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Technical Report

Electromagnetic compatibility and Radio spectrum Matters (ERM); Digital Mobile Radio (DMR) General System Design

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Foreword

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

Introduction

The present document has been produced to provide an introduction to DMR for potential system purchasers, network operators and service users.

It is in relation to multi-part TS 102 361 [1] to [4] covering the technical requirements for Digital Mobile Radio (DMR), as identified below :

Part 1: "DMR Air Interface (AI) protocol";

Part 2: "DMR voice and generic services and facilities";

Part 3: "DMR Data protocol";

Part 4: "DMR trunking protocol".

It provides an overview, a description on the DMR services and facilities, technical background and radio aspects, protocol and service performance, and guidance on numbering and addressing.

It should be understood that, as in all standard setting activities, there is an inherent conflict between the wish to have as broad a standard as possible and at the same time wanting to have as much of that broad standard available and implemented right from the beginning. Potential system purchasers, network operators and service users should make sure they influence the suppliers to have their required functionality available when they need it.

Equipment manufacturers will use the broad flexibility provided within the standard to develop and implement systems in various ways, and still be conforming according to the standard. This broad availability of systems, each optimized around certain features and functionalities, needs to be carefully analysed by a network operator and system user to find the supplier with a system suited best for their needs.

Clause 5 provides an overview of the DMR over-the-air protocol.

Information about DMR services is given in clause 6. In addition, clause 7 contains a summary of the DMR data services.

Information on DMR trunking is in clause 8 as well as annex A (power save) and annex B (channel access and throughput).

A short introduction to numbering and addressing is in clause 9.

Information on network design and management is in clause 10.

1 Scope

The present document is written as a "Read-me-first" manual or "Getting started with DMR". It is not intended to be a complete guide to the DMR technical specifications. If any conflict is found between the present document and the clauses in the DMR specifications then the technical specifications in TS 102 361 (all parts) [1] to [4] take precedence.

The aims of the present document are many, for example:

1) to provide the reader with sufficient knowledge to engage in qualified discussions with the equipment and service suppliers;

2) to expose the reader to the specific language and technical terminology used in the DMR specifications;

3) to enable the reader to understand the flexibility in system design, system network topography, system availability and various modes of operation;

4) information on radio aspects and network design and management is given.

2 References

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.
- Non-specific reference may be made only to a complete document or a part thereof and only in the following cases:
  - if it is accepted that it will be possible to use all future changes of the referenced document for the purposes of the referring document;
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2.1 Normative references

The following referenced documents are indispensable for the application of the present document. For dated references, only the edition cited applies. For non-specific references, the latest edition of the referenced document (including any amendments) applies.

Not applicable.

2.2 Informative references

The following referenced documents are not essential to the use of the present document but they assist the user with regard to a particular subject area**.** For non-specific references, the latest version of the referenced document (including any amendments) applies.

[1] ETSI TS 102 361-1: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Digital Mobile Radio (DMR) Systems; Part 1: DMR Air Interface (AI) protocol".

[2] ETSI TS 102 361-2: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Digital Mobile Radio (DMR) Systems; Part 2: DMR voice and generic services and facilities".

[3] ETSI TS 102 361-3: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Digital Mobile Radio (DMR) Systems; Part 3: DMR Data protocol".

[4] ETSI TS 102 361-4: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Digital Mobile Radio (DMR) Systems; Part 4: DMR trunking protocol".

[5] ETSI EN 300 113-2: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Land mobile service; Radio equipment intended for the transmission of data (and/or speech) using constant or non-constant envelope modulation and having an antenna connector; Part 2: Harmonized EN covering essential requirements of article 3.2 of the R&TTE Directive".

[6] ETSI EN 300 390-2: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Land mobile service; Radio equipment intended for the transmission of data (and speech) and using an integral antenna; Part 2: Harmonized EN covering essential requirements under article 3.2 of the R&TTE Directive".

[7] CEPT Recommendation T/R 25-08: "Planning criteria and coordination of frequencies in the Land Mobile Service in the range 29.7-921 MHz".

