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Technical Report

Electromagnetic compatibility and Radio spectrum Matters (ERM); System reference document for harmonized use of Digital Mobile Radio (DMR); Part 2: Systems operating under individual licences in the existing land mobile service spectrum bands

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Foreword

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

The present document is part 2 of a multi-part deliverable covering the Electromagnetic compatibility and Radio spectrum Matters (ERM); System reference document for harmonized use of Digital Mobile Radio (DMR), as identified below:

Part 1: "Tier 1 DMR#, expected to be for general authorization with no individual rights operation";

Part 2: "Systems operating under individual licences in the existing land mobile service spectrum bands".

Part 1 covers DMR for general-authorization-with-no-individual-rights operation in the 406,1 MHz to 410 MHz or 440 MHz to 450 MHz simplex frequency bands.

Part 2 covers professional market applications offering peer-to-peer mode, conventional and simulcast conventional repeater modes and trunked (single or multi-channel for single or multi-site) and simulcast trunked operation within the existing land mobile service frequency bands.

1 Scope

The present document contains functional requirements for individually licensed Digital Mobile Radio (DMR) operating in the existing licensed land mobile service frequency bands as identified in CEPT ECC/DEC/(02)03 [2] and T/R 25-08 [3]. It also proposes terms to facilitate sharing these bands with existing land mobile services and describes expected market information and compatibility issues.

The primary market to be addressed is that served by current land mobile services.

This market is considered to fall into three basic tiers of usage. Other standards already exist that provide more sophisticated suites of services and facilities than are proposed to be supported by DMR. In the present document the segments considered are:

- Tier 2: For the professional market offering peer-to-peer mode and repeater mode (expected to be licensed);
- Tier 3: Trunked or Simulcast operation (expected to be licensed).

The tier 1 usage is covered in part 1 of TR 102 335 [9]. It is to note that tier 2 products can also encompass simulcast as well as non-simulcast usage.

The present document describes a protocol that has been specifically developed with the intention of being suitable for all identified market tiers. Specifically, in this case for use in the existing land mobile service bands with the intention of causing minimum change to the spectrum planning and regulations. Thus the proposed DMR protocol is intended to be applicable to the current bands, channel raster, range assumptions and all other spectrum parameters without need for change.

The protocol also supports significant feature and facility enhancements, which are believed to be necessary to enable the future users to obtain the most benefit from the DMR service. This is detailed further in annex B.

It includes necessary information to support the co-operation between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Post and Telecommunications administrations (CEPT), including:

- Market information (annex A);
- Technical information (annex B);
- Expected compatibility issues (annex C).

2 References

For the purposes of this Technical Report (TR) the following references apply:

[1] ETSI EN 300 113 (parts 1 and 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".

[2] ECC/DEC/(02)03: "ECC decision of 15 March 2002 on the availability of frequency bands for the introduction of Narrow Band Digital Land Mobile PMR/PAMR in the 400 MHz band".

[3] CEPT Recommendation T/R 25-08: "Planning criteria and coordination of frequencies in the land mobile service in the range 29,7 to 960 MHz".

[4] CEPT WG FM PT 38 progress report, 18th meeting in Tallinn, 2-3 June 2004, Annex 1 T/R 25-08: "Recommended spacing, use and location of upper, lower and simplex bands".

[5] UK Radiocommunications Agency: "The Economic Impact of Radio".

[6] ETSI EG 201 212: "Electrical safety; Classification of interfaces for equipment to be connected to telecommunication networks".

[7] 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".

[8] ECC Report 25: "Strategies for the European use of frequency spectrum for PMR/PAMR applications".

[9] ETSI TR 102 335-1: "Electromagnetic compatibility and Radio spectrum Matters (ERM); System reference document for harmonized use of Digital Mobile Radio (DMR); Part 1: Tier 1 DMR#, expected to be for general authorization with no individual rights operation".

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

3 Definitions, symbols and abbreviations

3.1 Definitions

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

duty cycle: total transmitter on time within one hour

peer-to-peer: a communication technique where any radio unit may communicate with one or more other radio units without the need for any additional equipment (e.g. repeater)

polite protocol: a medium access protocol that implements a "listen before transmit" protocol in order to ensure that the channel is free before transmitting

3.2 Symbols

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

dBp	decibels of power
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 Key
CACH	Common Announcement Channel
CC	Colour Code
CEPT	European Conference of Post and Telecommunications Administrations
CTCSS	Continuous Tone Controlled Squelch System
DECT	Digital Enhanced Cordless Telecommunications
DMR	Digital Mobile Radio
ECA	European Common Allocations table
ECC	Electronic Communications Committee
EICTA	European Information and Communications Technology Association
EMB	Embedded Signalling Field
ERC	European Radiocommunications Committee
GDP	Gross Domestic Product
GPRS	Global Package Radio System
GPS	Global Positioning System
GSM	Global System for Mobile communication
GSM-R	Global System for Mobile communication for Railways applications
ITU	International Telecommunications Union

LC	Link Control
PAMR	Public Access Mobile Radio
PBX	Private Branch eXchange
PDA	Personal Digital Assistant
PMR	Private Mobile Radio
PSTN	Public Switched Telecommunications Network
R&TTE	Radio & Telecommunications Terminal Equipment
RC	Reverse Channel
RS	Reed-Solomon code
TDMA	Time Division Multiple Access
TX	Transmitter/Transmission
VOX	Voice Operated Switch
WLAN	Wireless Local Area Network

4 Executive summary

The high societal and economic benefit of individually licensed PMR services has been recognized for many years. Recent economic data has been published [5] on a national basis that confirms both the high level of benefit to the national GDP and, more significantly, the very high GDP contribution per user.

More recently, the professional environment has undergone a change whereby old operational models are not 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 (see annex A for details) 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). As this matter relates to the system design and the terms of the applicable licence the present document makes no further comment.

Enhanced Features are:

1) Hands-free operation.

2) Duplex (on the same channel), which also provides an appropriate means to communicate over the PSTN [6].

3) Security of communication.

4) The possibility of integrating the radio scheme into the specific operational methods of the undertaking.

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 will be undertaken to ensure that the digital protocol will comply with the harmonized spectrum regulation (references are provided in clause 2), 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.

A brief technical analysis of the proposed protocol which supports possible compatibility studies, together with the results of simulations done on its performance, are presented in clause 5 and annex B.

In terms of the spectrum requirements, it is considered that the existing land mobile service spectrum bands can support the immediate needs. However, in the event that this proves as popular as some industry organizations believe, the spectrum demand may need to be reviewed at a later date.

4.1 Status of the present document

The present document was discussed and approved at ETSI ERM TG32 DMR#7 and then at ETSI ERM RM#28. It has been subsequently forwarded to CEPT WGFM for consideration. The document has been submitted to ETSI ERM#24 for approval for publication.

5 Technical issues

5.1 Short background information

5.1.1 System description

There are no fundamental changes proposed in the architecture of either conventional or trunked systems. This proposal relates to a change in over the air protocol such that very much greater value can be derived from the use through applications that the protocol supports and that analogue schemes cannot.

The protocol is required therefore to support working through repeaters, peer-to-peer mode, simulcast mode and systems structures for trunked operation.

5.1.2 Applications and interoperability

The proposed 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, an applications and interoperability document could be 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.

