the 24 bits of Colour Code (frame numbers 01 or 11).

Finally the 4 x 72 bit blocks of Forward Error corrected vocoder data (TCH) are appended.

If the voice transmission is terminated before the end of the current superframe, then the superframe will be completed using silence data for the TCH ("silence data" is the vocoder output data when no sound is input).

In the case of a voice + data and the voice transmission ends before the end of the current superframe, the current frame will be completed using silence data for the TCH ("silence data" is the vocoder output data when no sound is input). After completion of the current frame, subsequent frames in the superframe are available for data and coded according to clause 9.3. DP in the SLD field will indicate if the frame contains voice or data information (clause 5.9.1).

Detail: Voice + Appended data call

In each transmitted item the format is always that of a series of complete superframes (SF) with Header and End frames as shown below:

H	SF	SF	SF	SF	SF	E

Within each superframe, there are 4 frames.

For this example we shall assume that the PTT is released in frame 2 and the voice codec data stops. 36 bytes of data with FEC (type 2) will be appended. As each frame has a capacity of 20 bytes of type 2 data, both frames 3 and 4 will be required.

Frame 1	Frame 2	Frame 3	Frame 4
FS2 CCH Payload	CC CCH Payload	FS2 CCH Payload	CC CCH Payload

The SLD field in each of these frames is composed as below:

Frame 1: with voice payload

Reserved	DP	Format	Cont.	Data length (bytes)
00000	00	4 bits	1	000000

Frame 2: with voice payload ending in this frame

Reserved	DP	Format	Cont.	Data length (bytes)
00000	00	4 bits	1	000000

Frame 3: with data payload starting in this frame

Reserved	DP	Format	Cont.	Data length (bytes)
00000	11	4 bits	0	010100 (20 bytes in this frame)

Frame 4: with data payload ending in this frame

Reserved	DP	Format	Cont.	Data length (bytes)
00000	11	4 bits	1	010000 (16 bytes in this frame)

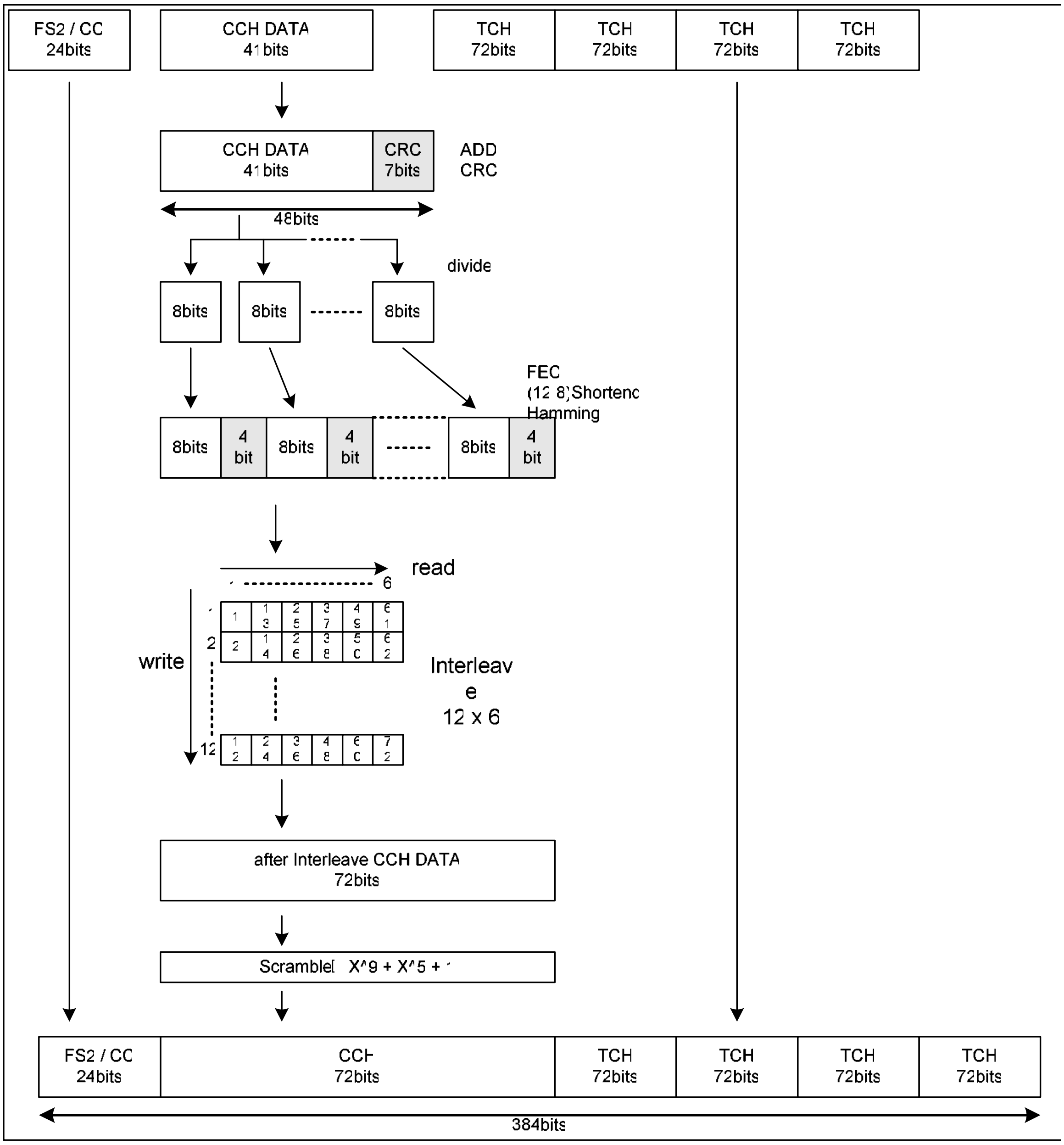
Notes for TCH payload:

In frame 2 the voice codec data ends when the PTT is released. "Silence data" is used to complete the TCH payload of frame 2 as previously stated.

In frame 4 the 16 bytes of data is not enough to complete the frame. Therefore 4 bytes of dummy data (i.e. zeros) is appended to complete the TCH payload of frame 4. The TCH payload is coded according to clause 9.3. The receiving party will know that there are 4 bytes of dummy data as the SLD data length field indicates that only 16 of the 20 bytes are valid data.

Table 9.1: CM, SLD, CI use

Communication mode		SLD field (CCH) see clause 5.9	CI field (Header) see clause 5.10
000	Voice Comm	ALL "0" (No user data)	Header Type
001	Voice + User SLD	User Slow Data (clause 5.9.1)	Header Type
010	Data Type 1	TCH data information (clause 5.9.2)	Header Type (see note) / Data Format
011	Data Type 2	TCH data information (clause 5.9.2)	Header Type (see note) / Data Format
100	Data Type 3	---------	Header Type (see note) / pDS,pDM
101	Voice and appended Data（Type 2）	TCH data information	Header Type
NOTE: Use Extended Header (clause 11.1).			



NOTE: Voice communication.

Figure 6: Voice frame coding

9.2 Type 1 data superframe

Construction of the type 1 data superframe starts with CCH control channel data.

Frame Numbering (FN) is from 00 to 11 (1 to 4)

FN is followed by 12 bits of the called station address or own ID as follows:

The called station ID and own ID make a total of 48 bits. These bits are split into 12 bit blocks and one block is included in each of the 4 frames of the superframe.

- FN 00 will include the upper 12 bits of the called station ID.
- FN 01 will include the lower 12 bits of the called station ID.

- FN 10 will include the upper 12 bits of the own ID.
- FN 11 will include the lower 12 bits of the own ID.

The communications mode, 010 is added (clause 5.7).

The communications format bits are now added according to clause 5.8. Generally these will be set to 0001 (peer-to-peer call). Occasionally they may be set to 0000 (all call) but this is a special case, similar to a broadcast.

The next 2 bits are set to 00 (reserved bits).

Finally there are the 18 bits of the slow user data field (SLD). These bits are set according to clause 5.9.2 depending on the data to be transmitted.

This gives the total of 41 bits of CCH data.

The 7 bit CRC checksum is added using the polynomial given in clause 7.2 giving a total of 48 bits.

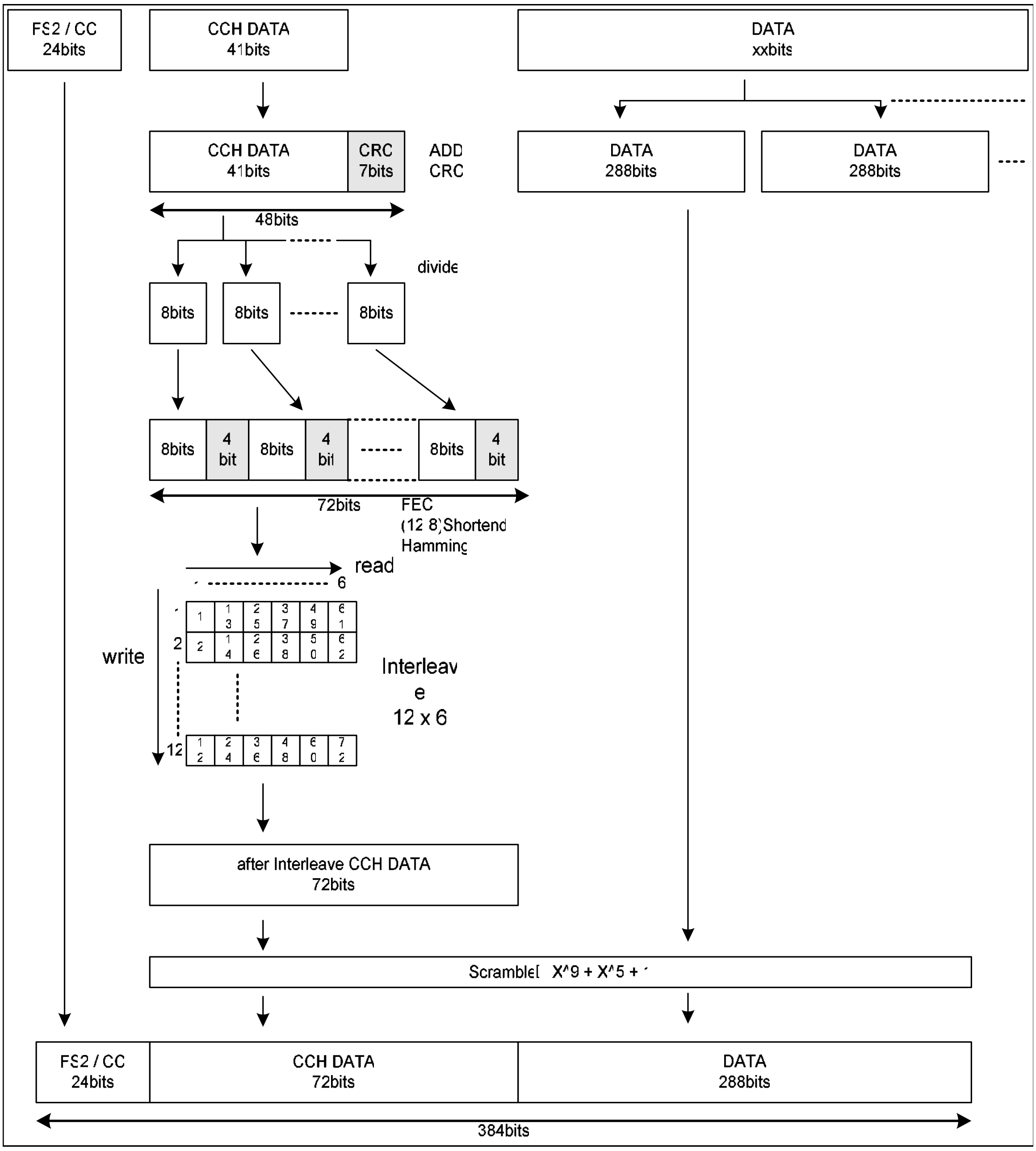
These 48 bits are now separated into 6 bytes. Each byte is now coded by a shortened 12,8 Hamming Code (clause 7.3) giving 6 x 12 bit blocks.