[8] CEPT ERC Report 25: "The European table of frequency allocations and utilizations covering the frequency range 9 kHz to 275 GHz".

[9] MPT1318: "Engineering Memorandum, Trunked Systems in the Land Mobile Service". February 1986, United Kingdom Department of Trade and Industry.

[10] CEPT ECC/DEC/(05)12: "ECC Decision of 28 October 2005 on harmonized 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".

[11] Draft CEPT ECC Decision (06)CC (WGFM, Cavtat, April 2006): "ECC Decision on the availability of frequency bands for the introduction of Narrow Band Digital Land Mobile PMR/PAMR in the 80 MHz, 160 MHz and 400 MHz bands".

[12] IEC 61162-1: "Maritime navigation and radiocommunications equipment and systems - Digital Interfaces - Part 1: Single talker and multiple listeners".

[13] IETF RFC 2529: "Transmission of IPv6 over IPv4 Domains without Explicit Tunnels".

[14] IETF RFC 3056: "Connection of IPv6 Domains via IPv4 Clouds".

[15] IETF RFC 3142: "An IPv6-to-IPv4 Transport Relay Translator".

[16] IETF RFC 4213: "Basic Transition Mechanisms for IPv6 Hosts and Routers".

[17] "Unicode: technical standards". www.unicode.org.

[18] ISO 8859 (parts 1 to 16): "Information technology - 8-bit single-byte coded graphic character sets".

[19] IETF RFC 791: "Internet Protocol".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

2:1-mode: 2 traffic channel mode

NOTE: 2:1-mode supports two independent calls which may be either "MS to fixed end" duplex calls or simplex calls using a two frequency BS.

Base Station (BS): fixed end equipment that is used to obtain DMR services

bearer service: telecommunication service providing the capability for information transfer between access points

burst: elementary amount of bits within the physical channel

NOTE 1: Three different bursts exist with different number of bits. The Traffic burst contains 264 bits, the CACH burst contains 24 bits and the RC burst contains 96 bits.

NOTE 2: The burst may include a guard time at the beginning and end of the burst used for power ramp-up and ramp-down.

NOTE 3: For detailed burst definition see TS 102 361-1 [1], clause 4.2.1.

call: complete sequence of related transactions between MSs

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

channel hold time: the total period for which a payload channel payload channel is assigned for a call

NOTE: Channel hold time is applicable to DMR tier III systems.

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

conventional: non-trunked communication

NOTE: This is a communication technique where any radio unit (MS) may communicate with one or more other radio units (MSs) without using a trunking protocol, and may be either in direct mode or using any additional equipment (e.g. BS).

Digital Mobile Radio (DMR): physical grouping that contains all of the mobile and/or fixed end equipment that is used to obtain DMR services

direct mode: mode of operation where MSs may communicate outside the control of a network

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

duplex: mode of operation by which information can be transferred in both directions and where the two directions are independent

NOTE: Duplex is also known as full duplex.

forward: logical channel from source to target in direct mode

frame: two continues time slots labelled 1 and 2

NOTE: A frame has a length of 60 ms.

grade of service: probability that a call will be queued at the point where the system is experiencing its most busy period (this is sometimes termed "the busy hour")

NOTE: Grade of service is applicable to DMR tier III systems.

inbound: MS to BS transmission

logical channel: distinct data path between logical endpoints

NOTE: The logical channels are labelled 1 and 2. The logical channel may consist of sub-channels, e.g. SYNC, embedded signalling, etc.

Mobile Station (MS): physical grouping that contains all of the mobile equipment that is used to obtain DMR mobile services

outbound: BS to MS transmission

payload: bits in the information field

physical channel: RF carrier who will be modulated with information bits of the bursts

NOTE: The RF carrier may be a single frequency or a duplex pair of frequencies. The physical channel of a DMR subsystem is required to support the logical channels.

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.

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 (RF) channel: radio frequency carrier (RF carrier)

NOTE: This is a specified portion of the RF spectrum. In DMR, the RF carrier separation is 12,5 kHz. The physical channel may be a single frequency or a duplex spaced pair of frequencies.