The extent to which interoperability can be applied is limited because the existing market has many different operational procedures that these units must comply to and not disrupt. For example, unlike some other communications schemes, it is not the case that a standardized numbering and dialling system can be universally employed. This is because some important customers already have methods of operating that include absolute requirements that have implications on dialling sequences. It would therefore not be possible to create a single dialling plan that would be acceptable to all users. For users such as these it will be necessary to address their requirements, perhaps on a case-by-case basis.

It is foreseen that other providers will enter the market to create software applications packages to further enhance the value the user can derive from this new service. Closely defined interoperability is a pre-requisite to encourage undertakings to develop such packages for multi-supplier situations. Naturally, it is equally anticipated that applications packages will be developed for particular solutions even if only one supplier is anticipated.

5.2 Over the air protocol summary

A summary of the over the air protocol is given in table 5.2.1. Further details of the protocol may be found in annex B.

Table 5.2.1

Basic Structure	50/50 duty cycle slot structure allowing forward and reverse transmission on a time division basis. Transmission can be used either for voice or data or generic signalling. Whilst active, the transmissions are maintained to establish synchronization, thus enabling peer-to-peer operation if so desired.
Duplex Operation	Forward and reverse signalling and voice is sufficiently rapid to permit communications in both directions to be maintained thus giving the opportunity to sustain a duplex conversation on a time division basis. The rapidity of the signalling interchange is sufficient to permit an accurate VOX to be implemented.
Battery Save	Slotted structure provides the opportunity for a variety of battery-save options to be taken. These can be optimized to meet the particular needs of users as desired.
Call Interruption	Slotted structure permits units to receive signals even while user is talking. This may prove attractive in schemes where superimposing bi-directional signalling while a call is attractive.
6,25 kHz Equivalence	Slotted structure provides the possibility of two calls being sustained on the same radio channel. Thus this structure provides the advantage of 6,25 kHz channel equivalence without the need to split the channel in the frequency domain. Thus the channel centre frequency remains unchanged. This may prove attractive in some markets.
Frequency range and Modulation	The protocol is intended for PMR equipment operating in the existing PMR bands. The modulation technique is 4FSK.
Vocoder	The protocol has been designed to be independent of choice of Vocoder. However, suppliers may choose to adopt a common vocoder in the future as part of arrangements for interoperability. This decision is outside the protocol.
Radiated Power and Range resulting	The protocol has been carefully balanced such that the range achieved is the same as is achieved by current analogue technology. The coding gain achieved is utilized to establish better reliability of the call up to the range boundary. This normalization of the range achieved is essential in order to preserve the current spectrum planning assumptions and so permit the digital equipment to be introduced into the existing PMR bands without modification of the current rules.
Channel Access	The protocol has a selectable option to disable the polite channel access that is assumed to be needed in order to share with other users. This is essential in order to support specific users have applications whereby the likelihood of the success of certain calls must be maximized. Otherwise the protocol is polite.
Rise and Fall of the Transmission	Compliant with current Harmonized Standard EN 300 113 [1].
Unit Identification and Numbering	Included in the Protocol.

6 Summary market information

6.1 Societal uses and enhanced benefit from digital technology

PMR 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.

6.2 Benefit to national GDP

A series of detailed analyses covering the economic benefit of PMR in each national economy does not appear to be available in the public domain. However, such estimation had been conducted for the United Kingdom [5]. In this case the initial investigation done in 1999 has been updated for 2002. The result is that for approximately 750 000 mobile units on the licensing database the economic benefit to the GDP is estimated at 1,6 million Euros per year, putting PMR in 5th position in the list of wireless services in terms of GDP contribution. This corresponds to 2 200 Euro a year per mobile. This greatly exceeds the amount per unit for any other wireless service.

It would appear to be very attractive on grounds of national economic advantage to increase the uptake of the PMR service.

6.3 Market size, forecasts, and timing

The Electronic Communications Committee recently completed a strategic plan for PMR [8] in which it was recognized that narrow band digital systems will provide enhanced features and that it can be expected that migration to these services can be reasonably expected starting as soon as suitable equipment becomes available. The following key points are taken from annex 5 of the strategies for the European use of frequency spectrum for PMR/PAMR applications, Electronic Communications Committee [8]. References to PAMR services have been removed to avoid confusion.

Market Indicators:

- "Substantial market potential exists for PMR".
- "Many PMR users continue to prefer their own systems but cost of ownership may be deterrent".
- "Improvement in voice quality and coverage is the no.1 issue".
- "Few users would relinquish the unique functionality provided by PMR systems".
- "Manufacturers expect robust demand for PMR system equipment in EMEA".
- "Growth in the mobile workforce".
- "Potential for growthin PMR usage".

Whilst this provides an overall picture, it does not provide specific information on the features and facilities that will provide the necessary impetus to encourage greater uptake of PMR services going forward. Confidential market research has been undertaken in 2004 that directly relates to these questions. Whilst most of the results remain confidential, some of the key findings have been released into the public domain. The available detail is contained in annex A.

The installed base for analogue radios in the conventional and trunked markets is believed to 6,9 million units considering public safety, transportation, utilities, industrial users and significant others. This number includes units of all types and all applicable usage categories.

The following headline figures are presented in summary in table 6.3.1.

Table 6.3.1

Description	Result
Predicted Growth rate for DMR service	7 % per annum overall total
Key basic feature focus points for professionals	Audio quality and battery life
Key advanced features for professionals to be added	Duplex and hands-free use
Estimated proportion of analogue users seeking more advanced solutions and may be planning to replace their current systems	36 % of users
Estimated proportions likely to migrate in the near term to digital systems having stated basic and advanced features and facilities	64 % of users
Estimated percentage of current users seeking compatibility with analogue thus allowing dual operation during migration	16 %
Privacy of communication	Strong encryption needed
Rate of increase of mobile workforce	5 % per annum

No known market research specifically investigates the appropriate timing of the introduction of these digital solutions. However, by examination of the above information it is clear that there may already be a demand to move to such services, and so it appears appropriate to consider the ideal timing of the change to be as soon as possible. Taking into consideration the delays associated with finalizing the over the air protocol, the interoperability and test standards and then the suppliers' ability to bring compliant products to market, it would seem that a 2005 time-frame would be appropriate.

6.4 Migration of existing customers

The available research indicates that in the existing customer base some users prefer an approach whereby the entire fleet is replaced in one single coordinated programme, while other users are oriented towards a migration to digital services in a gradual manner (seamless migration).

The research shows that there are a significant number of users awaiting the opportunity to migrate to digital services in the near term. Whilst this is clearly not something they will undertake immediately the equipment becomes available, it does indicate the need to cater for a significant number of migrations right from the early start of the digital service. This may be moderated in practice by the availability of new applications packages.

The research does not differentiate between users having dedicated spectrum licences and those who share use of a channel in this regard.

7 Main conclusions

7.1 Business importance

1) A new non-mandatory over-air protocol is needed from ETSI that provides professional users in both the conventional (both single-site and multi-site) and systems (trunking or multi-site operation as examples) markets with a DMR protocol that has the following key characteristics over and above the existing feature and facility set the users are familiar with:

   1.1 Low signalling latency

   1.2 Duplex speech where required, also enabling access to the PSTN where desired.

   1.3 Reverse channel signalling to support the operation of applications during speech sessions

   1.4 Selectable "politeness" channel access algorithms to avoid interference with currently established communications.

   1.5 Flexible arrangements for supplier choice of vocoder.

   1.6 Compatibility with the existing harmonized regulation for PMR licensed spectrum bands with no requirement to change them. Thus the spectrum planning may be continued unchanged.

