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TECHNICAL REPORT

Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference document (SRdoc); Land Mobile Service; Additional spectrum requirements for future Public Safety and Security (PSS) wireless communication systems in the UHF frequency range

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RTR/ERM-060

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Contents

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Foreword

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

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**may not**", "**need**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Executive summary

Background information

The current situation

CEPT/ECC

The WG FM#77 in May 2013 adopted the ECC Report 199 [i.70], which has been developed in FM PT49 throughout 2012. This Report is aimed at calculating the required amount of broad band PPDR Spectrum based on the assumprionassumption that the LTE standard will be applied throughout Europe. These calculations are based on PPDR scenarios prepared by the EU Council's Law Enforcement Working Party (LEWP) and other PPDR agencies and was carried out by a spectrum calculator developed by TC TCCE. This calculator has been adopted by CEPT/ECC and is embedded in the ECC Report 199, from where it can be studied. The Report concludes that an amount of 2 x 10 MHz of dedicated spectrum will be required for BB PPDR in Europe. This is also in alignment with the similar sized 700 MHz assignment (The D-Block) for BB PPDR decided in the US in 2011.

Furthermore the FM PT49 is working on ECC Report B [i.71] and FM PT49 #9 in April 2013 concluded that only two bands are left as candidate bands for BB PPDR, the 400 MHz band and the 700 MHz band (694 MHz - 790 MHz).

EU Commission - DG CONNECT

The EU Radio Spectrum Committee (RSC) adopted 2013, pursuant to Advisory Procedure under Article 4 of Regulation 182/2011/EU and Article 4.2 of Radio Spectrum Decision 676/2002/EC the "Mandate to CEPT to develop harmonised technical conditions for the 694-790 MHz ('700 MHz') frequency band in the EU for the provision of wireless broadband and other uses in support of EU spectrum policy objectives" [i.72] to be implemented after the World Radio Conference 2015.

The ECC has tasked its PT1 to elaborate the response to the Commission's Mandate.

ITU-R

The ITU-R World Radiocommunications Conference 2015 (WRC15) will deal with two very significant Agenda Items for BB PPDR: AI 1.2 and AI 1.3.

During WRC12 it was decided to change the band 694 MHz - 790 MHz from Broadcasting-only to MOBILE and Broadcasting on a so called co-primary basis.

The WRC15 AI 1.2 will study the technical conditions to be applied in this band including an eventual minor adjustment of its lower edge (694 MHz). Furthermore the WRC15 AI1.3 is inviting Member Nations to review and revise Resolution 646, (which contains for all three ITU-R Regions the recommended PPDR spectrum), with a view to update the Resolution 646 with additional recommended spectrum for Broadband PPDR. Currently this Resolution contains for Region 1 (CEPT+ MEA) only the 380 MHz - 400 MHz band used for Narrow-Band PPDR services.

The CEPT-ECC CPG PTA and PTD groups are working towards a European Common Position (ECP) on AI 1.2 and AI 1.3

A number of major man-made and natural disasters in recent years have changed the way governments are responding to these events. Europe is embracing the concept of Homeland Security resulting in an increasing co-operation between Police, Fire, Rescue, Health and Military organizations. This has called for interoperable, secure and wide-area coverage communications between these agencies often across national boundaries.

In addition to the PSS services, other organizations such as transportation, utilities, etc. are expected to share to some extent the same communications network infrastructure to enable reliable and interoperable communications in disaster situations.

An "ECC Decision on the harmonisation of frequency bands for the implementation of digital Public Protection and Disaster Relief (PPDR) radio applications in bands within the 380-470 MHz range" [i.2] covering narrowband and wideband PPDR applications" was approved in 2008.

Narrowband and wideband PPDR applications in Europe are covered to a great extent by TETRA Release 1 and TETRA Release 2 systems. ECC Decision (08)05 [i.2] is based on ECC Report 102 [i.4] which is an outcome of the ECC work programme on PPDR applications, developing spectrum requirements for PPDR communications for wide-band and broadband applications.

The demand for wider coverage as stipulated in the present document in terms of cell size, number of cells needed for wider-area coverage for use by daily and more permanent PP1 applications as defined in Report ITU-R M.2033 [i.5] differs very much from the BBDR as covered in TR 102 485 [i.9] (see clause 3.1 for the definition and terminology of PP1, PP2 and DR) and the LAES application as covered in TR 102 496 [i.38]. Both BBDR and LAES are complementary applications to wider coverage PPDR networks described in the present document. They provide only local coverage and are focusing on in-building usage scenarios. On the other side, such wider coverage emergency communications do not require the same high capacity offered in ad-hoc local high user density networks. The present document therefore complements the existing ECC deliverables on PPDR and proposes to close this gap on broadband PP1 and DR applications that need spectrum more permanently (i.e. "daily", more frequently used BB usage) and with wider coverage. Clauses A.4 and A.5 provide some results on the mixture of the broadband demand, in terms of local & temporary demand, need for minimum of permanent demand as well as demand requiring a larger coverage area.