To protect against burst interference, these 6 x 12 bit blocks are now interleaved using the 12 x 6 TCH interleaving matrix given in clause 7.6.

Next the 288 bit block of uncorrected user data are appended.

Finally the interleaved TCH data and appended data blocks are scrambled using the polynomial given in clause 7.5.

The frame is completed by prefixing with either the 24 bits of FS2 (frame numbers 00 or 10) or the 24 bits of Colour Code (frame numbers 01 or 11).



NOTE: DATA communication Type 1 (user data added to TCH part. No error correction).

Figure 7: Type 1 data frame coding

9.3 Type 2 Data superframe

Construction of the type 2 data superframe starts with CCH control channel data.

Frame numbering (FN) is from 00 to 11 (1 to 4).

FN is followed by 12 bits of the called station address or own ID as follows:

The called station ID and own ID make a total of 48 bits. These bits are split into 12 bit blocks and one block is included in each of the 4 frames of the superframe.

- FN 00 will include the upper 12 bits of the called station ID.
- FN 01 will include the lower 12 bits of the called station ID.

- FN 10 will include the upper 12 bits of the own ID.
- FN 11 will include the lower 12 bits of the own ID.

The communications mode, 011 is added (clause 5.7).

The communications format bits are now added according to clause 5.8. Generally these will be set to 0001 (peer-to-peer call). Occasionally they may be set to 0000 (all call) but this is a special case, similar to a broadcast.

The next 2 bits are set to 00 (reserved bits).

Finally there are the 18 bits of the slow user data field (SLD). These bits are set according to clause 5.9.2 depending on the data to be transmitted.

This gives the total of 41 bits of CCH data.

The 7 bit CRC checksum is added using the polynomial given in clause 7.2 giving a total of 48 bits.

These 48 bits are now separated into 6 bytes. Each byte is now coded by a shortened 12,8 Hamming Code (clause 7.3) giving 6 x 12 bit blocks.

To protect against burst interference, these 6 x 12 bit blocks are now interleaved using the 12 x 6 TCH interleaving matrix given in clause 7.6.

The user data is broken down into 5 byte blocks (40 bits) to which 1 bit of null data (i.e. set to 0) is appended. 4 of these 41 bit blocks will be allocated to each frame.

The 7 bit CRC checksum is added to each 41 bit block using the polynomial given in clause 7.2 giving a total of 48 data bits.

These 48 data bits are now separated into 6 bytes. Each byte is now coded by a shortened 12,8 Hamming Code (clause 7.3) giving 6 x 12 bit blocks.

To protect against burst interference, these 6 x 12 bit blocks are now interleaved using the 12 x 6 TCH interleaving matrix given in clause 7.6.

Next 4 of the 72 bit coded data blocks are appended to the interleaved TCH data and scrambled using the polynomial given in clause 7.5.

The frame is completed by prefixing with either the 24 bits of FS2 (frame numbers 00 or 10) or the 24 bits of Colour Code (frame numbers 01 or 11).

DATA communication Type 2

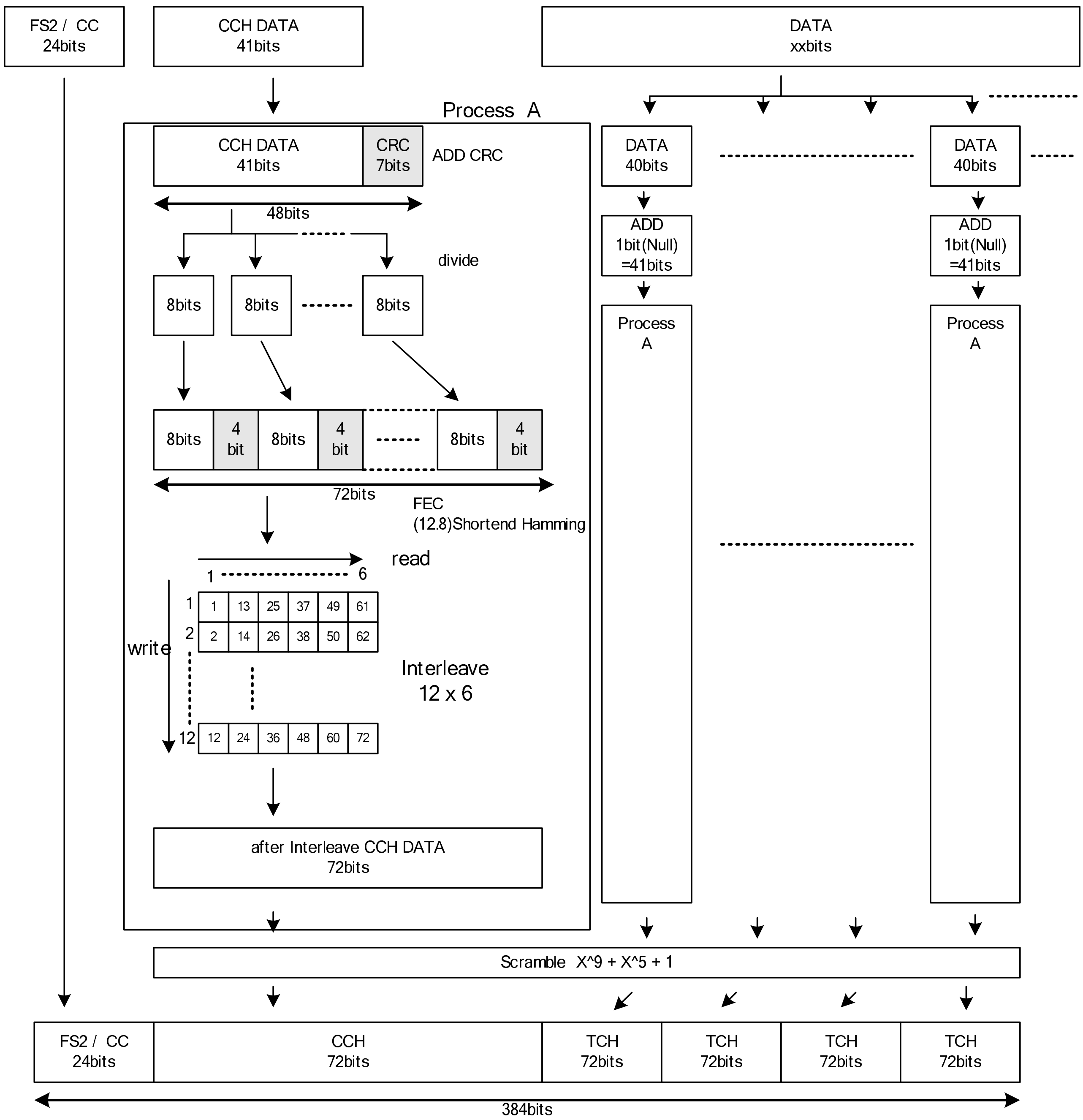


Figure 8: Type 2 data frame coding

9.4 Type 3 (Packet) Data frame

Construction of the type 3 Packet starts with the PAR (parameter) data.

The packet burst can consist of up to 8 data frames. The current data frame number (N) is from 000 to 111.

N is followed by 8 bits that give the total number of data bytes contained in the current burst.

This is followed by 14 dummy bits that are set to zero.

The next 16 bits are the CRC for the data field contained in this burst.

The 7 bit CRC checksum is added to these 41 bits using the polynomial given in clause 7.2 giving a total of 48 bits.

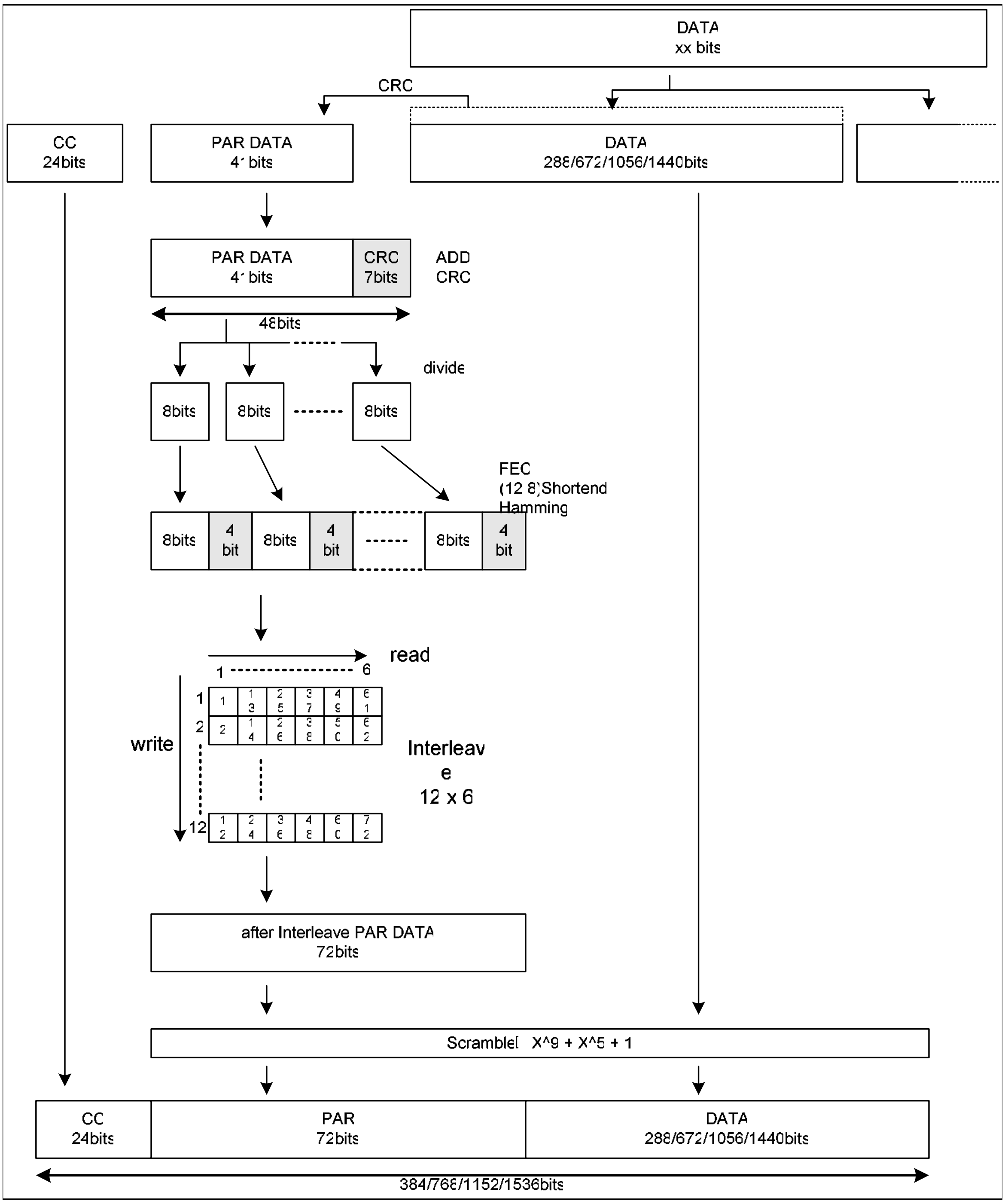
These 48 data bits are now separated into 6 bytes. Each byte is now coded by a shortened 12,8 Hamming Code (clause 7.3) giving 6 x 12 bit blocks.