   1.7 Possibility to apply improved battery saving techniques

   1.8 Capability for data transfers (consistent with narrow-band operation)

   The technical proposal described in the present document is believed to meet all these requirements.

2) A further non-mandatory document must be written to identify and then define specific applications, features and facilities that may be run on the over the air protocol that would benefit users were they to be made interoperable. In order to provide guidance to suppliers seeking to make equipment that is interoperable with other equipment, it is intended to provide a non-mandatory conformance document against which the operation of the applications, features and facilities may be tested.

3) An unsatisfied demand appears to exist amongst a large proportion of the professional users to migrate from the current analogue schemes to more feature and facility rich digital schemes. Furthermore, these users expect that applications to address their current and future needs will be hosted by these DMR systems. Accordingly, it would appear appropriate to seek to make these services available as soon as possible.

4) Due to the need of the current users to migrate to these enhanced services and recognizing that spectrum is a scarce resource, the existing PMR bands, with all the current channel planning arrangements should be utilized for this new service. To this end, no incompatible features or facilities should be implemented in the protocol. Furthermore, devices to assist the introduction of digital services into these bands should be included (see conclusions 1.4 and 1.6 above).

7.2 Expected timing for products to market

It is expected that all the relevant parts of the DMR standard will be completed by end of 2004. It is estimated that commercial DMR products would be available for first customer shipments within 18 months of the standard being published.

7.3 Requested ECC actions

There may be some alignments or adjustments in regulation or licensing terms necessary to allow the required flexibility for such improvements to be delivered to the users. The ECC is requested to consider this matter and if considered necessary to make specific amendments in ECC/DEC/(02)03 [2], T/R 25-08 [3] and any other ECC deliverables, if needed.

It is proposed to amend ECC/DEC/(02)03 [2] to include all frequency bands considered possible for DMR.

DMR is specifically designed to comply with the existing regulatory regime (also based on the harmonized standards EN 300 113-2 [1] and EN 300 390-2 [7]).

The introduction of digital technology into bands historically used for simple analogue schemes is believed to require some management in certain instances. There are four basic situations:

a) The migration of users having dedicated national licences.

In this case the user will not in principle be interfering with other users, and so this can be expected to be a relatively simple case. Users are likely to upgrade their system in a manner that is defined by their own particular circumstances. The terms of their licence may need to be amended.

b) The migration of users sharing channels with other users but in a geographically coordinated fashion under control of some authority.

The presence of coordination alleviates potential interference with other users, but it is not assumed that the coordination can completely remove the risk. This situation already exists in similar circumstances between two analogue schemes. Therefore, the replication of the range performance in this digital scheme is believed to allow similar planning procedures and arrangements to continue to be employed. However, some authorities may consider that the performance improvement due to digital technology and/or coding techniques is such that some difference can be expected. In response to this, an option is to be included in the protocol that will switch on a "politeness" algorithm to ensure digital transmissions do not interfere with analogue communication. However, as there is no expectation that the analogue schemes will be improved to include a politeness protocol to be included, this protection will not be available in the return direction from analogue transmitters to digital receivers.

c) The migration of users sharing channels in an uncoordinated manner.

Because this is uncoordinated, it is assumed that interference control will remain a potential problem for users. The politeness option could assist this in terms of protecting the old analogue users. However, it will not stop analogue users interfering with digital communication in exactly the same manner they interfere with each other today (see note).

NOTE: Currently analogue technology users on shared channels routinely interfere with each other resulting in loss of communication. The presence of CTCSS stops the interfering transmission disturbing the user, but it still blocks an incoming wanted communication if the interferer is of sufficient power at the receiver. Overall, this inefficiency will seriously reduce the useful traffic capacity of the channel.

Whilst there are a number of solutions possible, the choice will remain specific to the particular circumstances. However, the improvements in operational value added, together with the superior calling scheme means that it is likely that the amount of mixing between analogue and digital will rapidly decrease as users migrate away from analogue.

d) Systems having a pool of channels upon which users are serviced under a controller function. For example in a trunked system.

In general, these are carefully coordinated in terms of channel assignments and so may be considered to represent a lesser problem as the assignment is rarely shared.

It is recognized that some users will wish for the option to migrate their fleets from analogue to digital over time. During the transition they may operate using dual-mode infrastructure and/or terminals. Whilst this is expected to apply primarily to fleets operating on dedicated channels, this option could be attractive to users in other situations.

In some countries it is anticipated that the introduction of spectrum trading will greatly facilitate the introduction of digital technology as the clear advantages completely change the value that may be derived from the spectrum.

Annex A: Detailed market information

A.1 Range of interoperable applications, features, and facilities

At this time the list of features, facilities, and applications that are to be defined in such a way as to allow for interoperability is not defined.

However, as examples, it is anticipated that the interoperability work will include numbering schemes, dialling plans, and a strong recommendation for the vocoder to be used.

A.2 Market size and value

A.2.1 The ECC strategic plan

The Electronic Communications Committee recently completed a strategic plan for PMR [8] in which it was recognized that narrow band digital systems will provide enhanced features and that it can be expected that migration to these services can be reasonably expected starting as soon as suitable equipment becomes available. The following points are taken from the strategies for the European use of frequency spectrum for PMR/PAMR applications, Electronic Communications Committee [8]. The reference considers PMR and PAMR at the same time. Therefore points relating solely to PAMR have been completely removed and changes made to the text to limit the context of the remaining statements to the PMR environment to avoid confusion (see note).

NOTE: At the time of writing of the initial report there was a view that PAMR would be able to provide many of the things that analogue PMR users were thought to be seeking. This view may have changed subsequently. This is especially so as at the time this work was done, the critical success factors that DMR can provide and their potential impact on the professional market may not have been so well defined.

Market Indicators

- **"Substantial market potential exists for PMR:**
  Telecommunications consultants Logical Strategy (February 2002) have estimated that approximately 50 million of Western Europe's 160 million workers can be classified as being "mobile workers", defined as those who are mobile for at least 20 % of the time. Of these, in the region of 20 million are blue/grey collar mobile workers with specialized communications needs. One quarter of these 20 million potential PMR users are currently using PMR solutions, with the majority being served by ageing analogue PMR networks that no longer meet user requirements in terms of cost and functionality".

- **"Many PMR users continue to prefer their own systems but cost of ownership may be deterrent:**
  The IMS July 2001 survey indicates that 69 % of sample surveyed would prefer to own the system, rather than to rent from an operator, due to "the ability to maintain control of the system", although such preferences are often constrained when it comes to replacing existing systems at the end of their operational life by factors such as cost".

- **"Improvement in voice quality and coverage is the no.1 issue:**
  Network coverage and reliability of infrastructure as well as ruggedness and price of handsets are the main areas where customers expect improvements when deciding upon a replacement for their existing PMR solution. "Voice quality" is the most important factor when buying a future network or service, whereas price was the key determinant last time. Most respondents expect to transmit more data: from 20 % of network traffic in 2000 to 39 % in 2003 (47 % for current digital radio users) and accordingly would look for a solution able to meet this need".

- **"Few users would relinquish the unique functionality provided by PMR systems:**
  Even if most people are aware of alternative technologies (GSM-GPRS, GSM-R, cordless PBX), few users will consider replacing their radio system by one of them (preferred option: 3G cellular (32 %), 2-way paging (31 %)) in view of the unique and highly valued functionality provided by such radio systems".