There is an overwhelming list of reasons why the public mobile networks are unsuitable for providing the above type of service. The main shortcomings of such networks are in the areas of availability, lack of ultimate controllability/ operational control over the network, coverage, resilience, security, interoperability and a host of other specific Public Safety/PPDR functional requirements. A more detailed discussion of these differentiating features is given in clause 6.3.

The new proposal

In the present document the emphasis is on a designation for BB PPDR within the defined tuning range of the technology (e.g. LTE), to be used for broadband applications. It is of critical importance that:

1) The high-speed data emergency communication services assume a very high priority in European spectrum designation.

2) The nationally designated bands within the defined tuning range are considered as European-wide assets for BB PPDR communications across the Community and should not be subject to the usually applied criteria regardingspectrum licensingfor commercial consumer networks and services i.e. auctions, etc.

3) Such a band is to be designated on a dedicated basis for BB PPDR.

4) Such a dedicated spectrum resource chosen from within the defined tuning range will allow for seamless cross-border operation of BB PPDR terminals, which is a definite requirement when disasters strike in border areas between Member States. This band should be harmonized for use (interoperable) across Europe.

5) The forthcoming ECC Report B [i.71] is expected to conclude on the tuning range from within which Member States Spectrum Administrations have the freedom to designate BB PPDR spectrum following national needs and circumstances.

Although TC-TCCE is the originating body of the SRDoc, this initiative is being made on behalf of the PSS community at large and as such the future broadband communications needs may be developed in accordance to options given in clause B.2.3. If a single frequency band cannot be designated, a tuning range within the harmonized band is also acceptable.

With the support of the European Commission, "Forum for Public Safety Communication Europe" (PSC-E) has been established in order to facilitate consensus building in the area of public safety communication and information management systems. PSC-E have made representation on this subject to ECC plenary in June 2008 and to RSPG in November 2008. PSC-E regularly responds to EC consultations, participates in PT49 meetings and coordinates amongst user organizations and across industry.

The socio-economic benefits

Public Protection and Disaster Relief is a priority subject for citizens, National Governments and the European Union and effective communication is an essential element for Public Safety operations. Public safety services bring value to society by creating a stable and secure environment and this can only be done by building robust, secure and reliable, modern Public Safety mobile communications networks which also allow for interoperability across international borders. To fulfil this requirement, it is essential for Public Safety services to have access to appropriate and protected spectrum in all parts of the territory, sufficient to meet their evolving operational needs. Building these modern essential services requires a long project lead time, for example, today's national digital radio system for emergency services, often part of Critical National Infrastructure, typically takes 10 years in planning before they are operational.

The Socio-economic benefits of this single harmonized spectrum for PPDR communication are immense:

1) Saving lives of citizens and public safety officers and minimizing injury.

2) Minimizing damage to private properties and public places.

3) Faster response and more efficient communication at times of disaster.

4) Enhancement of a single emergency communication network with high reliability (QoS), availability (free from congestion at times of disaster) and a high level of security.

5) Better co-ordination between different agencies nationally and over international borders for routine and emergency communications.

6) Developing countries will benefit from availability of such a low cost and globally interoperable emergency communication network.

7) Prolonged investments in European national public safety infrastructures maintained by an evolutionary enhancement.

8) A single wide-area coverage network results in major cost savings in the network infrastructure.

9) Creation of a European (potentially global) harmonized set of equipment resulting in a higher economy of scale and lower costs.

10) European technology lead in this globally significant area.

Market information

Considering the special nature of PPDR, traditional market mechanisms are not appropriate to consider in determining the correct amount of spectrum needed. The PPDR community is a specialist market, driven by different market forces to those that drive the public mobile mass markets. The ERC decision [i.24] in 1996 for 380 MHz to 385 MHz / 390 MHz to 395 MHz has proven to be highly successful. Most European countries have deployed or are in the process of deploying nationwide PPDR (more exactly PP1 and PP2) networks based on that decision, shared by police, fire brigades, emergency services and other PPDR users. As a result the PPDR community has never before had so much competition, innovation, specialized products and improved cost/benefit ratio.

User communities have determined that mobile data is equally as "mission critical" as voice and therefore cannot be reliably transported over commercial networks. This is because officers will become more and more reliant and dependent on mobile data communications in support of their day to day operations and thus losing and or interrupting these services in an emergency would seriously impact their ability to meet their public safety commitments. Consequently, additional spectrum is required to meet the future needs of PPDR.

It is expected that some PSS TETRA networks will start being replaced at least in part, commencing within the 2016 to 2020 timeframe, with new technology that will need to support voice, NB, WB and BB data services and be backward compatible and interoperable with TETRA. For voice it is expected that TETRA will still be the solution because for "mission critical group voice communication" there are no real alternatives in that timeframe.
Furthermore, the users' expectation is that the new enhancements will not require addition of new base stations to the network.