To protect against burst interference, these 6 x 12 bit blocks are now interleaved using the 12 x 6 TCH interleaving matrix given in clause 7.6.

Next the associated data frames are appended to the interleaved PAR data and scrambled using the polynomial given in clause 7.5.

The frame is completed by prefixing the 24 bits of Colour Code.

NOTE: The packet data format used in these frames is indicated by the Call Information (CI) contained in the Packet data Header. See clause 8.3.



NOTE: DATA communication Type 3 (Packet Data).

Figure 9: Packet data frame coding

9.5 Headers

Construction of a Header starts with the Header Information (HI) bits.

First there are 4 bits allocated to Header Type (HT) which is selected according to clause 5.10.

HT is followed by the 24 bits of the called station ID. To this the 24 bits of the own ID is added.

The communications mode value is added according to the table in clause 5.7.

The communications format bits are now added according to clause 5.8. Generally these will be set to 0001 (peer-to-peer call). Occasionally they may be set to 0000 (all call) but this is a special case, similar to a broadcast.

The next 2 bits are set to 00 (reserved bits).

Finally there are the 11 bits of Call Information (CI) that are made up of 3 data bits and 8 information bits as described in clause 5.9 (see note 1).

This gives the total of 72 bits of HI data.

The 8 bit CRC checksum is added using the polynomial given in clause 7.2 giving a total of 80 bits.

These 80 bits are now separated into 10 bytes. Each byte is now coded by a shortened 12,8 Hamming Code (clause 7.3) giving 10 x 12 bit blocks.

To protect against burst interference, these 10 x 12 bit blocks are now interleaved using the 12 x 10 HI interleaving matrix given in clause 7.6.

Then the interleaved HI data is scrambled using the polynomial given in clause 7.5.

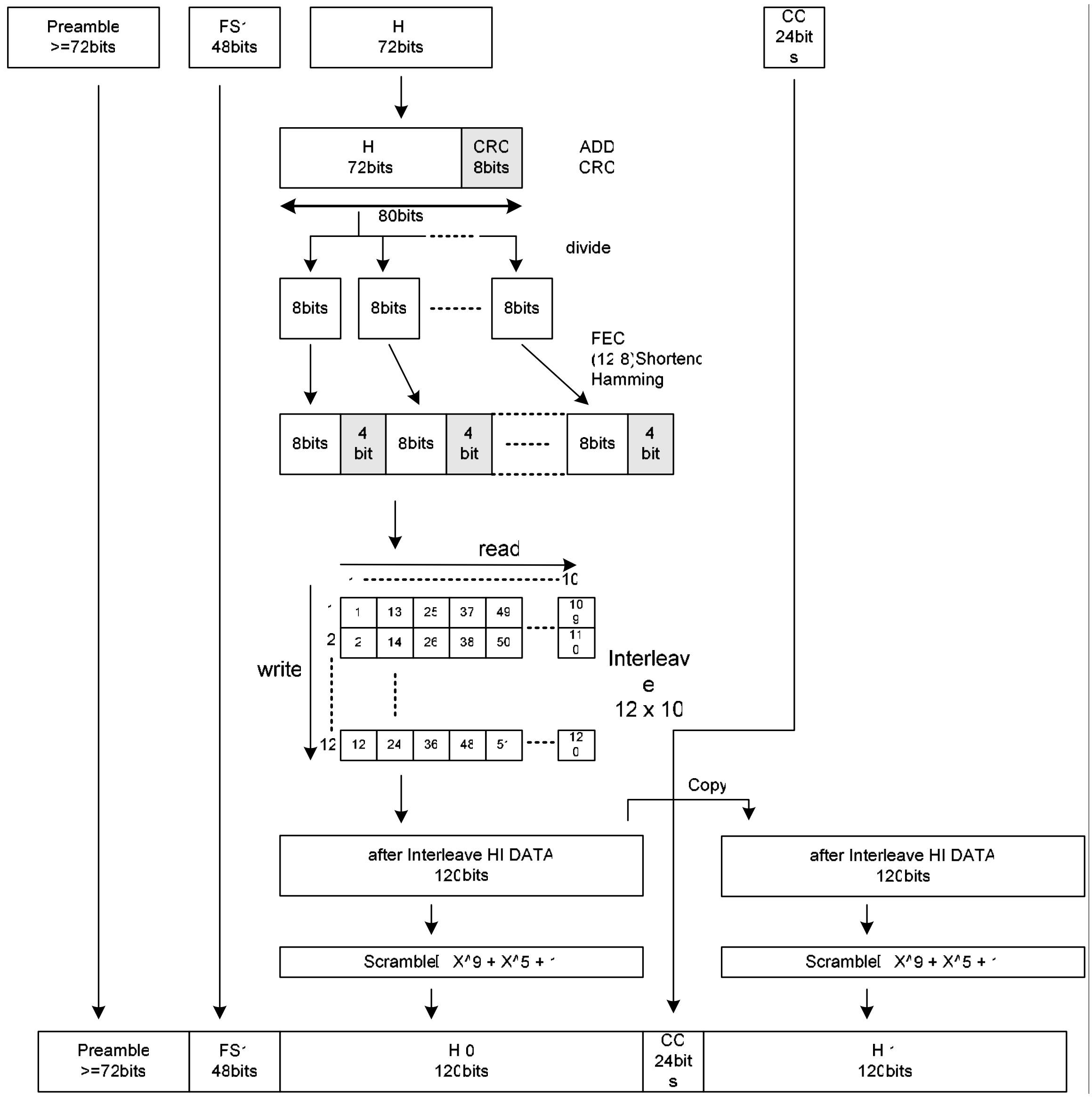
The 24 bit Colour Code is appended to the HI data and then the HI data is repeated after the CC.

The header is completed by prefixing with the 48 bit FS1 synchronization sequence and then prefixing FS1 with a minimum of 72 bits of alternating 0, 1 preamble (see note 2).

NOTE 1: In the case where this is a Packet Data header, the Call Information is as follows:

Type	Information	
011	pdS 4 bits	pdM 4 bits

NOTE 2: In the case where this is a Packet Data header, the 48 bit FS4 synchronization sequence shall be used.



NOTE: Header Frame Channel Coding.

Figure 10: Header frame coding

9.6 End frames

Construction of the End frame starts with the 17 bits of End data.

The end data starts with the End Type (ET) which is either 00 (normal end frame) or 01 (end frame with status message).

The next 2 bit are the acknowledgement request (ARQ). 00 signifies that no acknowledgement is requested and 01 requires an acknowledgement.

The next 4 bits define any Tx wait time (WAIT) using the values given in clause 5.13.

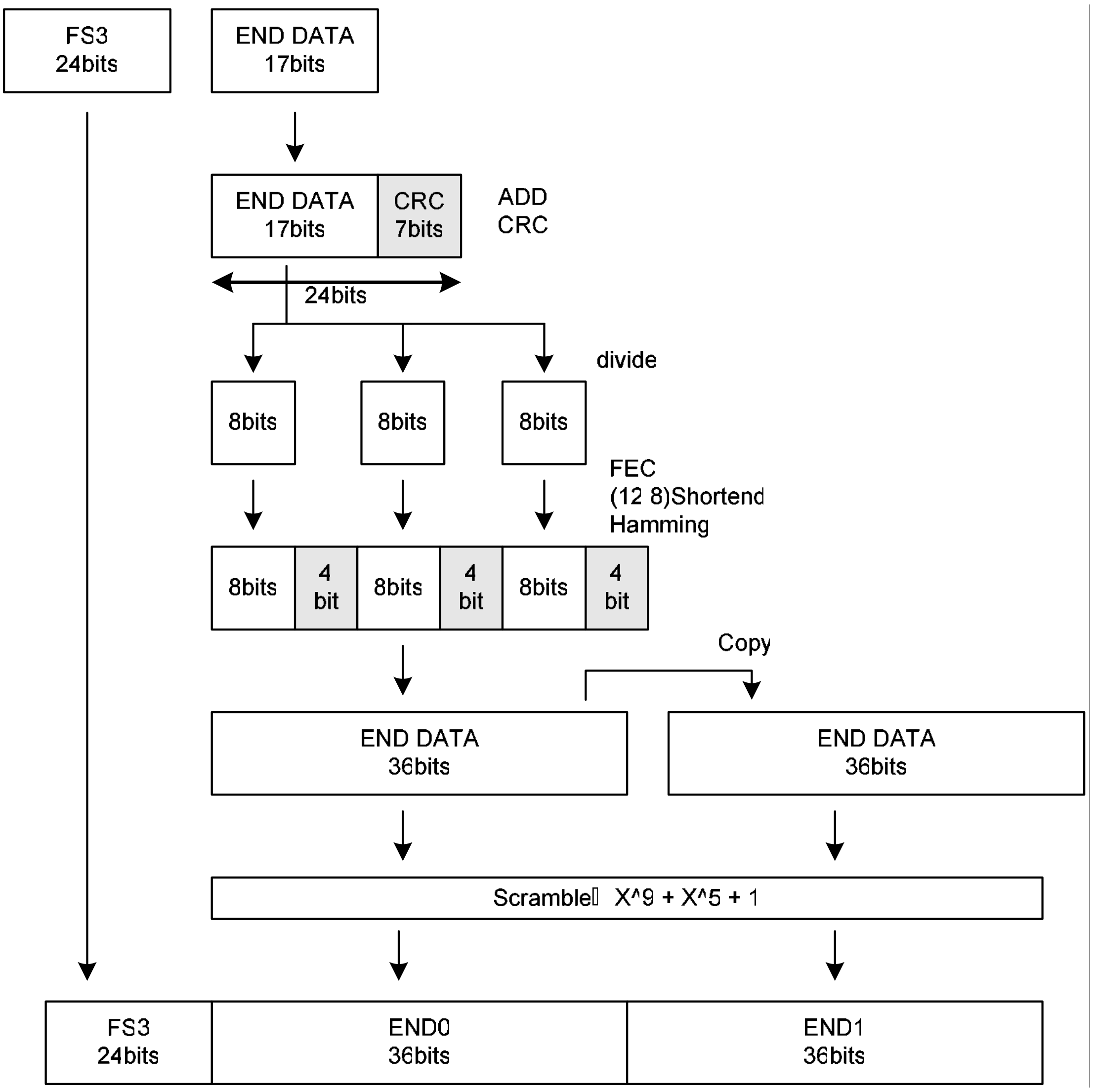
5 bit of status message will then follow if ET has been set to 01 (or 5 bits of dummy data if ET = 00).

Finally the 4 reserved bits are set to 0000.

The 7 bit CRC checksum is added using the polynomial given in clause 7.2 giving a total of 24 bits.

These 24 bits are now separated into 3 bytes. Each byte is now coded by a shortened 12,8 Hamming Code (clause 7.3) giving 3 x 12 bit blocks. These 36 bits are now repeated and the total 72 bits are scrambled using the polynomial given in clause 7.5.

Finally the 24 bit FS3 synchronization sequence is prefixed to these end data bits.



NOTE: END Frame Channel Coding.