- **"Manufacturers expect robust demand for PMR system equipment in EMEA:**
  IMS (July 2001) predicts a 20 % yearly €: -13 % per year in "Indirect business" and +28 % per year in "Direct business". West/Central Europe representing 70 % of total EMEA market. Robust growth in the PMR market is expected for the foreseeable future due to the potential for new services and applications realized by the shift from analogue to digital technology".

- **"Growth in the mobile workforce:**
  The size of the mobile workforce, with its specific communications needs, is increasing strongly across Europe in all business sectors. For instance, UK mobile workforce of 7,9 m predicted to rise to 10,4 m by 2010. Mobile communications will penetrate 95 % of the mobile workforce by 2004 - many mobile workers carrying advanced mobile devices. (Logical analysis 2002)".

- **"Potential for growth in PMR usage:**
  However license statistics show that use of PMR has to-date reached less than 10 % of the mobile workforce in the key European countries while in the USA more than 25 % of the total mobile workforce is using two-way radio, either PAMR or PMR, indicating considerable growth potential for the European market. A recent EICTA Report on PMR concluded that easier purchase conditions would foster growth in the use of PMR terminals through standardization of equipment and services and that considerable user productivity gains would be realized as a result of the availability of more efficient digital PMR [editor: DMR] systems".

This provides an overall picture that many of the existing analogue PMR users are potentially seeking to move to a richer environment but had not successfully found the appropriate alternative. DMR is believed to fulfil this demand.

A.2.2 Information from other sources

A major manufacturer conducted a market research programme in the first quarter of 2004 to examine the potential for DMR. Most of the information gathered is specific to that company's market approach and so is confidential. However, elements of the research relate to horizontal trends and have been provided to ETSI in support of the present System Reference Document.

A.2.2.1 Population surveyed

The research was conducted across Europe through direct interviews with small and large-scale users, dealers and other significant market actors such as applications providers. There were face-to-face interviews, a large number of which were in-depth interviews.

The sectors covered by the research were:

- Private Security.
- Construction.
- Local Government.
- Manufacturing.
- Transportation.
- Public Utilities.
- Rental Companies.
- Public Safety Organizations.

A.2.2.2 The findings

In quantifying the findings, a scale is frequently used to express how important an item is. In all cases the scheme used is 1 = unimportant and 10 = extremely important. In cases of likelihood, a similar scheme is employed with 1 = very unlikely and 10 = very likely.

A.2.2.2.1 Key basic features required

Figure A.2.2.2.1.1 shows the priority of the key basic features identified by the research.

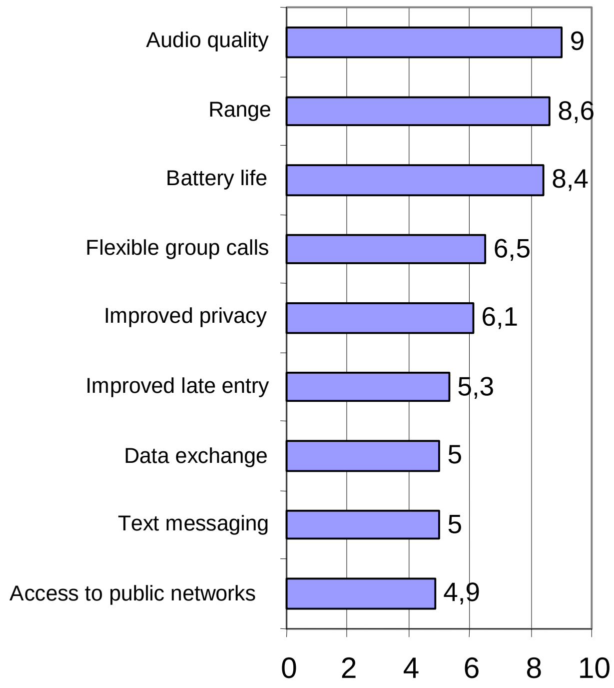


Figure A.2.2.2.1.1: Priority of Key Basic features

The current analogue services are clearly causing some dissatisfaction with respect to basic communications facilities. There appears to be a very significant weight of opinion that DMR should seek to improve these basic performance issues. The average scores for these matters are extremely high which could be taken as measure of the dissatisfaction.

The most important matter is poor audio quality at the coverage boundary. A close second is the ability for larger coverage. Coverage is a design issue and is in any event subject to the terms of the licence and not actually a matter for the technical standard.

Battery life is considered a basic feature and should be improved. While several strategies exist that can assist, having a protocol that assists this goal is an important advantage.

There is an additional concern over the lack of privacy of conversations due to the ability of other users to listen-in. Digital protocols are seen as means to assist this.

In the case of a digital radio, data exchange is an obvious basic facility. However, it scores surprisingly low, hardly above simplex access to public networks and only the same as text messaging.

Late entry into group calls and more flexible group calls are an operational requirement, which require no further comment.

A.2.2.2.2 Key advanced features and facilities required

Figure A.2.2.2.2.1 shows the priority assigned to the key advanced features as a result of the research.

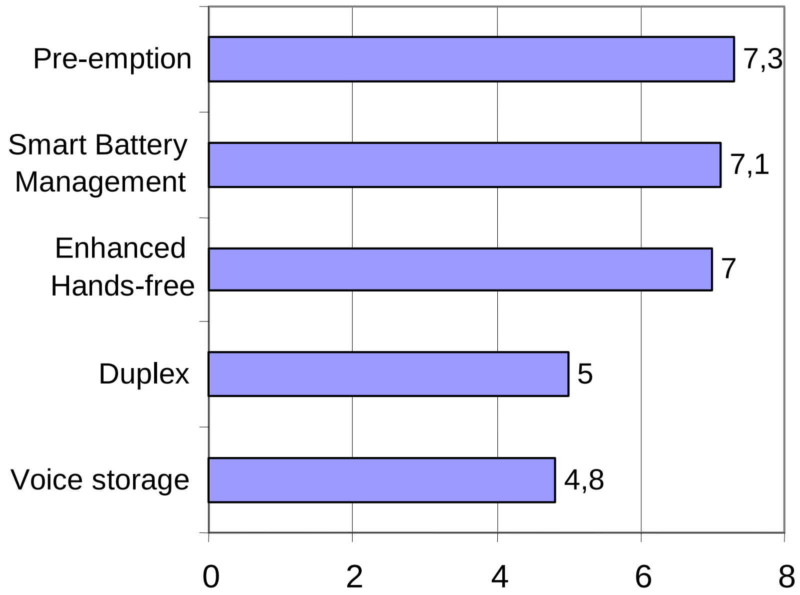


Figure A.2.2.2.2.1: Key Advanced Features and Facilities

The different market sectors responded with stronger emphasis in some of these features than did others. For example, the importance attached to having pre-emptive signalling (which is facilitated by the reverse signalling in this proposal) was universally extremely high from those interviewees working in some areas. Others not involved in such uses prioritized it lower.

Having even better battery life as made possible by so-called "smart" battery management received a universally high priority, as did hands-free operation. In this case hands-free is not only as it is in the GSM arena, where hands-free is taken as the ability to use the mobile while driving vehicles in the applicable countries. In this case, hands-free includes the additional ability for a professional to use both hands to perform the job and at the same time being able to communicate.

The research was structured to allow the interviewees to consider products with packaged "suites" of applications, features and facilities. In responses to these proposals, the same feature list emerged as given in the graphs (figures A.2.2.2.1.1 and A.2.2.2.2.1) but the priorities were in some instances very different. Duplex emerged as something that received high priority under all circumstances. The air-protocol for DMR considers this variability and therefore includes facilities for all identified features to allow suppliers the necessary flexibility to address the market adequately.