With the support of the European Commission, "Forum for Public Safety Communication Europe" (PSC-E) has been established in order to facilitate consensus building in the area of public safety communication and information management systems. PSC-E have made representation on this subject to ECC plenary in June 2008 and to RSPG in November 2008. PSC-E coordinates amongst user organizations and across industry.

The Mason study also supports the above findings [i.32].

Detailed market information is provided in annex A.

Introduction

The present document has been created by TC-TCCE with support from ETSI SC EMTEL. It was approved for publication by ERM as an ETSI Technical Report.

The present document has been updated following work carried out within TC-TCCE and within CEPT WGFM PT49 in collaboration with the LEWPLaw Enforcement Working Party whereby new annexes have been created to calculate the amount of spectrum required for PPDR services using a new approach based on a bottom up study of user application needs. Calculations in the present document are based on the working assumption that LTE technology will be the chosen technology to fulfil PPDR needs. This assumption has been adopted by both TC-TCCE and the TETRA and Critical Communications Association.

1 Scope

The present document is aimed at establishing a dedicated, harmonized European spectrum designation for PPDR mission-critical Public Safety and Emergency Communications. This proposed resource would be a harmonized spectrum across Europe allowing interoperable and permanent PPDR networks to be established in the 300 MHz to 790 MHz band. It is proposed that such a network would cater for all narrowband, wideband and broadband PPDR applications requiring wide area coverage. The applications will be used for voice in Narrowband networks, and voice and data or data only in Wideband and Broadband networks. For local and temporary broadband PPDR usage, so-called 5 GHz [4,9 GHz] Broadband Disaster Relief (BBDR) applications, the current regulation may also be reviewed.

Additional information is given in the following annexes:

- Annex A: Detailed market information.
- Annex B: Detailed technical information including some suggestions for considerations in frequency management.
- Annex C: Expected sharing and compatibility issues.
- Annex D: Public Safety frequency statements from 18 countries that were provided to ECC WG FM in 2010 and 2012, and statement on RSPG draft opinion on Wireless Broadband.
- Annex E: The Swedish Presidency of the EU informed the ETSI that the Council in June 2009 approved Council Recommendations on improving radio communication between operational units in border areas and invites to start producing a European standard satisfying law-enforcement and public-safety services' operational requirements regarding high-speed data communication and roaming functionality in the medium term.
- Annex F: Further technical calculation based on LEWP user application matrix and corresponding spectrum calculator as developed by TC TCCE.
- Annex G: Estimation for voice spectrum demand using LTE technology, compared with voice spectrum demand using TETRA.

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

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

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long term validity.

2.1 Normative references

The following referenced documents are necessary for the application of the present document.

Not applicable.

2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI EN 302 561 (V1.2.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Land Mobile Service; Radio equipment using constant or non-constant envelope modulation operating in a channel bandwidth of 25 kHz, 50 kHz, 100 kHz or 150 kHz; Harmonized EN covering essential requirements of article 3.2 of the R&TTE Directive".

[i.2] ECC Decision (08)05 on the harmonisation of frequency bands for the implementation of digital Public Protection and Disaster Relief (PPDR) radio applications in bands within the 380-470 MHz range.

[i.3] ECC Recommendation (08)04 on the identification of frequency bands for the implementation of Broad Band Disaster Relief (BBDR) radio applications in the 5 GHz frequency range.

[i.4] ECC Report 102 (January 2007): "Public protection and disaster relief spectrum requirements".

[i.5] Report ITU-R M.2033: "Radiocommunication objectives and requirements for public protection and disaster relief".

[i.6] Commission Recommendation C(2003)2657 (25 July 2003) on the processing of caller location information in electronic communication networks for the purpose of location-enhanced emergency call services.

[i.7] CEPT/ERC Report 25: "The European table of frequency allocations and utilisations in the frequency range 9 kHz to 3000 GHz".

[i.8] Void.

[i.9] ETSI TR 102 485: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Technical characteristics for Broadband Disaster Relief applications (BB-DR) for emergency services in disaster situations; System Reference Document".

[i.10] ETSI EN 300 392-2 (V3.2.1): "Terrestrial Trunked Radio (TETRA); Voice plus Data (V+D); Part 2: Air Interface (AI)".

[i.11] ETSI TR 102 580: "Terrestrial Trunked Radio (TETRA); Release 2; Designer's Guide; TETRA High-Speed Data (HSD); TETRA Enhanced Data Service (TEDS)".

[i.12] ETSI TR 102 491 (V1.2.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); TETRA Enhanced Data Service (TEDS); System reference document".

[i.13] ECC Report 99 (2007): "TETRA Enhanced Data Service (TEDS): Compatibility studies with existing PMR/PAMR and Air Ground Air (AGA) systems in the 400 MHz band".