Figure 11: End frame coding

10 Channel access

10.1 Listen Before Transmit (LBT)

When accessing a channel to transmit, a radio shall take account of the following types of activity which may already be present on the channel:

- 6,25 kHz FDMA activity;
- other digital protocol activity;
- analogue activity.

When determining whether activity is present on a channel, the radio shall monitor the RSSI level. If after a maximum period of time (T_ch_chk) the RSSI level has not exceeded a configurable (within a predefined range) threshold RSSI_LO, then the radio shall assume that activity is not present on the channel.

RSSI_LO shall be set to -105 dBm ± 3 dB.

If however the RSSI level does exceed this threshold, then the radio shall assume that activity is present on the channel and it shall attempt to become frame synchronized to the activity.

If the radio is successful in becoming frame synchronized to the activity, then the radio shall assume that 6,25 kHz FDMA activity is present on the channel. If however after a maximum period of time (T_ch_free), the radio has not become frame synchronized to the activity, then the radio shall assume that the activity is non-6,25 kHz FDMA activity. If the Colour Code is different then the radio shall assume that the activity is interference.

10.2 Hang time messages and timers

A voice call shall consist of a series of speech items separated by gaps known as "call hang time periods".

As the protocol is inherently asynchronous, these gaps will be of random duration but it is possible for a radio to define a minimum call hang time period using Tx WAIT.

The minimum call hang time period [Tx WAIT] (which may be zero) shall be determined by the radio configuration and during this period of time any radios that employ a "polite to own talkgroup" or "polite to own group" level of politeness shall consider the channel as busy if they are participating in the specified voice call unless they have prekeyed a break-in request. Radio may transmit any such break-in request during the Tx WAIT delay announced.

10.3 Call duration timers

dPMR HSs shall have a transmit TimeOut timer which limits the time of a single transmission item. This timer shall be set to the value of 180 seconds whenever the PTT key is pressed and counts down to zero.

If the transmit TimeOut timer expires, then all HSs will stop transmitting immediately and may not re-transmit until PTT has been released and pressed again.

10.4 Transmit admit criteria

Where a radio has been solicited to transmit a response, it may transmit the response within response time [T_ack] irrespective of whether the channel is "Idle" or "Busy". Additionally, while a radio is partied to a voice call, it may transmit irrespective of whether the channel is "Idle" or "Busy" with 6,25 kHz FDMA activity pertaining to the same voice call but may not transmit if a Tx WAIT time has been invoked. However, for all other situations, radios shall be configurable to employ the following levels of "politeness" on a channel:

- Polite to own Group or Talkgroup: The radio shall refrain from transmitting on a channel while the channel is "Busy" with other 6,25 kHz FDMA activity from radios within its own group or talkgroup. For all other types of activity already present on the channel, the radio shall transmit regardless. For ISF radios, Group or Talkgroup means Common ID.

- Polite to own Colour Code: The radio shall refrain from transmitting on a channel while the channel is "Busy" with other 6,25 kHz FDMA activity from radios using the same Colour Code. For all other types of activity already present on the channel, the radio shall transmit regardless. For ISF radios, there is no "own" Colour Code so this cannot be implemented in ISF radios.

- Impolite: The radio shall transmit on a channel regardless of any other activity (either 6,25 kHz FDMA or otherwise) already present on the channel.

On a given channel, not all features may be supported the same level of politeness. So for example, voice transmissions may be configured to be "impolite" while packet data transmissions are configured to be "polite".

10.5 Transmission re-tries

Certain transmissions solicit responses and where these responses are not received (e.g. due to collisions, interference etc.) the transmitting entity may repeat the original transmission a number of times either until the response is received or the transmitting entity gives up.

The waiting times for re-transmission and the maximum number of re-tries are defined in clause 10.10.

10.6 Radio Out_of_Sync_Channel_Monitored Channel Access

A transmission request employing impolite channel access from the High Level radio Out_of_Sync_Channel_Monitored state is always granted.

10.7 Radio In_Sync_Unknown_System Channel Access

A transmission request employing impolite channel access from the High Level radio In_Sync_Unknown_System state is always granted.

10.8 Radio Not_in_Call Channel Access

10.8.1 CSF Radios

A transmission request employing impolite channel access from the High Level radio Not_in_Call state is always granted.

A transmission request employing polite to own Group, Talkgroup or Colour Code channel access from the High Level Not_in_Call state will be denied. This occurs since in order to reach this state the radio has matched the Group, Talkgroup or Colour Code. The radio will stay in the Not_in_Call state. However, if this is a break in request and the transmitting radio has announced a Tx WAIT time then the break in request may be transmitted immediately following the End frame of the current transmission.

10.8.2 ISF Radios

A transmission request employing impolite channel access from the High Level radio Not_in_Call state is always granted.

A transmission request employing polite to own Common ID channel access from the High Level Not_in_Call state will be denied. This occurs since in order to reach this state the radio has matched the Common ID. The radio will stay in the Not_in_Call state. However, if this is a break in request and the transmitting radio has announced a Tx WAIT time then the break in request may be transmitted immediately following the End frame of the current transmission.

10.9 Radio My_Call Channel Access

In this state the radio is party to the call and will use the impolite channel access method but may be required to back off for any period specified in the Tx WAIT field. This is regardless of the programmed channel access method programmed into the radio.

10.10 Channel access timers and constants

10.10.1 Timers

T_ch_chk: Channel check timer: 100 ms.

T_ch_free: Unsynchronizable activity timer: 200 ms.

10.10.2 Constants

Automatic retries are permitted for acknowledgement (and nack) signalling.

A maximum of four retries are permitted. The time between any such repeated signalling shall be in the range 300 ms to 500 ms.

11 Powersave

11.1 Transmitted format

Powersave is implemented by using a call set-up procedure of multiple repeated header frames. Each of these repeated header frame are numbered and count down to zero, so that radios sampling the channel can calculate exactly when the payload item or signalling will commence.

In the case of repeated headers for powersave use, the preamble used by each header shall be fixed at 72 bits.

These extended wake-up headers shall be coded according to clauses 5.2 and 5.10.

The 11 bits of Call Information (CI) are used as follows:

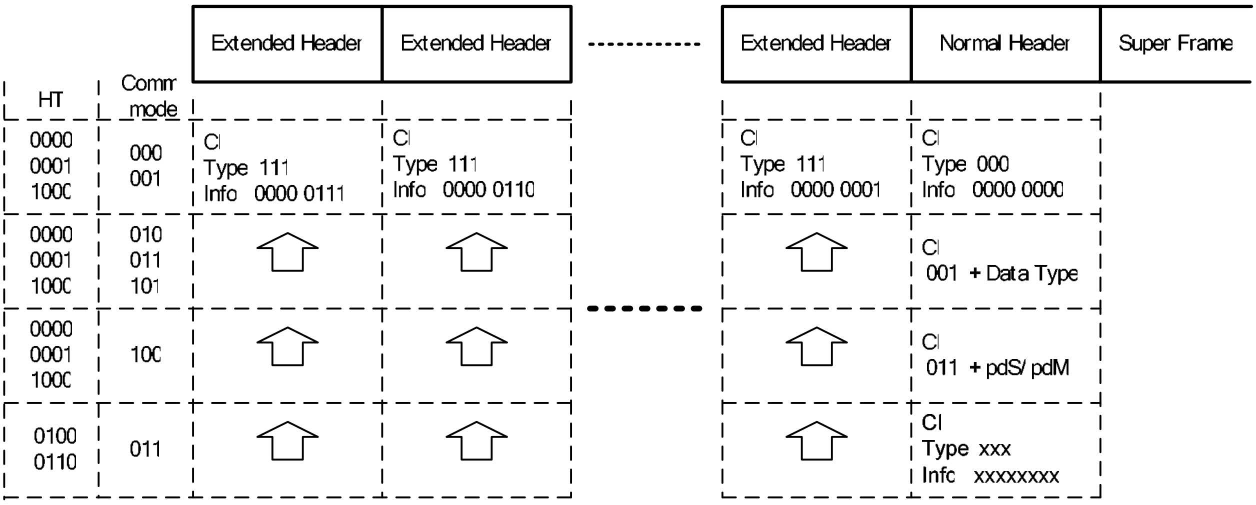
CI Type = 111 (extended wake-up header).

CI Information uses that last 4 bits to show how many header frames follow the current one:

Table 11.1: Extended wake up header numbering

0000 0000	END Frame follows this header
0000 0001 ------ ↓ -------- 0000 1111	1 Header frame follows -- 15 Header frames follow
Other	Reserved

Radios can be programmed to use up to 15 repeated header frames for extended wake-up purposes. This will give a maximum time of 1,2 seconds.



11.2 Receive format

Radio in standby (sleep) will be programmed to wake-up and monitor the channel at regular intervals. Each wake-up shall have a minimum duration of T_ch_chk (clause 10.10). The intervals between successive wake-ups shall be dependant on the number of repeated header frames used in extended wake-up according to clause 11.1.

The maximum sampling interval between wake-ups shall be:

T_sam = (n - 1) x 80 ms.

Where T_sam is the sampling interval and n is the number of extended wake-up headers used.

If the radio wakes and there is no activity on the channel for the duration of T_ch_chk it may return to sleep.

If the radio wakes and decodes the dPMR activity but the called station ID does not match it may return to sleep.

If the radio wakes and decodes the dPMR activity and the called station ID matches, it shall then be able to calculate from the CI information bits when the payload item or signalling will commence. Upon completion of the payload item or signalling the radio may return to sleep again after T_sam ms.

12 Physical Layer

12.1 General parameters

The radio shall comply with the essential requirements as stated in EN 301 166-2 [1].

12.1.1 Frequency range

The radio system operates within the RF frequency range of 446,100 MHz to 446,200 MHz as identified in ECC/DEC/(05)12 [2].

12.1.2 RF carrier bandwidth

The radio system operates within a 6,25 kHz RF carrier bandwidth.

12.1.3 Transmit frequency error

The maximum transmit frequency error from the assigned RF carrier centre shall be within ±625 Hz as stated in EN 301 166-2 [1].

12.1.4 Time base clock drift error

The maximum time base clock drift error shall be ±2 ppm. This error is the amount of clock drift that is acceptable during a transmission.

12.2 Modulation

12.2.1 Symbols

The modulation sends 2 400 symbols/sec with each symbol conveying 2 bits of information. The maximum deviation, D, of the symbol is defined as:

The maximum deviation, D, of the symbol is defined as:

$$D = 3h / 2T$$

Where:

- h is the deviation index defined for the particular modulation; and
- T is the symbol time (1 / 2400) in seconds.

12.2.2 4FSK generation

This clause describes the characteristics of the constant-envelope modulation, entitled 4FSK.

12.2.2.1 Deviation index

The deviation index, h, for 4FSK is defined to be 0,29. This yields a symbol deviation of 1 050 Hz at the symbol center. The mapping between symbols and bits is given below.

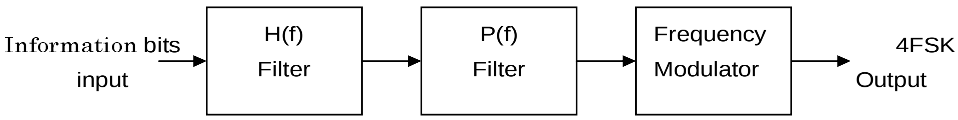
Information Bits Symbol Mapping to 4FSK Deviation.