A.2.2.2.3 Migration propensity

Two situations were presented to the interviewees. The first was intended to determine their intentions in the event that DMR was not to be available in an acceptable timeframe. The finding was that the current users seek some concrete evidence of the availability of DMR. At present 36 % of the interviewees were actually planning to replace their existing analogue services in the near term. Whilst the different market sectors gave different answers, GSM was the most likely next technology. DECT, PDA, WLANs, and a variety of others did not prove popular choices for alternative solutions except in the manufacturing sector where DECT was the found to be leader (above GPRS).

The second situation presented was under the assurance that DMR (as described in the present document) will become available. The finding was that the intentions of the interviewees completely reversed with 64 % of all users declaring themselves "very likely" to migrate to DMR. The remainder were predominantly staying with their existing analogue service until their situation changed. Those who would still consider a technology change are considering moving to GSM (mostly).

A.2.2.2.4 Comments on current analogue radio usage

There will be no attempt to detail current analogue usage in this clause as that is well known. However, in the course of the investigation, it appeared that the current analogue PMR radios are used in operational conjunction with other technologies and not separately. However, the extent to which this occurred varied considerably. Figure A.2.2.2.4.1 shows the findings relating to this point.

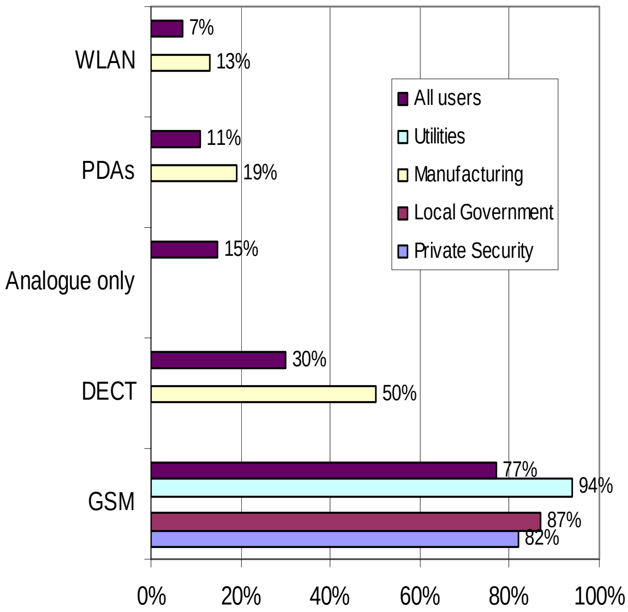


Figure A.2.2.2.4.1: Radio usage per user category

This is considered to be an extremely important point as it may provide some level of evidence of the potential demand for integrated applications and/or services such as may be provided by DMR and which would be complimentary to other communications systems.

In designing applications it is anticipated that this will become a significant consideration.

A.3 Traffic evaluation

It is anticipated that the value that users can derive from DMR greatly exceeds what can be achieved with analogue equipment. This has two principle effects:

1) the uptake will increase thus increasing the number of users that are trying to gain access to the spectrum;

2) the digital equipment will be better integrated into the operational system of the organizations and so the per-unit traffic generated will increase both in terms of the number of calls and also the nature of the calls.

These effects need to be considered carefully and the utilization of the spectrum carefully monitored to check that undue congestion is not occurring over time.

At this time there is insufficient information available to provide a set of utilization input assumptions. Therefore a mathematical prediction of traffic trends is not presented. As more experience is gained it is expected that this will be possible to do in a meaningful way.

At this time, there is no perceived need for additional spectrum over and above the existing PMR bands.

Annex B: Detailed technical description

B.1 General summary of the over-the air protocol

B.1.1 General summary of protocol

The protocol proposed for DMR is built around a 30 ms slot structure with a 50 % duty cycle. This allows sufficient transmitted data in one direction to support both good quality voice and a very substantial level of signalling. In the spaces between the transmitted blocks the protocol calls for the unit to be receiving. This therefore allows signalling and/or voice in the reverse direction even during a conversation. The perception of the user will be that this unit is providing a full duplex conversation. This protocol therefore supports duplex in either the repeater, simulcast, trunked or peer-to-peer modes. Specific requirements on system delays needed for simulcast architectures are taken into account.

Figure B.1.1.1 provides the general organization. The protocol calls for means to synchronize the transmitter and the receiver states at each end of the conversation such that one always receives at time when the other is permitted to transmit.

The proposed solution is a 2-slot TDMA channel for both the inbound and outbound channels. A generalized timing diagram of exchanges between subscribers and the fixed end equipment is shown in figure B.1.1.1 where the slots for the two TDMA channels are labelled channel "1" and "2". Inbound signalling is labelled "MS TX" and outbound signalling is labelled "Repeater TX". This diagram is intended to illustrate a number of signalling features and timing relationships and does not represent a particular scenario. Key points illustrated by this diagram include:

- While active, the outbound channel is continuously transmitted (see note), even if there is no information to send. Each of the inbound channels is unused if there is no information to transmit.

NOTE: The protocol allows that the transmissions may cease under some circumstances such as after a determined period of inactivity.

- The inbound channel has an unused guard band between bursts to allow for synthesizer lock and PA settling.
- The outbound channel has a Common Announcement CHannel (CACH) between bursts for channel management (framing and access) as well as low speed signalling.
- The channel 1 and 2 bursts in the inbound channel are offset in time from the channel 1 and 2 bursts in the outbound channel. This number scheme allows a single channel identifier field in the outbound CACH to refer to the same channel number on the inbound (channel usage) and outbound (channel number).
- Bursts have either a synchronization pattern or an embedded signalling field located in the centre of the burst. Placing the embedded signalling in the middle of a burst allows time for a transmitting subscriber to transition to the outbound channel and recover Reverse Channel information.
- Different sync patterns are used in voice bursts and data bursts to allow the receiver to differentiate between them. Different sync patterns are used for inbound and outbound channels to help the receiver reject co-channel interference.
- A Colour Code (CC) is present in the embedded signalling field and data/control burst to provide a simple means of addressing radio networks or a specific repeater, so that co-channel interference can be rejected.
- The location of the sync bursts in channel 1 is independent from the location of the sync bursts in channel 2. The location of sync bursts in the inbound channels is independent from the location of the sync bursts in the outbound channels.