[i.14] Void.

[i.15] Delaere, D. and Ballon, P. (April 2007): "Flexible spectrum management and the need for controlling entities for reconfigurable wireless systems", IEEE DySPAN 2007 Conference, Dublin, Ireland.

[i.16] Void.

[i.17] ETSI TR 102 621: "Terrestrial Trunked Radio (TETRA); TWC2007 Future of TETRA workshop report".

[i.18] wik-Consult, study white paper (May 2008): "Safety first: Reinvesting the digital dividend in safeguarding citizens".

[i.19] ETSI TS 102 181 (clause 5): "Emergency Communications (EMTEL); Requirements for communication between authorities/organizations during emergencies".

[i.20] ETSI TR 102 021-2 (V1.2.1): "Terrestrial Trunked Radio (TETRA); User Requirement Specification TETRA Release 2; Part 2: High Speed Data".

[i.21] ETSI TR 102 445: "Emergency Communications (EMTEL); Overview of Emergency Communications Network Resilience and Preparedness".

[i.22] ETSI EN 302 625: "Electromagnetic compatibility and Radio spectrum Matters (ERM); 5 GHz BroadBand Disaster Relief applications (BBDR); Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

[i.23] Void.

[i.24] ITU Resolution 646 (WRC-03): "Public protection and disaster relief".

[i.25] ITU Resolution 647 (WRC-07): " Spectrum management guidelines for emergency and disaster relief radiocommunication".

[i.26] ITU Radio Regulations footnote 5.286AA.

[i.27] Void.

[i.28] Council of the European Union (December 2008): "Progress report from the PCWG Ad hoc Working Party on Radiocommunications", Brussels.

[i.29] PSCE presentation to the Radio Spectrum Policy Group on Spectrum requirements regarding public protection and disaster relief (November 2008).

[i.30] Motorola: "Reuse methodology": (25th January 2008) ETSI TETRA WG4 document 407076r1.

[i.31] WiMAX Forum® (June 2006): "Mobile WiMAX- Part 1: A Technical Overview and Performance Evaluation".

[i.32] Analysis Mason (November 27, 2008): "Wireless network traffic to increase tenfold".

[i.33] Council of the European Union: "Council Recommendation 10141/09 on improving radio communication between operational units in border areas".

[i.34] Void.

[i.35] Void.

[i.36] Void.

[i.37] MESA TS 70.001 (Version 3.2.1) project MESA: "Service specification group - services and applications; Statement of Requirements (SoR)".

[i.38] ETSI TR 102 496: "Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference Document; Short Range Devices (SRD); Technical characteristics for Location tracking Applications for Emergency Services (LAES) in disaster situations operating within the frequency range from 3,4 GHz to 4,8 GHz".

[i.39] Recommendation ITU-R P.370-7: "Dependence of field strength on horizon angle theta in ITU-R Recommendation P.370-7".

[i.40] ETSI TR 102 513: "Terrestrial Trunked Radio (TETRA); Feasibility Study into the Implications of Operating Public Safety Sector (PSS) TEDS using the proposed "Tuning Range" concept in the 410 MHz to 430 MHz and 450 MHz to 470 MHz frequency bands".

[i.41] PCWG letter from Swedish presidency to CEPT-ERO with request for a harmonised frequency band for mobile data.

[i.42] PCWG letter from Swedish presidency to ETSI with request for a technology solution for mobile data.

[i.43] PCWG interim report December 2009.

[i.44] Void.

[i.45] Void.

[i.46] Void.

[i.47] Void.

[i.48] Report ITU-R M.2014: "Digital land mobile systems for dispatch traffic".

[i.49] Recommendation ITU-R M.1073: "Digital cellular land mobile telecommunication systems".

[i.50] Recommendation ITU-R M.1221:"Technical and operational requirements for cellular multimode mobile radio stations".

[i.51] Recommendation ITU-R M.1457: "Draft revision of Recommendation ITU-R M.1457-8 - Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications 2000 (IMT-2000)".

[i.52] Void.

[i.53] IEEE Std 802.16e-2005: "Amendment to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems - Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands".

[i.54] IEEE Std 802.16m: "Amendment to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Broadband Wireless Access Systems - Advanced Air Interface".

[i.55] IEEE 802.11: "IEEE Standard for Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks-Specific requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications".

[i.56] Jakes, W. C. (1974): "Microwave Mobile Communication", John Wiley and Sons.

[i.57] ERC Report 68: "Monte-Carlo Simulation Methodology For The Use In Sharing And Compatibility Studies Between Different Radio Services Or Systems", Naples, February 2000, revised in Regensburg, May 2001 and Baden, June 2002.

[i.58] Y. Okumura, E. Ohmori, T. Kawano, and K. Fukuda: "Field strength and its variability in VHF and UHF land-mobile service" Rev. Elec. Comm. Lab., vol. 16,No. 9-10,pp. 825-873, 1968.