Table 12.1: FSK symbol mapping

Information Bits		Symbol	4FSK Deviation
Bit 1	Bit 0		
0	1	+3	+1 050 Hz
0	0	+1	+350 Hz
1	0	-1	-350 Hz
1	1	-3	-1 050 Hz

12.2.2.2 Square root raised cosine filter

***Tx Baseband Filter**



$$|H(f)| = \begin{cases} 1 & , \quad 0 \le |f| < (1-\alpha)/2T \\ \cos\left[(T/4\alpha)(2\pi|f| - \pi(1-\alpha)/T)\right] & , \quad (1-\alpha)/2T \le |f| < (1+\alpha)/2T \\ 0 & , \quad (1+\alpha)/2T \le |f| \end{cases}$$

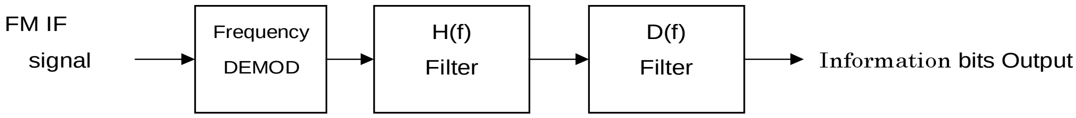
$$|P(f)| = \frac{\sin(\pi f T)}{\pi f T}$$

α = 0.2 **T = 1 / 2400**

4FSK Deviation

Di-bit	Symbol	Deviation
01	+3	+1050Hz
00	+1	+350Hz
10	-1	-350Hz
11	-3	-1050Hz

***Rx Baseband Filter**



$$|H(f)| = \begin{cases} 1 & , \quad 0 \le |f| < (1-\alpha)/2T \\ \cos\left[(T/4\alpha)(2\pi|f| - \pi(1-\alpha)/T)\right] & , \quad (1-\alpha)/2T \le |f| < (1+\alpha)/2T \\ 0 & , \quad (1+\alpha)/2T \le |f| \end{cases}$$

$$|D(f)| = \frac{\pi f T}{\sin(\pi f T)}$$

α = 0.2 **T = 1 / 2400**

12.2.2.3 4FSK Modulator

The 4FSK modulator consists of a Square Root Raised Cosine Filter, cascaded with a frequency modulator as shown in figure 12. The Square Root Raised Cosine Filter is described in clause 12.2.2.2.

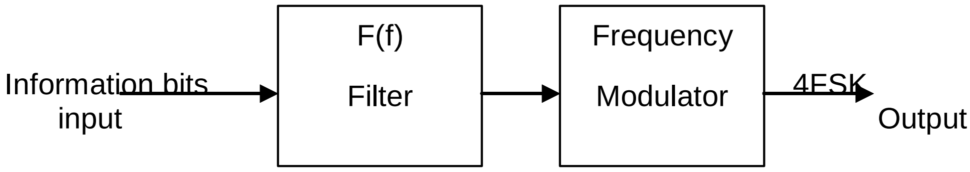


Figure 12: 4FSK Modulator

Annex A (informative): Numbering and dialling plan

A.1 Introduction to the numbering and dialling plan

It is recognized that manufacturers of MSs will wish to exercise design independence in their products and, accordingly, the requirements of this annex are informative only.

This annex is intended to:

- define the user visible numbering (User Interface domain); and
- dialling in a MS for accessing other MS(s) over the AI; and
- to describe how the visible user numbering and dial strings may be mapped on to the AI.

The Man Machine Interface (MMI) issues have been addressed in these annex only to the extent of those strictly related to numbering and dialling.

It should be ensured in the MS implementation, that no non-deterministic user input results in an ambiguous call set-up attempt over the Air Interface. For example, if a user inputs a dialled string of digits that is not assigned to any of the presented dialling algorithms, then the MS should not try to establish the call and appropriate feedback or alert should be given to the user.

As not to restrict manufacturer's independence, it is envisaged that dialling selection may be initiated in many ways. Some methods are:

- direct number entry via a keypad;
- mode selection buttons; and
- soft key menu selection.

The dialling method may vary according to the MS terminal type. This annex is applicable to MSs with a basic CCITT number keypad, as shown in figure C.1 and/or with a display capable of displaying the decimal numbers "0" to "9" and the keys "*" and "#". However, manufacturers may employ other keypad layouts.

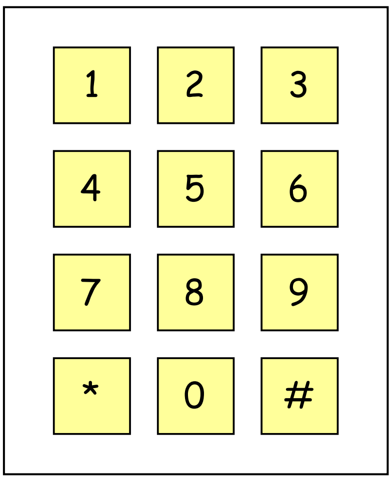


Figure A.1: CCITT keypad layout

The primary use for the keypad is to enable the user to select the destination address, the type of service, and to initiate calls from the MS. Certain other services may be requested by dialling "call modifier" strings prior to entering the destination address.

The user input in case of establishing a call is defined for the purposes of this annex as two sequential events:

a) user dials digits; and

b) user initiates call.

The call initiation is the event, which terminates the user input related to the digits and normally causes a call set-up. The call initiation event itself may be either when the user presses the "#" key or Push-To-Talk (PTT) or other method that may be manufacturer or implementation specific.

NOTE: This definition of the user input for call establishment is valid only for the cases when a user dials a number using the number keypad or selects a number e.g. from a list of predefined numbers. There may be methods to combine all the three events so that e.g. PTT causes a call establishment using a predefined dialling algorithm to a predefined address requiring no explicit dialling event.

Manufacturers may implement barring of certain types of call or restrict calls to certain addresses. However, such constraints are outside the scope of this annex.

The MS may contain predefined parameters prescribing the minimum and maximum length of the user dial string. By limiting the length of the dialled string the address range the MS is able to dial is restricted. The minimum length parameter may be set according to the user needs, e.g. to disable accidental 1-digit dialling.

The (User Interface) address that an individual MS is assigned (its own address) may be defined by the dialled digits another MS would dial to reach that MS rather than the Air Interface binary number. If the algorithm specified in this annex were implemented, an MS individual address would be fully specified by seven decimal digits. Similarly, if a MS was personalized with one or more talkgroup addresses, they may be specified at the user interface by seven decimal digits.

A.2 Subscriber mapping

A.2.1 User Interface - Air Interface

Dialled digits are represented in decimal notation and utilize the numbers "0" to "9" and the keys "*" and "#". For an MS fitted with a keypad, the "#" key may initiate a call (although other initiate methods may be implemented by a manufacturer). Dialled digits that represent a destination address are translated to a form for the Air Interface by one of two algorithms specified in clauses A.2.1.1 and A.2.1.2. This is illustrated in figure A.2.

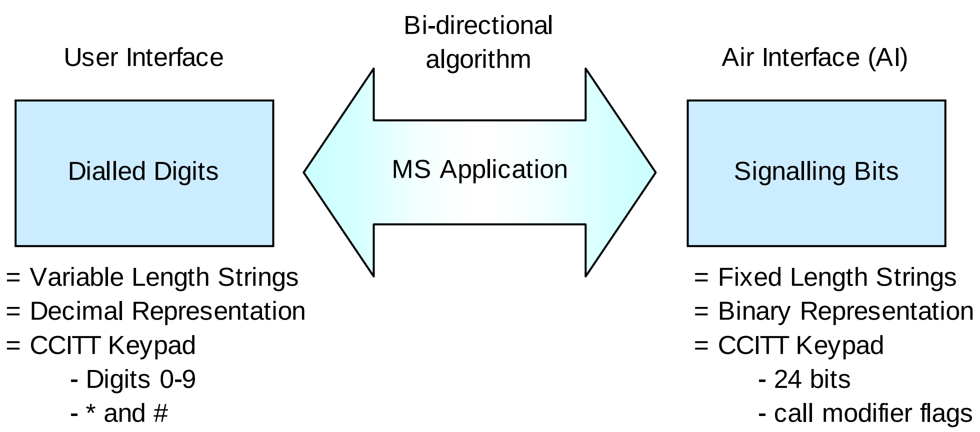


Figure A.2: Number conversion

Address fields in the Air-Interface domain structure has a length of 24 bits.

The content of a 24-bit AI MS address field may represent:

- an MS individual address;
- an MS group address;

The Air Interface provides call services for voice and data. The AI also permits the call services to be modified. The application that converts the User Interface to the Air Interface recognizes the "call modifier" and request the lower layers to set appropriate bits in the PDUs carried between the entities. At the User Interface, the "call modifier" is indicated by preceding the destination address digits with additional "call modifier" digits.

A.2.1.1 Mapping for MS individual address space

The mapping between the User Interface and individual AI address space for dialable digits is shown in figure A.3.

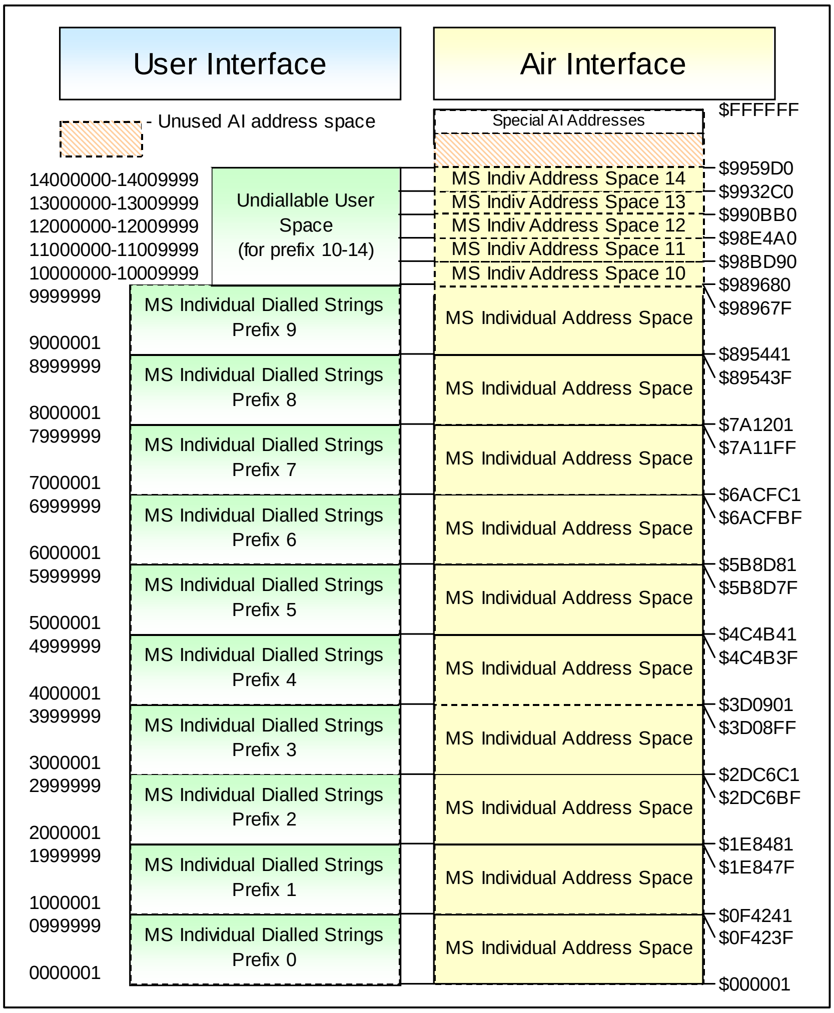


Figure A.3: User domain mapping for calls in the individual addresses space

Figure A.3 illustrates the individual address space domain mapping. It can be seen that there is un-dialable address space within prefixes 10 to 14. These addresses are not reachable by user dialling and are available for devices with fixed addresses (for example telemetry devices could use these addresses. They would never be addressed by an MS in error because they are not reachable by dialling).