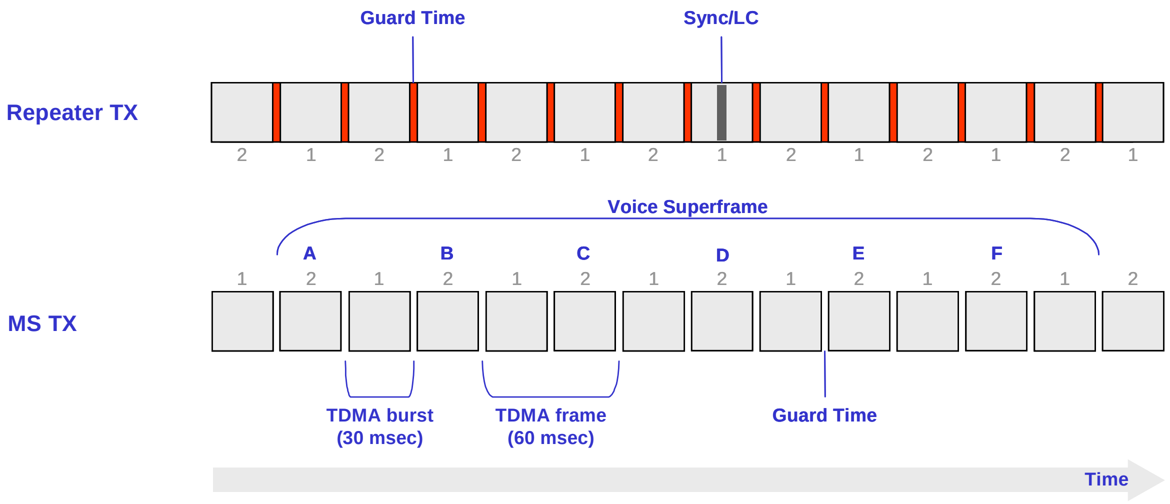


Figure B.1.1.1: Timing Overview

B.1.2 Signalling advantages

Because of the rapid forward and reverse nature of the protocol, duplex operation in the time domain is possible and also signalling interchanges with an interchange latency of 60 ms (cycle-time). In addition to this, the ability to test voice at either end in this rapid manner gives the possibility for an excellent VOX scheme to be implemented. This can therefore be used to provide the extremely important hands-free operation.

Because the duty cycle in transmit is 50 % (even while transmitting) this scheme offers significant potential battery efficiency. In cases where only signalling is being passed the duty cycle could be even less than 50 %.

However, the protocol also provides the opportunity to have both forward slots used for transmission is desired. This allows a very wide range of applications to be supported. Figure B.1.2.1 shows some variations on the basic block organization and how the reverse channel timing can be accommodated.

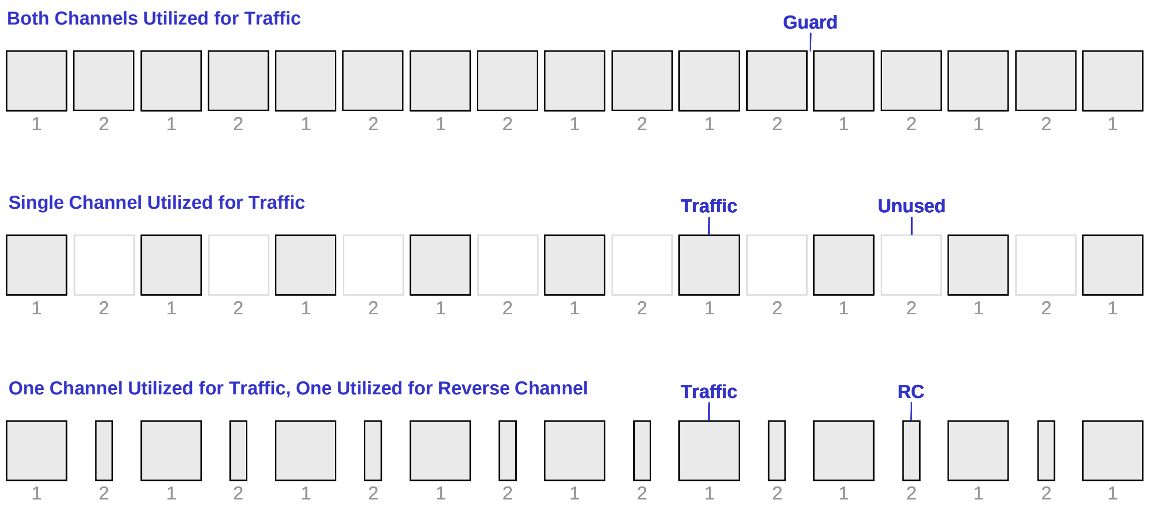


Figure B.1.2.1: Traffic Channel Arrangements and Guard Times

There are many uses to which these facilities can be put. Clearly a popular use amongst some market segments will be to interrupt transmissions while users are still talking to support advanced emergency call features. Perhaps even complete the entire procedure without stopping the call currently in progress if the operational procedures allow for that.

B.1.3 6,25 kHz equivalence

As there is no restriction on what happens in neither each slot nor any interrelation between them (other than the need to maintain time synchronicity, it is therefore possible to have two entirely separate conversations at the same time from two different units. By this means it is possible that two simplex calls can be independently supported in a single 12,5 kHz channel. Secondly, this means that DMR units fitted with this protocol will also comply with the North American requirements for 6,25 kHz channel equivalence.

B.1.4 The vocoder

In order to achieve interoperability between units from different suppliers, it is clear that the same vocoder or a completely compatible vocoder will have to be used. However, it is also recognized that vocoders vary enormously. In order to avoid undue restrictions being placed on suppliers and thus limiting the markets that they may choose to address, it has been resolved not to specify any particular vocoder in the standard. This leaves the choice up to the supplier. To make this much easier, the protocol will be written to be independent of the vocoder selection.

In order to provide for interoperability in situations where that is appropriate, the applications and interoperability standard will have to specify a vocoder together with any equivalents (if any).

B.1.5 Spectrum parameters

It is a fundamental assumption that the spectrum parameters of the proposed protocol fit exactly with the current spectrum and regulatory regime in so far as technical requirements are concerned. However, in recognition of the very significant differences between analogue and digital performance the following general comments are made. Annex C discusses some aspects of these further.

B.1.6 Radiated power and range

Digital coding allows significantly improved recovery of the wanted signal in the presence of noise. This coding gain is often used to provide better absolute range. However, to apply this in this case would have severe impact on the frequency re-use and interference potential in the land mobile radio bands. Therefore, this proposal considers similar transmit powers being used but the coding gain being employed to provide a good quality service to the edge of the planned coverage but thereafter a fairly rapid roll-off. By this means it is believed that the spectrum planning assumptions used for the analogue service will remain valid for the digital upgraded service.

This is a careful balance to achieve. Figure B.1.6.1 shows the code performance at walking pace.