[i.59] Hata M.: "Empirical formula for propagation loss in land mobile radio services" Vehicular Technology, IEEE Transactions on, Volume 29, Issue 3, Aug 1980 Pages 317 - 325.

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[i.61] Perahia E., Cox D.C., Ho S.: "Shadow fading cross correlation between basestations", Vehicular Technology Conference, 2001. VTC 2001 Spring. IEEE VTS 53, Volume 1, 6-9 May 2001 Pages 313 - 317 vol.1.

[i.62] Zayana K., Guisnet B.: "Measurements and modelisation of shadowing cross-correlations between two base-stations", Universal Personal Communications, 1998. ICUPC '98. IEEE 1998 International Conference on, Volume 1, 5-9 Oct. 1998 Pages 101 - 105 vol.1.

[i.63] Nazar Elfadhil, Salam M.A., Al-Lawati A., Al-Qasmi O., Al-Gheithi M., Nadir Z.: "Modification of an Open Area Okumura-Hata Propagation Model Suitable for Oman", TENCON 2005 IEEE Region 10, Nov. 2005 Pages 1 - 4.

[i.64] Weitzen J., Lowe T.J.: "Measurement of angular and distance correlation properties of log-normal shadowing at 1900 MHz and its application to design of PCS systems", Vehicular Technology, IEEE Transactions on, Volume 51, Issue 2, March 2002 Pages 265 - 273.

[i.65] Council Decision 2008/616/JHA of 23 June 2008 on the implementation of Decision 2008/615/JHA on the stepping up of cross-border cooperation, particularly in combating terrorism and cross-border crime.

NOTE: Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:210:0012:0072:EN:PDF.

[i.66] Draft Council Recommendation 13796/08 of 3 October 2008 on improving communication between operational units in border areas.

NOTE: Available at http://register.consilium.europa.eu/pdf/en/08/st13/st13796.en08.pdf.

[i.67] Communication from the Commission to the European Parliament and the Council on Reinforcing the Union's Disaster Response Capacity.

NOTE: Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0130:FIN:EN:PDF.

[i.68] ERC Report 52 (December 1997): "Methodology for the assessment of PMR systems in terms of spectrum efficiency, operation and implementation", Bucharest.

[i.69] ECC Report 42 (February 2004): "Spectrum efficiency of CDMA-PAMR and other wideband systems for PMR/PAMR", Granada.

[i.70] ECC Report 199: 'User requirements and spectrum needs for the future European broadband PPDR systems (Wide Area Networks), May 2013'.

[i.71] ECC Report "B" [PPDR]: "Harmonised conditions and spectrum bands for the implementation of future European broadband PPDR systems".

[i.72] Mandate to CEPT to develop harmonised technical conditions for the 694-790 MHz ('700 MHz') frequency band in the EU for the provision of wireless broadband electronic communications services and other uses in support of EU spectrum policy priorities.

[i.73] 3GPP contribution R4-101492.

NOTE: Available at http://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_AHs/R4_AH%2310-02_Dublin_April_2010/Documents/R4-101492.zip

[i.74] ETSI TS 136 101: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception (3GPP TS 36.101)".

[i.75] ETSI TS 136 213: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures (3GPP TS 3GPP 36.213)".

[i.76] Radio Spectrum Policy Group: "RSPG Report of 12 November 2013 on Strategic Sectoral Spectrum Needs".

[i.77] Report ITU-R M.2198: " The outcome of the evaluation, consensus building and decision of the IMT-Advanced process (Steps 4 to 7), including characteristics of IMT-Advanced radio interfaces.

[i.78] ETSI TR 136 912: "LTE; Feasibility study for Further Advancements for E-UTRA (LTE-Advanced) (3GPP TR 36.912)".

3 Definitions and abbreviations

3.1 Definitions

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

π/4-DQPSK channel: channel on which signalling and data messages are sent using π/4-DQPSK bursts

air-interface: wireless interface between a base station and a mobile station (trunked mode) or between two mobile stations (direct mode)

broadband: communication service providing data rates higher than wideband (typically above 1 Mbit/s)

NOTE: ITU-R Definition [i.5]: "Broadband technology could be seen as a natural evolutionary trend from wideband. Broadband applications enable an entirely new level of functionality with additional capacity to support higher speed data and higher resolution images. It should be noted that the demand for multimedia capabilities (several simultaneous wideband and/or broadband applications running in parallel) puts a huge demand with very high bit rates on a wireless system deployed in a localized area with intensive on-scene requirements (often referred to as "hot spot" areas) where PPDR personnel are operating.