A.2.1.1.1 Mapping for dialable addresses (prefix 0 to 9)

A MS individual address is a 7 character numeric string in the range "0000001" to "9999999", these characters are mapped to the Air Interface domain structure bits by the reversible function $\boldsymbol{B_1}$.

Individual dialled addresses do not contain the symbol "*" which would be interpreted as a call to an MS talk-group.

Table A.1: 7-number dialable address mapping by B_1

Character							B_1	Air Interface ID
1	2	3	4	5	6	7		
K_1	K_2	K_3	K_4	K_5	K_6	K_7		24 bits

If the dialled string is considered as a string array K_1 to K_7

$$B_1 = \sum 10^6 * K_1, 10^5 * K_2, 10^4 * K_3, 10^3 * K_4, 10^2 * K_5, 10 * K_6, K_7$$

The seven user dialled digits K_1 to K_7 in the range "0000001" to "9999999" are converted to the 24 bits of the AI ID using true decimal to binary conversion.

A.2.1.1.2 Mapping for non-dialable individual addresses (prefix 10 to 14)

Table A.2: Non-dialable address mapping by B_3

Character							B_3	Air Interface ID
1	2	3	4	5	6	7		
K_1	K_2	K_3=0	K_4=0	K_5	K_6	K_7		24 bits

The $\boldsymbol{B_3}$ algorithm provides a numeric User Interface for the non-dialable individual address space. Each prefix has the capacity for 10 000 individual addresses.

If the MS individual address is represented by 8 digits K_1 to K_8 (K_3 and K_4 are always 0).

$$B_3 = \sum 9900000, 10^5 * K_1, 10^4 * K_2, 10^3 * K_5, 10^2 * K_6, 10 * K_7, K_8$$

The following steps are needed to convert the dialled digits to an ID in the AI domain using the $\boldsymbol{B_3}$ algorithm:

c) start with the number 9 900 000;

d) take the first digit (0 to 9) and multiply by 100 000;

e) take the second digit (0 to 9), multiply by 10 000;

f) take the fifth digit (0 to 9), multiply by 1 000;

g) take the sixth digit (0 to 9), multiply by 100;

h) take the seventh digit (0 to 9), multiply by 10;

i) take the eighth digit (0 to 9); and

j) add a) to g).

A.2.1.1.3 Examples of individual address mapping

Examples of individual MS numbers in the user domain and AI domain are given in table A.3 ($\boldsymbol{B_1}$ algorithm).

Table A.3: Examples of dialable individual address translation

User-Interface	Air-Interface (Hex)	Air Interface (Binary)
1234567	$12D687_{16}$	$0001\ 0010\ 1101\ 0110\ 1000\ 0111_2$
9876543	$96B43F_{16}$	$1001\ 0110\ 1011\ 0100\ 0011\ 1111_2$

For non-dialable address space and prefixes in the range 10 to 14 the address in the user domain may be specified using 8 digits as shown in the table A.4 ($\boldsymbol{B_3}$ algorithm).

Table A.4: Examples of non-dialable individual address translation

Non dilatable User-Interface	Air-Interface (Hex)	Air Interface (Binary)
10000000	989680_{16}	$1001\ 1000\ 1001\ 0110\ 1000\ 0000_2$
13004567	$991D87_{16}$	$1001\ 1001\ 0001\ 1101\ 1000\ 0111_2$
14009876	995954_{16}	$1001\ 1001\ 0101\ 1001\ 0101\ 0100_2$

NOTE: For non-dialable individual addressing, digits K_3 and K_4 are always zero.

A.2.1.2 Mapping for MS talkgroup address space

A talkgroup call is a separate dPMR service to an individual call . The mapping between the User-Interface domain and the Air Interface uses a different algorithm to the MS individual address.

There must be no ambiguity if the initiator wishes to setup a talkgroup call (i.e. the MS must be able to differentiate between an individual call request and a talkgroup call request). There are a number of methods by which a MS may distinguish a talkgroup call described in the following clauses.

A.2.1.2.1 The concept of the wildcard character

The MS may discriminate a talkgroup call from an individual call by the use of the "wildcard".

In the User Interface domain structure, if the dialled string represents an MS address, and contains a "*" in any of the four least significant characters, then that MS address represents a group of MSs. The "*" character is the "wildcard" and represents all numeric values in that digit position, as defined in example 1 to 3.

EXAMPLE 1: The user dials "012345*" means that the MS is addressing 10 separate MSs whose individual addresses are "0123450", "0123451", "0123452", "0123453", "0123454", "0123455", "0123456", "0123457", "0123458", and "0123459".

EXAMPLE 2: The user dials "01234*6" means the MS is addressing 10 separate MSs whose individual addresses are "0123406", "0123416", "0123426", "0123436", "0123446", "0123456", "0123466", "0123476", "0123486", and "0123496".

EXAMPLE 3: Wildcards may be combined. The user dials "01234**" represents 100 MSs in the range "0123400" to "0123499".

For operators who have no interest in this method of defining talkgroups, the "wildcard" feature may be disabled by MS programming.

A.2.1.2.2 The concept of stored parameters

The MS equipment may contain predefined parameters prescribing the MS addresses that will be interpreted as talkgroup addresses. These addresses may be stored as a list programmed during manufacture or before connecting an MS into service.

A.2.1.2.3 The concept of ad-hoc arrangement

The MS equipment may simply rely on a range of addresses that all equipment is known to be talkgroup addresses.

A.2.1.2.4 The rules for the sender

The following rules may determine if the call is to a talkgroup:

```
IF dialled_string
    contains a "*" in any of the least significant four characters
OR
    matches a string of numeric digits that are stored in the MS specifically indicating a talkgroup
OR
    can be determined as a talkgroup by any other method chosen by the manufacturer
THEN
    the address represents a talkgroup. Initiate the talkgroup service
ELSE
    the address represents an individual call. Initiate the individual call service
ENDIF
```

A.2.1.2.5 The rules for the recipient

These rules determine a call is to a talkgroup and will be accepted by a MS. (All reference to MS in this clause refer to the recipient.)

MS receives a dPMR service addressed to a talkgroup.

MS uses the reverse of the $\boldsymbol{B_2}$ function specified in clause A.2.1.2.6 to translate the AI talkgroup address to the User Interface domain.

```
IF digits (User Interface)
    contains a "*" in any of the least significant four characters
THEN
    each digit received is compared with each corresponding digit of the MS individual address
    except where the received digit is a "*". If there is a match on all applicable digits then this
    MS is party to the talkgroup call.
ELSE
    (consists of numeric characters only)
THEN
    EITHER
        The string of digits received is compared with each corresponding string of talkgroup digits
        that the MS has stored (specifically indicating a talkgroup).
        If there is a match then this MS is party to the talkgroup call.
    OR
        The MS is party to the talkgroup call by any other method chosen by the manufacturer
ENDIF
```

A.2.1.2.6 Mapping of dialled strings to the AI talkgroup address space

A MS talkgroup address is a 7-character numeric string in the range "0000001" to "999****", these characters are mapped to the Air Interface domain structure bits by the reversible function $\boldsymbol{B_2}$.

Talkgroup addresses may consist of all numeric characters (but the MS must be able to ascertain the address is a talkgroup address rather than an individual address). Alternatively any of the last four characters may contain one or more "*" characters that explicitly signifies the address is a talkgroup address.

The algorithm to convert from the user is slightly more complex for talkgroups in order to accommodate the extra "*" character.

A.2.1.2.6.1 Mapping of numeric dialled strings to the AI talkgroup address space

Table A.5: Dialable talkgroup address mapping by B_2

Character							B_2	Air Interface ID
1	2	3	4	5	6	7		
K_1	K_2	K_3	K_4	K_5	K_6	K_7		24 bits

K_1,K_2,K_3 represent decimal symbols in the range 0 to 9.

K_4,K_5,K_6,K_7 represent symbols to base 11 using the digits 0,1,2,3,4,5,6,7,8,9,*.

The "*" is a symbol that has the value of 10.

The six least significant user dialled digits K_2 to K_7 in the range "000001" to "999999" are converted to the 20 least significant 20 bits of the AI ID using true decimal to binary conversion. The most significant user dialled digit K_1 is converted to the most significant 4 bits of the AI ID using a true decimal to binary conversion.

$$B_2 = \sum K_1 * 1464100, K_2 * 146410, K_3 * 14641, K_4 * 1331, K_5 * 121, K_6 * 11, K_7$$

To following steps are needed to convert the dialled digits to an ID in the AI domain:

k) take the first digit (0 to 9) and multiply by 1 464 100;

l) take the second digit (0 to 9), multiply by 146 410;

m) take the third digit (0 to 9) and multiply by 14 641;

n) take the fourth digit (0 to 9) or * (* has a value of 10) and multiply by 1 331;

o) take the fifth digit (0 to 9) or * (* has a value of 10) and multiply by 121;

p) take the sixth digit (0 to 9) or * (* has a value of 10) and multiply by 11;

q) take the seventh digit (0 to 9) or * (* has a value of 10);

r) add a) to g); and

s) convert the sum to a 24-bit binary number.

Figure A.4 illustrates the talkgroup address space domain mapping.

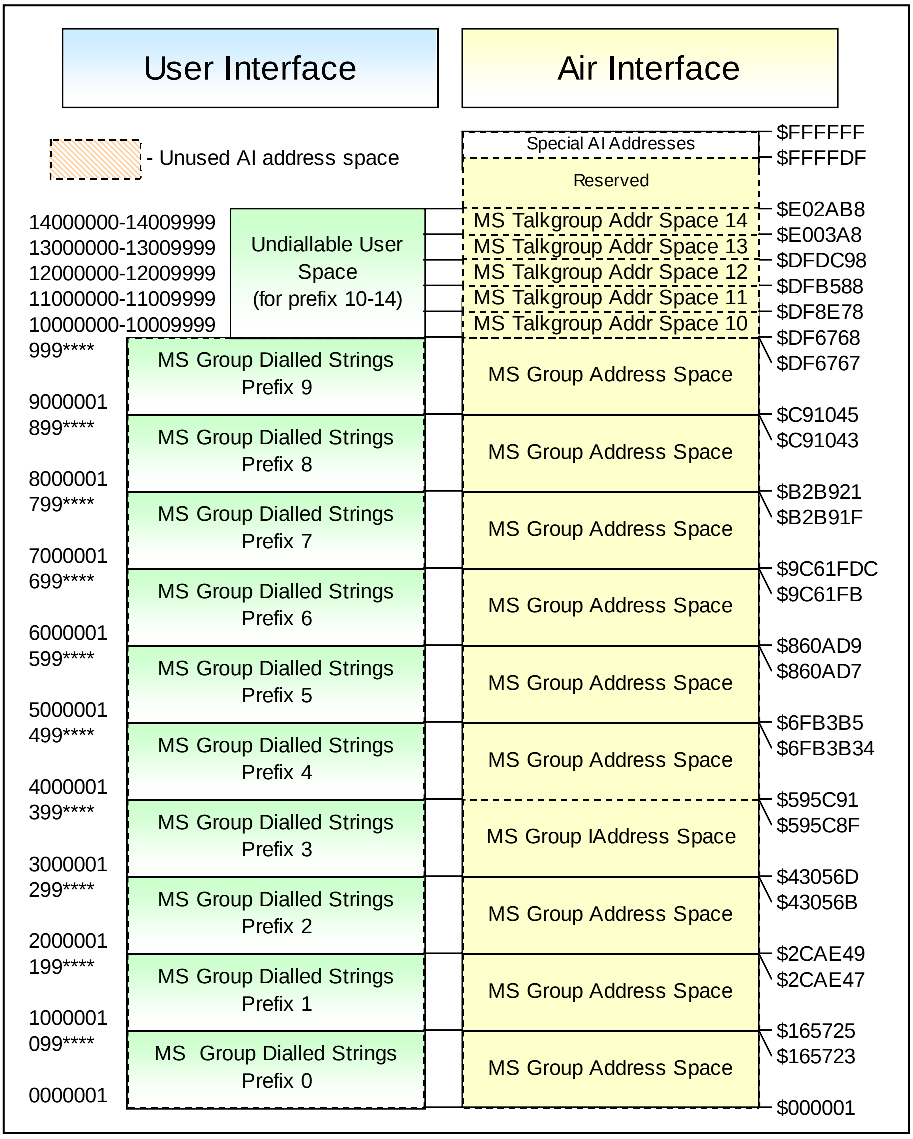


Figure A.4: Domain mapping for calls in the talkgroup addresses space

Examples are shown in table A.6.