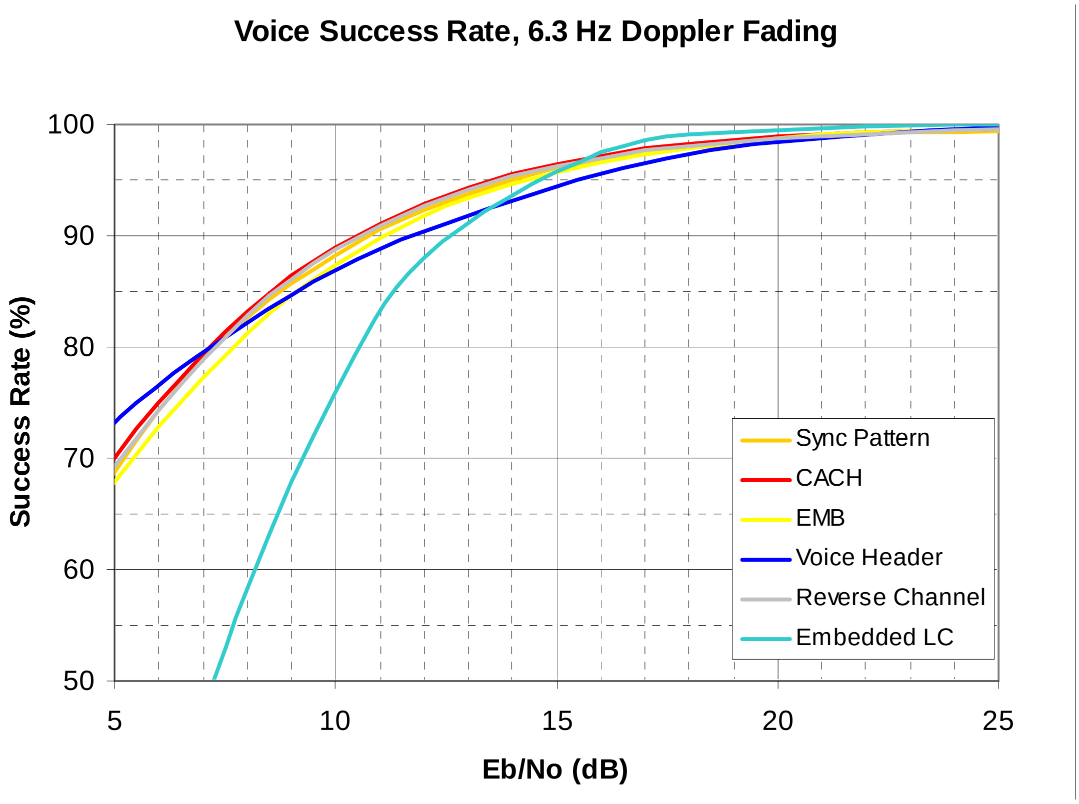


Figure B.1.6.1: The Roll-off of Performance At coverage Boundaries (Walking Speed)

Simulations have additionally been conducted to show high velocity performance.

B.1.7 Frequency considerations

The modulation employed is 4FSK. This is considered to provide an extremely robust communication and fits well with the existing land mobile radio band spectrum planning.

Because all the existing harmonized regulation has been taken as the reference point in the design of the protocol and other technical characteristics, there is reason to be confident that there will be no exceptional frequency considerations arising from the introduction of DMR.

Thus the present document assumes:

1) A 12,5 kHz channel raster in accordance with the existing plan even in cases where 6,25 kHz equivalence is employed.

2) T/R 25-08 band planning [3]. However, it is stressed that this is not the only possibility that the protocol can support. This recognizes that not all national PMR band plans are arranged in accordance with T/R 25-08 [3] at this time. The figure B.1.7.1 shows the May 2003 implementation of T/R 25-08 [3] as noted in the strategies for the European use of frequency spectrum for PMR/PAMR applications, Electronic Communications Committee [8].

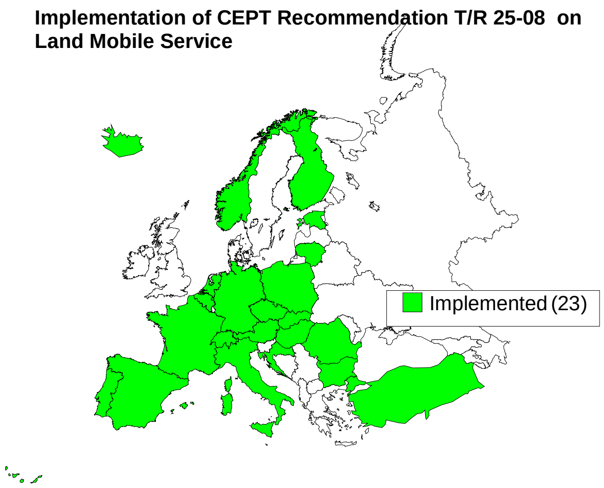
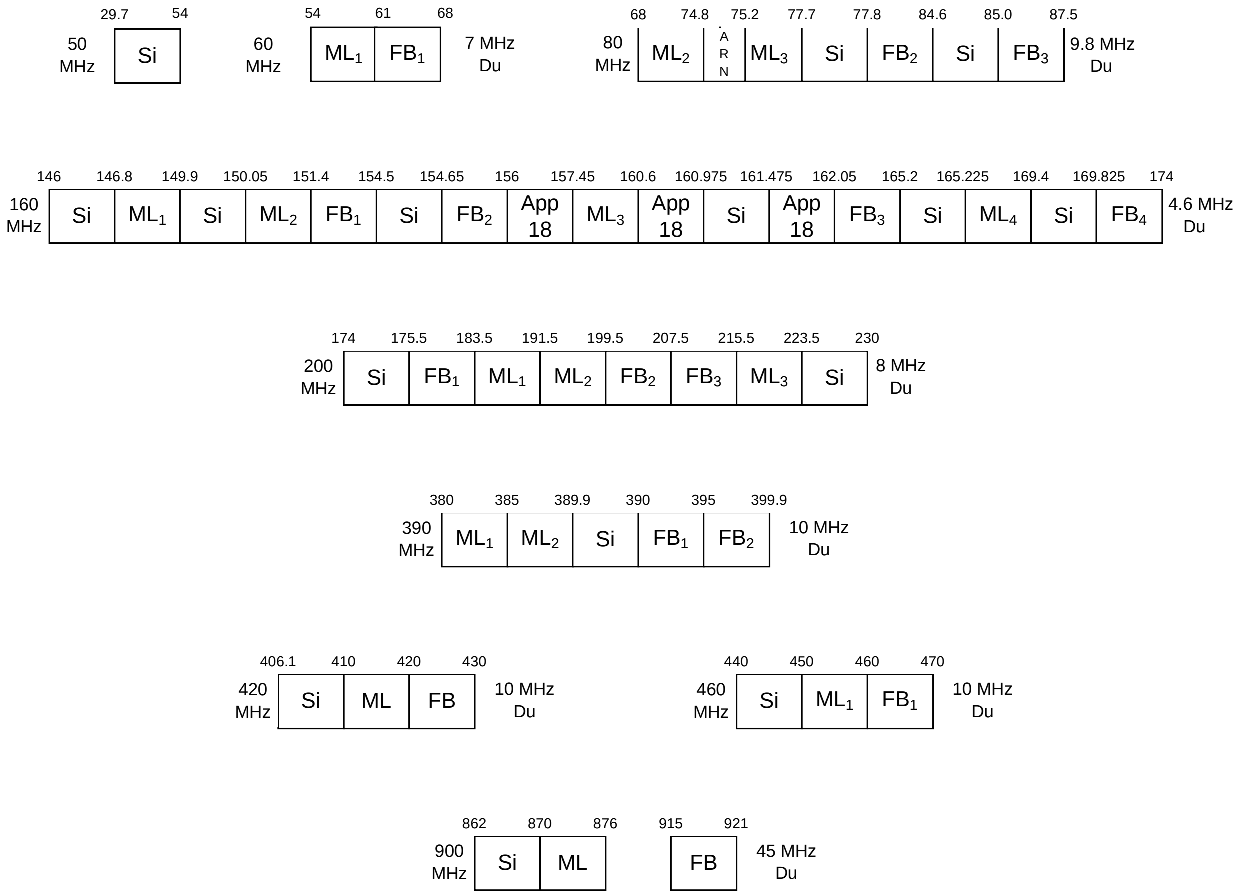


Figure B.1.7.1: Implementation of CEPT Recommendation T/R 25-08 on Land Mobile Service – May 2003 [8]

Figure B.1.7.2 is an excerpt taken from the ECC-WG FM PT38 progress report, 18th meeting in Tallinn, 2-3 June 2004 [4], Annex 1 T/R 25-08: Recommended spacing, use and location of upper, lower and simplex bands (based on the ERC Report 25 [10]).