Broadband applications could typically be tailored to service localized areas (e.g. 1 km^2 or less) providing voice, high-speed data, high quality digital real time video and multimedia (indicative data rates in range of 1-100 Mbit/s) with channel bandwidths dependent on the use of spectrally efficient technologies. Examples of possible applications include:

- high-resolution video communications from wireless clip-on cameras to a vehicle-mounted laptop computer, used during traffic stops or responses to other incidents and video surveillance of security entry points such as airports with automatic detection based on reference images, hazardous material or other relevant parameters;
- remote monitoring of patients and remote real-time video view of the single patient demanding up to 1 Mbit/s. The demand for capacity can easily be envisioned during the rescue operation following a major disaster. This may equate to a net hot spot capacity of over 100 Mbit/s.

Broadband systems may have inherent noise and interference tradeoffs with data rates and associated coverage. Depending on the technology deployed, a single broadband network may have different coverage areas in the range of a few metres up to hundreds of metres, providing a wide range in spectrum reuse capability. Collectively, the high data speeds and localized coverage area open up numerous new possibilities for PPDR applications (tailored area networks, hot spot deployment and ad-hoc networks)."

common control channels: control channels transmitted by the infrastructure to control the MS population

NOTE: The common control channels comprise the main control channel and common secondary control channels.

Cognitive Pilot Channel (CPC) for PPDR: channel which conveys the elements of necessary information facilitating the operations of Cognitive Radio Systems involving the PPDR network

day-to-day operations (PP1): routine PPDR operations

NOTE: "Day-to-day operations encompass the routine operations that PPDR agencies conduct within their jurisdiction. Typically, these operations are within national borders. Generally, most PP spectrum and infrastructure requirements are determined using this scenario with extra capacity to cover unspecified emergency events." (Quotation from Report ITU-R M.2033 [i.5]).

PP1 networks are for general public protection and require reliable, available, secure systems provided by dedicated systems permanently available and covering all necessary wide areas (regional, country, continent) on a permanent basis. These operations insure primarily voice and messaging communications which can be fulfilled by narrowband and wideband communications.

dedicated PPDR spectrum: spectrum assigned to PPDR networks

NOTE: This does not imply an exclusive use but sharing part of the spectrum with other networks under strict pre-emptive regime to ensure the expected performance of the PPDR network for disaster relief.

disaster relief operations: special operations to minimize the effects of a disaster

NOTE: "Disasters can be those caused by either natural or human activity. For example, natural disasters include an earthquake, major tropical storm, a major ice storm, floods, etc. Examples of disasters caused by human activity include large-scale criminal incidences or situations of armed conflict. Generally, both the existing PP communications systems and special on-scene communications equipment brought by DR organizations are employed." (Quotation from Report ITU-R M.2033 [i.5]).

These require efficient rapid deployment incident networks. Applications are used temporarily by emergency services in all aspects of disaster situations, including disaster prevention. For instance, they provide simultaneous hot spot type of robust communications, video or robotic data information, telemetry parameters, critical data base queries, location information exchange and other heavy data communications.

Furthermore interoperability of equipment to ensure joint operations is a mandatory requirement.

disaster relief radiocommunications: radiocommunications used to facilitate disaster relief operations

NOTE: "Radiocommunications used by agencies and organizations dealing with a serious disruption of the functioning of society, posing a significant, widespread threat to human life, health, property or the environment, whether caused by accident, nature or human activity, and whether developing suddenly or as a result of complex, long-term processes." (Quotation from Report ITU-R M.2033 [i.5]).

emergency service or public safety agency: organization providing immediate assistance and relief in emergency situations

NOTE: A service or agency, recognized as such by the Member State, that provides immediate and rapid assistance in situations where there is a direct risk to life or limb, individual or public health or safety, to private or public property, or the environment but not necessarily limited to these situations (Source: Commission Recommendation C(2003)2657 [i.6]).

IP packet data: packetized data according to the Internet Protocol

large emergency and/or public events (PP2): events outside routine operations (i.e. not PP1 operations)

NOTE: "Large emergencies and/or public events are those that PP and potentially DR agencies respond to in a particular area of their jurisdiction; however they are still required to perform their routine operations elsewhere within their jurisdiction. The size and nature of the event may require additional PPDR resources from adjacent jurisdictions, cross-border agencies, or international organizations. In most cases, there are either plans in place or there is some time to plan and coordinate the requirements." (Quotation from Report ITU-R M.2033 [i.5]).

A large fire encompassing 3-4 blocks in a large city (e.g. London, Paris) or a large forest fire are examples of a large emergency under this scenario (also the plane crash at Schiphol 2009). Likewise, a large public event (national or international) could include the Commonwealth Heads of Government Meeting (CHOGM), G8 Summit, the Olympics, etc.

Generally, additional radiocommunications equipment for large events is brought to the area as required. This equipment may or may not be linked into the existing PP network infrastructure.