Table A.6: Examples of talkgroup address translation

User-Interface	Air-Interface (Hex)	Air Interface (Binary)
1234567 (see note)	$1B91FD_{16}$	$0001\ 1011\ 1001\ 0001\ 1111\ 1101_2$
468956*	$68BF08_{16}$	$0110\ 1000\ 1011\ 1111\ 0000\ 1000_2$
012345*	$02C00A_{16}$	$0000\ 0010\ 1100\ 0000\ 0000\ 1010_2$
0123460 (see note)	$02C00B_{16}$	$0000\ 0010\ C000\ 0000\ 0000\ 1011_2$
999****	$DF6767_{16}$	$1101\ 1111\ 0110\ 0111\ 0110\ 0111_2$
NOTE: The MS must have already distinguished the dialled string as a talkgroup address using the rules defined in clauses A.2.1.2.1 to A.2.1.2.4.		

A.2.1.2.6.2 Mapping for non-dialable talkgroup addresses (prefix 10 to14)

Table A.7: Non-dialable talkgroup address mapping by B_4

Character							B_4	Air Interface ID
1	2	3	4	5	6	7		
K_1	K_2	$K_3=0$	$K_4=0$	K_5	K_6	K_7		24 bits

The B_4 algorithm provides a numeric User Interface for the non-dialable individual address space. Each prefix has the capacity for 10 000 individual addresses.

If the MS talkgroup address is represented by 8 digits K_1 to K_8 (K_3 and K_4 are always 0).

$$B_4 = \sum 14541000, 10^5 * K_1, 10^4 * K_2, 10^3 * K_5, 10^2 * K_6, 10 * K_7, K_8$$

The algorithms result in unique unambiguous translation between the User Interface domain and the Air Interface, are reversible and result in no lost codes.

To following steps are needed to convert the dialled digits to an ID in the AI domain using the B_4 algorithm:

t) start with the number 14 541 000;

u) take the first digit (0 to 9) and multiply by 100 000;

v) take the second digit (0 to 9), multiply by 10 000;

w) take the fifth digit (0 to 9), multiply by 1 000;

x) take the sixth digit (0 to 9), multiply by 100;

y) take the seventh digit (0 to 9), multiply by 10;

z) take the eighth digit; and

aa) add a) to g).

A.2.1.2.6.3 Examples of talkgroup non-dialable address mapping

Examples of non-dialable talkgroup in the user domain and AI domain are given in table A.8 (B_4 algorithm).

Table A.8: Examples of non-dialable talkgroup address translation

User-Interface	Air-Interface (Hex)	Air Interface (Binary)
12005678	$DFCBB6	1101 1111 1100 1011 1011 0110
13001234	$DFE16A	1101 1111 1110 0001 0110 1010

NOTE: For non-dialable individual addressing, Digits K_3 and K_4 are always zero.

A.2.1.2.7 The concept of the prefix

A Colour Code (CC) is defined in the AI to provide a simple means of distinguishing overlapping radio sites, in order to detect co-channel interference.

The Colour Code may be combined with the prefix to separate differing system operators using shared channels. The prefix separates the total address space into non-overlapping bands. This may be specified using the syntax

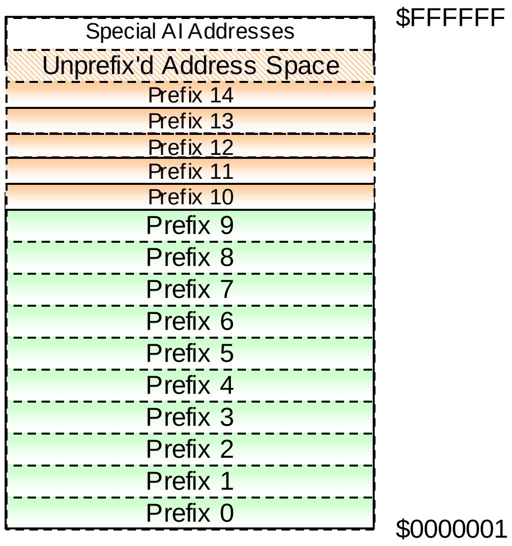
cc.pp,

where:

- "cc" is the decimal value of the Colour Code; and

- "pp" is the decimal value of the prefix.

The prefix bands illustrated in figure C.5 show how the total dPMR address space is split into bands.



NOTE: The prefix exists in the User Domain although the effect is to split up the address space in the AI domain.

Figure A.5: Illustration showing how the prefix separates the address space

In the user domain a full MS address is defined using 7 digits, $K_1,K_2,K_3,K_4,K_5,K_6,K_7$ for the dialable addresses.

The non-dialable addresses use a two digit prefix so the full MS address is defined using 8 digits, $K_1,K_2,K_3,K_4,K_5,K_6,K_7,K_8$.

The prefix is selected by the most significant digit in the full 7 digit string (K_1).

NOTE: Only prefixes 0 to 9 may be dialled by a user. Prefixes 10 to 14 provide a sub-set of the address space just as prefixes 0 to 9, but those addresses are not dialable by users.

If a system uses the prefix to separate autonomous operators, special arrangements need to be made for certain Air Interface Addresses. These are:

- for the MS talkgroup service:
  - Unaddressed talkgroup IDs;
  - special talkgroups containing all MSs;
  - gateways to system (e.g. repeater) and system interfaced devices not addressable via the ID (e.g. PABX, PSTN, SMS router).
- for the MS individual call service:
  - special IDs used to address all MSs.

The services specified above, each have sixteen addresses. Fifteen of the addresses (n=0-14) are provide a service that is specific to a prefix-n. The address for n=15 is the default if prefixes are not employed, or if a service to "ALL prefixes" if prefixes are employed. An example is given below.

EXAMPLE: To address all MSs in prefix 5 with an ALLCALL, the sender may set the recipients address as "All Talkgroup ID5" ($FFFFF5_{16}$). In this example only the MSs programmed as prefix 5 will take any action. If the sender wished to address all MSs irrespective of their prefix the recipient address may be set to "All Talkgroup ID15" ($FFFFFF_{16}$).

The default special Air Interface addresses use the address indexed by n=15.

A.2.2 Addresses

An MS is pre-programmed with at least one individual or one talkgroup identity.

An MS is permitted to have multiple individual identities and multiple talkgroup identities.

An MS may contain a list of talkgroup identities, which may be pre-programmed or dynamically updated (manually or over the AI).

The User Interface domain maps to the AI individual dialable address space by the $\boldsymbol{B_1}$ algorithm.

The User Interface domain maps to the AI talkgroup dialable address space by the $\boldsymbol{B_2}$ algorithm.

A.2.3 Conversion rules

A.2.3.1 MS addresses

An MS address in the User-Interface structure is defined as 7 characters of which for an individual MS address contain the characters "0" to "9". This is converted to the Air-Interface Domain by the $\boldsymbol{B_1}$ function. For a talkgroup address the three most significant contain the characters "0" to "9" and least significant four characters contain the characters "0" to "9" or "*". This is converted to the Air-Interface Domain by the $\boldsymbol{B_2}$ function.

A.2.3.2 Limiting the length of the destination address

The MS equipment may contain predefined parameters prescribing the minimum and maximum length of the user dial string. By limiting the length of the dialled string, the address range that the MS is able to dial is restricted.

A.2.3.3 All talkgroup address

The All Call dialled string "n******" (All Call within a prefix) is mapped as shown in table A.9.

Table A.9: Mapping of prefixed All Call to the AI

User dialled string	Air Interface ID	Remark
"0******"	$FFFFF0_{16}$	All Talkgroup ID0
"1******"	$FFFFF1_{16}$	All Talkgroup ID1
etc.	etc.	etc.
"9******"	$FFFFF9_{16}$	All Talkgroup ID9

The All Call dialled string: "******" is mapped to the All Talkgroup ID15 and addresses all MSs irrespective of their prefix.

Table A.10: Mapping of all prefix call to the AI

User dialled string	Air Interface ID	Remark
"*******"	$FFFFFF_{16}$	All Talkgroup ID15

A.3 User dialling plan

A.3.1 User numbering

A unified dialling plan is defined for both peer-to-peer and networked modes. The plan provides up to 9 999 990 dialable individual user addresses and 14 640 990 dialable talkgroups.

All dialled strings, as defined in the clause A.3 of the present document, are read from left to right and are dialled in the sequence in which they are read. Throughout this clause all representations of dialled strings are underlined.

MSs may only be required to dial sufficient numbers of characters unambiguously define the destination and service required.

A.3.1.1 Dialling method

To maximize channel utilization, the user should enter a string of digits and then press a button to initiate the call.

The "#" key or a dedicated "send" key is used to initiate the call. The "#" key has an additional purpose of modifying the call type or priority.

A.3.1.2 Call Type determination

Underlying signalling and system functionality is hidden from the user. MSs determine the call type and function from the length and content of the dialled string.

A.3.1.3 Call modifier strings

Dialled strings that commence with a hash "#" provide secondary uses for the keypad.

Secondary dialling functions may be as follows:

- Call Diversion, see clause C.3.4.3.5;
- Broadcast Call, see clause C.3.4.3.1;

Secondary dialling is achieved by the use of call modifier strings in front of the dialled number. These call modifier sequences utilize the "#" and "*" keys.

A.3.2 Dialled digits to address mapping

The User-Interface employs 11 symbols "0" to "9" and "*" and "#".

In the User-Interface domain structure, if the string represents an MS address, and contains a "*" in any of the four least significant characters, then that MS address represents a group of MSs.

The length of destination MS address dialled digits is in the range from 1 to 7, and is interpreted as the right most digits of the recipient's number. The MSs individual address is used as a base address, and the right-most digits of that number are replaced by the user dialled digits, as shown in example 1 and 2. The resulting number is then converted to the AI ID using the algorithm presented in the annex A.

EXAMPLE 1: An MS whose individual address is "1234567" (in the user domain), dials "43".

MS source address	1	2	3	4	5	6	7
Dialled destination						4	3
Full destination address, see note	1	2	3	4	5	4	3
NOTE: Destination address after processing.							

EXAMPLE 2: This example is a call to a talkgroup, described in clause A.2.1.2.1.

MS source address	1	2	3	4	5	6	*
Dialled destination							*
Full destination address, see note	1	2	3	4	5	6	*
NOTE: Destination address after processing.							