Reverse Channel (RC): signalling burst from target to source

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

superframe: 6 continuous traffic bursts on a logical channel labelled "A" to "F"

NOTE: A superframe has a length of 360 ms and is used for voice traffic only.

time slot (or slot): elementary timing of the physical channel

NOTE: A timeslot has a length of 30 ms and will be numbered "1" or "2".

transmission: transfer period of bursts containing information or signalling

NOTE: The transmission may be continuous, i.e. multiple bursts transmission without ramp-up, ramp-down, or discontinuous, i.e. single burst transmission with ramp-up and ramp-down period.

trunking: network controlled communication

NOTE: This is a communication technique where any radio unit (MS) may communicate with one or more other radio units (MSs) using a trunking protocol and all MSs will be under control of a network.

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

vocoder socket: 216 bits vocoder payload

3.2 Symbols

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

dBm	absolute power level relative to 1 mW, expressed in dB
dBp	Power relative to the average power transmitted over a burst in decibel
e	Natural logarithm
Eb	Energy per bit
ms	millisecond
No	Noise per Hz

3.3 Abbreviations

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

4FSK	Four-level Frequency Shift Keying
ACV	All Call Voice
AI	Air Interface
AT	Access Type
BCV	Broadcast Call Voice
BS	Base Station

NOTE: A reference designating a fixed end device.

CACH	Common Announcement CHannel
CC	Colour Code
CCL	Call Control Layer
CLI	Call Line Information
C-plane	Control plane
CRC	Cyclic Redundancy Checksum for data error detection
CSBK	Control Signalling BlocK
CSC	Common Slot Counter
DLL	Data Link Layer
DMR	Digital Mobile Radio
ERC	European Radiocommunication Commitee
FEC	Forward Error Correction
FID	Feature set ID
FLCO	Full Link Control Opcode
ID	IDentifier
LBT	Listen Before Transmit
LC	Link Control
MBC	Multiple Block Control packets
MFID	Manufacturer's FID
MS	Mobile Station, a reference designating a mobile or portable radio
OACSU	Off Air Call Set-Up
OVCM	Open Voice Channel Mode
PA	Power Amplifier
PABX	Private Automatic Branch eXchange
PATCS	Press And Talk Call Setup
PDP	Packet Data Protocol
PDU	Protocol Data Unit
PL	Physical Layer
PSTN	Public Switched Telephone Network
PTT	Press To Talk
RC	Reverse Channel
RF	Radio Frequency
SAP	Service Access Point, where a network provides a service
SDS	Short Data Service
SFID	Standards FID
SLCO	Short Link Control Opcode
SYNC	SYNChronization

TCP	Transmission Control Protocol
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TS	Trunked Station
TSCC	Trunk System Control Channel
U-plane	User plane
UDP	User Datagram Protocol
UDT	Unified Data Transport
UI	User Interface
Unicode	16 bit character encoding
VOX	Voice Operated transmit/receive switch

4 Overview of DMR

There are three tiers of DMR equipment:

- Tier I equipment is for the lowest-cost "digital PMR446" application,
- Tier II is for professional market offering peer-to-peer mode and repeater mode, and
- Tier III is for trunked operation.

DMR tier II and tier III products encompass both simulcast and non-simulcast systems.

The present document describes a Digital Mobile Radio (DMR) system for tier II and tier III products which employs a Time Division Multiple Access (TDMA) technology with a 2-slot TDMA solution and RF carrier bandwidth of 12,5 kHz. Additionally, a DMR system for tier I products is described which employs a continuous transmission variation (FDMA) of the above mentioned technology.

More recently, the professional environment has undergone a change whereby old operational models are no longer applicable in many cases. This has meant that the operational requirements placed on communication equipment have evolved, and the traditional analogue service is no longer able to meet the users' needs completely. It is therefore appropriate that more sophisticated services are made available which will meet this need. This raises the need for a technology enhancement that allows the PMR model (which remains very attractive in many regards) to support the basic and enhanced features and facilities existing and future users will require.