It is to be noted that the equipment used for large extraordinary local incidents will request reinforced communications means including BB equipment.

mission critical situations: situations where human life, rescue operations and law enforcement are at stake

NOTE: In a mission critical situation public safety organizations cannot afford the risk of having transmission failures in their voice and data communications or for police in particular to be "eaves-dropped".

narrowband: communication service providing data rates up to about 100 kbit/s

NOTE: ITU-R Definition [i.5]: "To provide PPDR narrowband applications, the trend is to implement wide area networks including digital trunked radio networks providing digital voice and low speed data applications (e.g. pre-defined status messages, data transmissions of forms and messages, access to databases). Report ITU-R M.2014 [i.48] lists a number of technologies, with typical channel bandwidths up to 25 kHz, that are currently used to deliver narrowband PPDR applications. Some countries do not mandate specific technology, but promote the use of spectrum-efficient technology." (Quotation from Report ITU-R M.2033 [i.5]).

non-mission critical situations: situations where human life and properties are not at stake

NOTE: In non-mission critical situations communication needs are non critical: human life and properties are not at stake, administrative tasks for which the time and security elements are not critical.

QAM channel: channel on which signalling and data messages are sent using QAM bursts

real-time class data: data that cannot tolerate delay but can tolerate some packet loss

public protection radiocommunications: specific radiocommunication for agencies and public safety organizations

NOTE: "Public protection radiocommunications used by responsible agencies and organizations dealing with maintenance of law and order, protection of life and property, and emergency situations." (Quotation from Report ITU-R M.2033 [i.5]).

public safety operations: any kind of operation performed by a public safety organization

NOTE: Public Safety organizations addresses three (PP1, PP2, DR) types of operations. (Source: Report ITU-R M.2033 [i.5]). Furthermore it should be noted that training exercises will also take place and consequently have to be taken into account when considering frequency planning and harmonization. In order to avoid unnecessary use of spectrum, a training mode may be required for BB.

tuning range: the maximum continuous span of spectrum usable by a radio transceiver for its intended purpose

wideband: communication service providing higher data rates than narrowband (typically hundreds of kbit/s)

NOTE: ITU-R Definition from section 1.4.3 of Report ITU-R M. 2033 [i.5]: "It is expected that the wideband technologies will carry data rates of several hundred kilobits per second (e.g. in the range of 384-500 kbit/s). Since it is expected that networks and future technologies may require higher data rates, a whole new class of applications including: wireless transmission of large blocks of data, video and Internet protocol-based connections in mobile PPDR may be introduced.

The use of relatively high-speed data in commercial activities gives a wide base of technology availability and will therefore spur the development of specialist mobile data applications. Short message and e-mail are now being seen as a fundamental part of any communications control and command system and therefore could most likely be an integral part of any future PPDR capability.

A wideband wireless system may be able to reduce response times of accessing the Internet and other information databases directly from the scene of an incident or emergency. It is expected that this will initiate the development of a range of new and secure applications for PPDR organizations.

Systems for wideband applications to support PPDR are under development in various standards organizations. Many of these developments are referenced in Report ITU-R M.2014 [i.48] and in Recommendations ITU-R M.1073 [i.49], M.1221 [i.50] and M.1457 [i.51] and with channel bandwidths dependent on the use of spectrally efficient technologies."

3.2 Abbreviations

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

π/4-DQPSK	π/4-shifted Differential Quaternary Phase Shift Keying
3G	3rd Generation
ACP	Adjacent Channel Power
ACR	Adjacent Channel Rejection
ADC	Analogue-to-Digital Converter
AG	AktienGesellschaft
AI	Agenda Item
ANPR	Automatic Number Plate Recognition
APCO	Association of Public-Safety Communications Officials
ASM	Adaptive Spectrum Management
AVLS	Automatic Vehicle Location Services
BB	BroadBand
BBDR	BroadBand Disaster Relief
BLER	Block Error Ratio
BS	Base Station
BU	Bad Urban
CCC	Command and Control Centre
CCTV	Closed Circuit TeleVision
CEPT	Conference Européenne des administrations des Postes et des Telecommunications
CPC	Cognitive Pilot Channel