Key to symbols:

ARN Aeronautical radionavigation (ILS/Marker beacons)
Du Duplex operation
FB Base station
ML Mobile station
Si Simplex operation
App 18 Use in accordance with RR Appendix 18 "Table of Transmitting Frequencies in the VHF Maritime Mobile Band"

Figure B.1.7.2: Recommended spacing, use and location of upper, lower and simplex bands (based on the ERC Report 25 [10])

3) TDD and FDD usage.

The protocol considered in the present document provides considerable flexibility in the available modes of operation. This flexibility is achieved by dividing the communications into blocks of signalling. The block structure allows systems implementers to split the capacity of the channel in the time domain into two separate logical streams that can be used to different purposes (see clause B.1.1 General summary of protocol).

For example, the protocol can support simplex communication on a single frequency, duplex communication on a single frequency, simplex communication using two-frequencies (facilitating simple repeater operation) or duplex operation on two frequencies superimposing additional communications on top of the primary stream (again by capacity splitting of the channel). This flexibility can even extend to peer-to-peer duplex operation on a single frequency if synchronization of the channel can be achieved. Many other combinations are possible.

Table B.1.7.1 summarizes the possibilities.

Table B.1.7.1

	Through a repeater		Peer-to-peer	
	Single frequency	**Dual frequency**	**Single frequency**	**Dual frequency**
Simplex individual call	Y	Y	Y	Y (Allows two communications streams between same source and destination)
Simplex group call	Y	Y	Y	Y (Allows two communications streams)
Duplex individual call	N	Y	Y	Y (two streams possible with the use of RF duplexer)
Duplex group call	One or two frequencies are insufficient to support conferencing			
NOTE: Duplex group call is not applicable to systems having only up to two frequencies, and so this line is only added to the table for completeness.				

Because of this flexibility, this protocol is considered to be suitable for deployment in all current frequency bands of T/R 25-08 [3] subject to spectrum management planning conditions and any applicable terms of the licence.

This flexibility enables applications whereby customers may use voice communications together with the transmission of images or perhaps even multiple language supports.

4) Conformity to the existing harmonized standards, e.g. EN 300 113-2 [1].

Of particular interest in a switching scheme like this is the limits placed on the transmit power transients. Figure B.1.7.3 shows the design envelope.

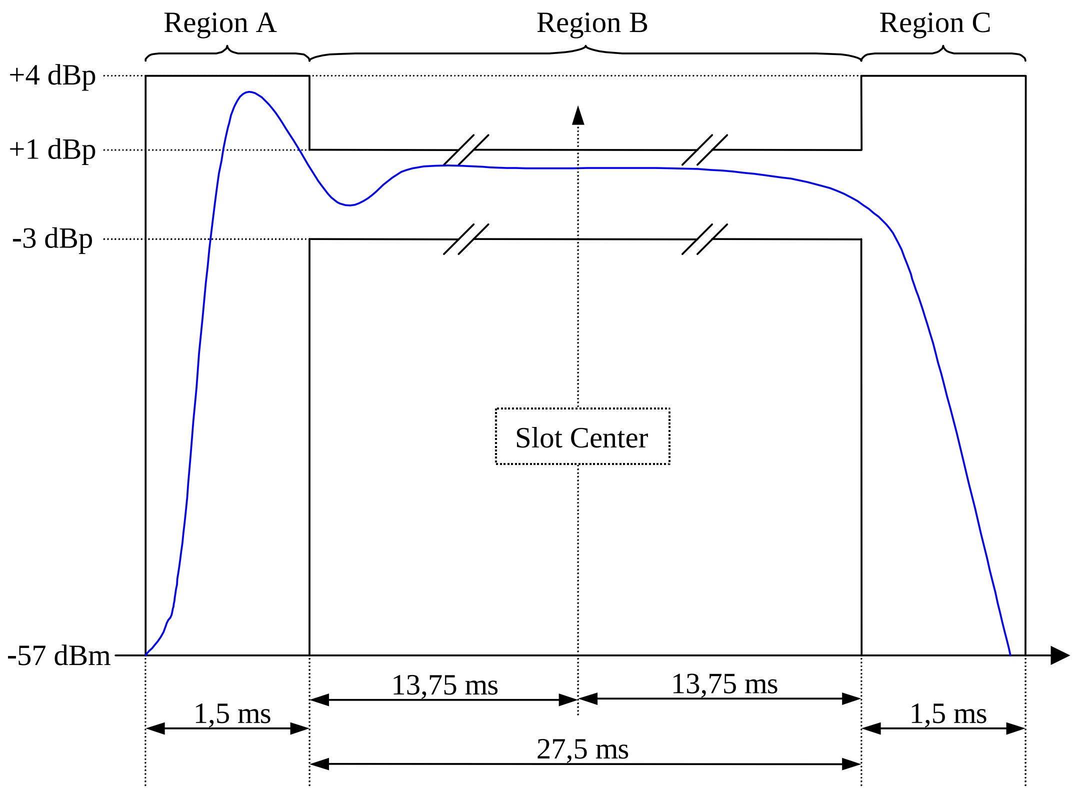


Figure B.1.7.3: Power waveform mask for a normal burst

The power levels given in the mask are given in dBp, where 0 dBp is defined as:

$$0dB_p \equiv \frac{1}{27{,}5} \int_{-13{,}75}^{13{,}75} TxP(t)dt$$

where TxP(t) is the instantaneous transmitter power and the timing is relative to slot centre. Thus, 0 dBp is the average power during the 27,5 ms period.

With these limits, conformity to existing spectrum requirements is assumed.

B.2 Technical justification for access to existing PMR spectrum bands

The specifications and operating parameters of DMR will be no different from current analogue PMR in terms of those parameters relevant to spectrum planning and administration. Thus, it is anticipated that radio units operating with the DMR over-the-air protocol will comply with the existing Harmonized European Standards ([1], [7]).

It is believed that the current users will wish to migrate their existing systems in a manner coordinated to meet their own specific requirements. It would thus appear appropriate to adopt a strategy of allowing the continued usage of their existing spectrum in all appropriate cases possible. Thus, this proposal considers the re-use of the entire existing PMR spectrum bands rather than a scheme whereby new spectrum is identified.

B.3 Information on existing and future ETSI standards

DMR considered in the present document meets the conformity requirements of the existing harmonized standards EN 300 113-2 [1] or EN 300 390-2 [7].

It is accepted that in some situations users will require a variety of equipment to fulfil the full operational requirement. It is foreseen that these may be supplied by a variety of vendors, and thus it is important that in such situations, interoperability is ensured. It is therefore proposed that further standards over and above the protocol standard be created. Firstly, an applications standard is envisaged that lists the features and facilities that are considered to require interoperability. The present document will detail the exact method of operation of the feature or facility, including all necessary detail to ensure interoperability. In addition to this, radio and protocol conformity standards will be written that allow suppliers to have a consistent and coherent suite of test procedures against which they can assure the performance of their products.

Annex C: Expected compatibility issues

C.1 Coexistence studies (if any)

Not envisaged to be necessary.

C.2 Current ITU allocations

The frequency bands proposed are allocated to the Land Mobile Service in Region 1 and in the ECA table [10]. Therefore, no modifications of the allocation tables are necessary.

C.3 Sharing issues

The medium access protocol uses a "listen before transmit" protocol in order to ensure that the channel is free before transmitting.

However, analogue radios may be unable to distinguish between noise and DMR modulated signals and therefore would not be "polite" in the presence of DMR radios.

History

Document history		
V1.1.1	November 2004	Publication