Industry research has indicated that in the event that certain key facilities can be provided, it may be expected that a significant improvement in the current market performance of this service can be expected. There are only a relatively small number of such features and facilities that are needed. However, these will dramatically change the value that the users can derive from the equipment and services.

The main user required features are:

Basic Features:

1) Improved audio quality.
2) Improved battery performance.
3) Better range performance (this is taken to mean a good quality of service out to the range boundary rather than much greater absolute range).

Enhanced Features are:

1) Hands-free operation.
2) Duplex (on the same channel), which also provides an appropriate means to communicate over the PSTN.
3) Security of communication.
4) The possibility of integrating the radio scheme into the specific operational methods of the undertaking.

DMR is recognized as having specific advantages when used in applications relating to public services and similar environments. These are rarely quantified in economic terms due to the complexity of making such an analysis.

However, due to the importance of these uses, it is important to recognize how the introduction will improve the operational efficiency of the service achieved. Here are a small number of examples by way of illustration.

1) Security Services

   The introduction of digital signalling greatly facilitates the inclusion of location and status services such as GPS. This could easily be integrated with automatic units providing details of status at particular locations under this security umbrella. The end impact to the security organization is greatly improved awareness of the location of all the security personnel and much faster response to incidents or other unusual situations. This in turn leads to improved levels of security and also improves the safety of the individuals involved.

2) Site Safety

   The introduction of significantly improved emergency facilities through reverse channel signalling means that an immediate notification can be sent to site personnel that an incident is in progress. This can be accompanied by data giving further details. It is equally possible to interrupt the current communication to pass the information by voice if so desired.

   This can have extremely important safety implications in very high noise or low-visibility environments because having a hands-free possibility may encourage the use of headsets and similar accessories.

3) Local Government and Social Services

   Location information, coupled with status information can more easily be accumulated and sent back to other officers. This allows them a better ability to respond to incidents or perhaps aid co-workers who are in dangerous situations.

   The superior signalling allows a very large degree of automation at the application level to be employed. This therefore offers the potential of having much improved operation with only small headcount implications.

4) Utilities

   Maintenance workers in the field can be supported with much improved information through the signalling capability while maintaining the important closed user group structure. This information cannot currently be reliably provided through the analogue systems.

5) Specific Public Safety Applications

   Whilst many public safety organizations are moving to sophisticated schemes, there remain some organizations whose needs are not so complex.

   Typically, these users already have an analogue scheme and are seeking to upgrade to a scheme that meets their current and future needs. It may be that DMR with this level of signalling may provide a suitable platform for their use.

In technical terms these requirements can be all met by using a low-latency, DMR protocol employing a suitable quality vocoder. The coding gain is used to recover good quality audio at the coverage boundary rather than to extend the range to distances not achievable by analogue schemes at the same transmit power.

As this is intended to be an enhancement that existing analogue users will most likely wish to take advantage of in the near term, it is assumed that the preferred approach will be to locate these new schemes on their existing frequency assignments wherever possible and in any event to be within the allocated land mobile service bands. Therefore, in preparation for this, every effort has been undertaken to ensure that the digital protocol complies with the harmonized spectrum regulation, the adjacent channel performance, and be carefully adjusted to not disturb with the existing spectrum planning by excessive ranges being achieved in the field. Thus, the proposed protocol is to be designed to fit into the existing regulatory environment and spectrum planning assumptions with an absolute minimum of disruption.

The DMR protocol is required to support a very wide variety of applications. Many users will continue to require customized solutions. However, it is recognized that in some instances, users will require units from a variety of suppliers, perhaps fulfilling different needs within the same overall operational environment. To assist this, the technical specifications on DMR in TS 102 361 (all parts) [1] to [4] for applications and interoperability have been created that defines an agreed list of specific features and facilities that are to be implemented and give sufficient detail to allow them to be implemented in a consistent way. This would ensure the necessary interoperability is achieved. To confirm the correct implementation of these features a conformity testing document would also be beneficial.