A.3.3 Storage requirements

A.3.3.1 MS individual address

An MS is allocated a numeric address in the range in the range "000001" to "9999999", see note. MSs may be programmed with more than one individual address.

NOTE: The addresses "1000000", "2000000", "3000000", "4000000", "5000000", "6000000", "7000000", "8000000", and "9000000" are not valid.

A.3.3.2 Talkgroups

Talkgroups may be both all numeric numbers, or contain a "*" in any of the least significant four digits.

A.3.3.3 All MSs

All units respond to All MSs address "*******#".

All units with prefix "n" respond to the prefixed All MS address "n******#" with n=0 to 9.

See clause A.2.3.3 of the present document for the mapping of MS dialled digits "n******#".

A.3.3.4 Non-dialable numbers

MS Address's "0000000", "1000000", "200000", "300000", "4000000", "5000000", "6000000", "7000000", "8000000", "9000000" are not dialable. If the user inputs a dialled string of digits that is not assigned to any of the dialling algorithms, then the MS should not try to establish the call and appropriate feedback given to the user.

A.3.3.5 Talkgroup recognition

A.3.3.5.1 All numeric talkgroups

Each MS has storage allocated for a minimum of 16 numeric talkgroup addresses. The table is populated during MS personalization by the user, or over the AI. The sender (MS) may use entries in this table to establish that the destination address is a talkgroup rather than an individual address.

The talkgroup table contains entries consisting of the full talkgroup address consisting of 7 characters as shown in the example.

EXAMPLE: The sender (MS) whose individual address is "1234561" has the destination "12345567" stored in its talkgroup table. The user enters a single digit "7" as the destination address.

The full destination address is formed from the dialled digit(s) and the MS own individual address.

MS source address	1	2	3	4	5	6	1
Dialled destination							7
Full (Talkgroup), see note	1	2	3	4	5	6	7
NOTE: Destination address after processing.							

The talkgroup table is searched for a match. In this example there is a match so the destination address is a talkgroup addresses.

A.3.3.5.2 Talkgroups defined by wildcards

The dialled string is examined by the initiating MS. If the destination is identified as a talkgroup because the address contains a "wildcard" character in one of the four least significant digits then call set-up procedure is to a talkgroup as shown in the example. Abbreviated dialling minimizes the number of dialled digits. An advantage of using "wildcard" to define talkgroups is that no pre-arrangement is necessary, i.e. there is no need for a talkgroup table or other MS configuration to recognize an address as a talkgroup.

EXAMPLE:

MS source address	1	2	3	4	5	6	1
Dialled destination							*
Full destination address, see note	1	2	3	4	5	6	*
NOTE: Destination address after processing.							

A.3.3.5.3 MS receives a talkgroup call

The recipient MS applies the reverse $\boldsymbol{B_2}$ to recover the dialled digits K_1 to K_7.

- If the received digits contain a "*" in the digits K_4 to K_7 then:
    - each digit is compared in turn with the corresponding digit of the MS individual identity looking for a match. If an "*" is encountered then a match for that digit is assumed.
- If the received digits are all numeric then:
    - the digits K_1 to K_7 are compared with each of the entries in the talkgroup table looking for a match (after each entry in the table has been expanded to the full 7 address digits as described in clause A.3.3.5.1.

A match must exist for the MS to respond to the talkgroup call.

A.3.4 Dialling procedures

A.3.4.1 MS calls

A.3.4.1.1 Seven digit dialling

The user may enter the whole seven digit address to complete the dialled string prior to transmission. The number of digits within an address may be restricted by MS programming to restrict the number range over which the MS may access.

EXAMPLE: MS may be restricted to six digits to prevent the MS from reaching other MSs outside its own prefix.

A.3.4.1.2 Abbreviated dialling

Where abbreviated keypad dialling is used in the MS, the MS should insert the more significant characters from the MS individual address to complete the dialled string prior to transmission.

If all digits are not dialled the more significant digits from the MS individual address are copied to the dialled string to build a seven digit address so -

For the MS individual address "2112345":

- if the user dials 6#, the destination address shall be 2112346;
- if the user dials 56#, the destination address shall be 2112356;
- if the user dials 958#, the destination address shall be 2112958;
- if the user dials 1385#, the destination address shall be 2111385;
- if the user dials 13*5#, the destination address shall be 21113*5 (talkgroup).

(The double underlined characters represent those that have been copied from the MS individual address).

At the Air Interface the calling party address is transferred to the called party. The abbreviated dialling may be applied to display only an abbreviated calling party address on the display of the called party.

Figure A.6 shows abbreviated dialling applied to the calling party and shows how the recipient may display the abbreviated calling party address.

bb) The calling party dials a single digit "2".

cc) The MS inserts the more significant digits from its individual address to complete the dialled string prior to transmission - i.e. the destination address becomes "1234562".

dd) The called and calling party addresses are passed across the Air Interface.

ee) The "B" party decodes the called party address and there is a match and the "B" party receives the call.

ff) The "B" party decodes the calling party address and may display only an abbreviated digit(s). In this case a single digit "1".

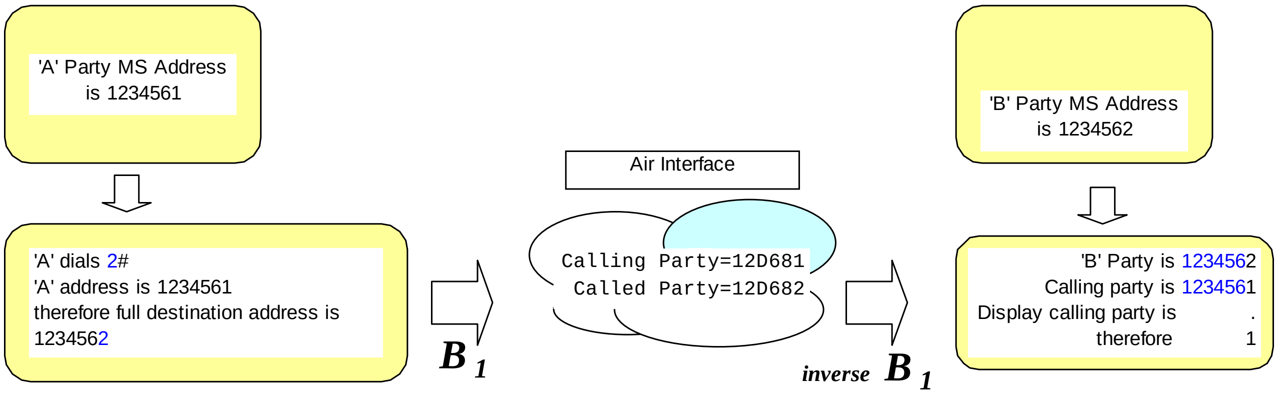


Figure A.6: Example of abbreviated dialling

The abbreviated display is sufficient for the "B" party to know who has called because the "B" party could call the "A" party by the same abbreviated dialling.

By using abbreviated dialling, the dPMR dialling plan is appropriate for the smallest and largest fleets.

A.3.4.1.3 Individual call

Individual calls can be initiated by another MS user entering the full seven digit number followed by the "#" character to indicate that dialling is complete and that the call is to be initiated. Abbreviated dialling should be allowed.

EXAMPLE: The dialled digits "2164324#" should initiate an individual call to MS "2164324".

A.3.4.1.4 Talkgroup Call

Talkgroup calls can be initiated by another MS user entering the full seven digit number, with any of the only four least significant characters contains a "*", followed by the "#" character to indicate that dialling is complete and that the call is to be initiated. Abbreviated dialling should be allowed.

A.3.4.1.5 All Call

All units respond to All MSs address "*******#".

All units within a prefix respond to All MSs address "n******#":

- in direct mode if permitted during MS personalization;
- in a networked system, if permitted by personalization and if permitted by the system.

A.3.4.2 Call modifiers

Functions such as the modification of call requests to change to type of service request, and the implementation of other facilities (status, diversion, etc), are initiated using the syntax in the following clauses. The call modifier is defined by the dialled string by adding extra digits to the dialled destination in the form:

<call modifier code> * destination as defined in clauses A.3.4.3.1 to A.3.4.3.7.

Table A.11: Summary of call modifiers

Dialled Digits	Call Modifier
#1*nn…#	Broadcast call, clause A.3.4.3.1
#0ss*nn…#	Status call, clause A.3.4.3.4
#41*nn…#	Divert Own call, clause A.3.4.3.5
#6*nnn..#	Force talkgroup service, clause A.3.4.3.7

A.3.4.2.1 Broadcast call

The MS shall set-up a broadcast call to the destination talkgroup nn by dialling "#1*nn#".

EXAMPLE 1: "#1*112345*#" should make a broadcast talkgroup call to MS address "112345*".

NOTE: The dialled string "#1*nnn". "#" should generate an error if the address is not a talkgroup address.

EXAMPLE 2: If the MS calling party address is "1234567". "#1**#" should make a broadcast talkgroup call to "123456*" (i.e. to "1234560", "1234561", etc., "1234569").

A.3.4.2.2 Status call

The string "#0ss*nnn#" causes the MS to set up a status call to the destination address nnn. The status digits "ss" are numeric in the range 0 to 99.

A.3.4.2.3 Force talkgroup service

The string "#6*nnn..#" causes the MS to set up a talkgroup call to destination talkgroup nnn. where nnn. is a numeric string of length from 1 to 7 digits.

EXAMPLE: To make a talkgroup call from MS 1122345 to talkgroup MSs 1122356 dial "#6*1122356#". In this case dialling "#6*56#" would achieve the same result.

A.3.4.3 MS behaviour commands

Functions such as the changes to the MS configuration or display of MS parameters are instigated using the syntax in the following clauses.

Table A.12: Summary of MS behaviour commands

Dialled Digits	MS Behaviour Command
	Edit the talkgroup table, clause A.3.4.4.1
#42*nnnnnnn#	Add entry
#43*nnnnnnn#	Delete Entry
#43*# or #43#	Delete All
	Edit the OVCM table, clause A.3.4.4.2
#44*nnnnnnn#	Add entry
#45*nnnnnnn#	Delete Entry
#45*# or #45#	Delete All
#48*# or #48#	Display Own identity, clause A.3.4.4.4
#49*# or #49#	Display Own talkgroup table, clause A.3.4.4.5
#59*# or #59#	Display Own OVCM table, clause A.3.4.4.6

A.3.4.3.1 Edit the talkgroup table

The string "#42*nnnnnnn#" causes the MS to add an entry to the talkgroup table. "nnnnnnn" must be the full 7 digit user domain address. If the talkgroup table is full an appropriate error indication is provided to the user.

The string "#43*nnnnnnn#" causes the MS to delete an entry from the talkgroup table. "nnnnnnn" must be the full 7 digit user domain address. If a match is not found between "nnnnnn" and a talkgroup table entry an appropriate error indication is provided to the user.

The string "#43*#" or "#43#" causes the MS to delete all entries from the talkgroup table.

A.3.4.3.2 Display own identity

For an MS that is fitted with a display, the dialled digits "#48*#" or "#48#" causes the MS to display its own Identity.

A.3.4.3.3 Display Own talkgroup table

For an MS that is fitted with a display, the dialled digits "#49*#" or "#49#" causes the MS to display each entry in its talkgroup table.

A.3.4.4 Call set-up abandon or call complete

"##" may be dialled after digits and a terminator have been entered on the keyboard. If the radio unit has not transmitted a call request, it shall abandon the call.

History

Document history		
V1.1.1	December 2005	Publication