CPG	Conference Preparatory Group
CQI	Channel Quality Information
DAC	Digital-to-Analogue Converter
DG	Directorate General
DL	Downstream Link
DMO	Direct Mode Operation
DR	Disaster Relief
EC	European Community
ECC	Electronic Communications Committee
ECP	European Common Position
ECS	Electronic Communications Services
ERC	European Radiocommunication Committee
ETCS	European Train Control System
ETSI	European Telecommunications Standards Institute
EV-DO	Evolution Data Only
FDD	Frequency Division Duplex
GIS	Geographic Information Systems
GOS	Grade of Service
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile communications
GSM-R	Global System for Mobile communication for Railway application
HEN	Harmonized European Norm
HSD	High Speed Data
HSPA	High Speed Packet Access
ICT	Information & Communication Technology
IMT	International Mobile Telecommunications
IP	Internet Protocol
ITU	International Telecommunication Union
LAES	Location Application for Emergency Services
LEWP	Law Enforcement Working Party
LS	Location Services
MAC	Medium Access Control
MBMS	Multimedia Broadcast Multicast Service
MBSFN	MBMS over a Single Frequency Network
MC	Multi Carrier
MCL	Minimum Coupling Loss
MEA	Middle East and Africa
MIMO	Multiple-Input Multiple-Output
MISO	Multiple-Input Single-Output
MOB	MOBility
MS	Mobile Station
NB	NarrowBand
NPIA	National Policing Improvement Agency
NPSPAC	National Public Safety Planning Advisory Committee
NR	Number of cells in Reuse pattern
NRA	National Regulatory Authority
NTFA	National Table of Frequency Allocations
OFDM	Orthogonal Frequency Division Multiplexing
OTAR	Over The Air Re-keying
PAMR	Public Access Mobile Radio
PCWG	Police Cooperation Working Group
PDA	Personal Digital Assistant
PMR	Private Mobile Radio
PNC	Police National Computer
PP	Public Protection

NOTE: See clause 3.1 definitions and terminology for PP1 and PP2.

PPDR	Public Protection and Disaster Relief
PS	Public Safety
PSC-E	Forum for Public Safety Communication Europe

PSCE	Public Safety Communications Europe
PSK	Phase Shift Keying
PSS	Public Safety and Security
PT	Project Team
PTA	Project Team A
PTD	Project Team D
PWMS	Professional Wireless Microphone System
QAM	Quadrature Amplitude Modulation
QCI	QoS Class Identifier
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RCEG	Radio Communication Experts Group
REC	Recommendation
RF	Radio Frequency
RSC	Radio Spectrum Committee (of the European Commission)
RSPG	Radio Spectrum Policy Group (of the European Commission)
RSPP	Radio Spectrum Policy Programme
RSSI	Receive Signal Strength Indication
RX	Receiver
SC	Special Committee
SEAMCAT	Spectrum Engineering Advanced Monte Carlo Analysis Tool
SIM	Subscriber Identification Module
SINR	Signal to Interference plus Noise Ratio
SNR	Signal to Noise Ratio
SRDoc	System Reference Document
SU	Sub Urban
TCCA	TETRA and Critical Communications Association
TC-TCCE	Technical Committee TETRA and Critical Communications Evolution (formerly TC-TETRA)
TC-TETRA	Technical Committee TETRA (now TC-TCCE)
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TEDS	TETRA Enhanced Data Service
TETRA	TErrestrial Trunked RAdio
TS	Technical Specification
TU	Typical Urban
TV	TeleVision
TX	Transmitter
UE	User Equipement
UHF	Ultra High Frequency
UL	Upstream Link
UMB	Universal Mobile Broadband
UMTS	Universal Mobile Telecommunication System
UPS	Uninterruptible Power Supply
URS	User Requirement Specification
USA	United States of America
V+D	Voice plus Data
VHF	Very High Frequency
WAPECS	Wireless Access Policy for Electronic Communications Services
WB	WideBand
WGFM	Working Group on Frequency Management (of ECC)
WRC	World Radio Conference

4 Comments on the System Reference Document

No ETSI members raised any comments.

5 Void

6 Market information

Considering the special nature of PPDR, traditional market mechanisms are not appropriate to consider in determining the correct amount of spectrum needed. The PPDR community is a specialist market, driven by different market forces to those that drive the public mobile mass markets. The ERC decision [i.24] in 1996 for 380 MHz to 385 MHz / 390 MHz to 395 MHz has proven to be highly successful. Most European countries have deployed or are in the process of deploying nationwide PPDR (more exactly PP1 and PP2) networks based on that decision, shared by police, fire brigades, emergency services and other PPDR users. As a result the PPDR community has never before had so much competition, innovation, specialized products and improved cost/benefit ratio.

User communities have determined that mobile data is equally as "mission critical" as voice and therefore cannot be reliably transported over commercial networks. This is because officers will become more and more reliant and dependent on mobile data communications in support of their day to day operations and thus losing and or interrupting these services in an emergency would seriously impact their ability to meet their public safety commitments. Consequently, additional spectrum is required to meet the future needs of PPDR.

It is expected that some PSS TETRA networks will start being replaced at least in part, commencing within the 2016 to 2020 timeframe, with new technology that will need to support voice, NB, WB and BB data services and be backward compatible and interoperable with TETRA. For voice it is expected that TETRA will still be the solution because for "mission critical group voice communication" there are no real alternatives in that timeframe.

For detailed market information please refer to annex A.

7 Technical Information

7.1 Detailed technical description

Please refer to Annex B.

8 Radio spectrum request and justification

8.1 Future spectrum requirements and justification

Future spectrum requirements are summarized below:

- The following future spectrum pairs (FDD operation, for uplink and downlink as a basis, however also to study possible asymmetry of the demand in up- and downlink, see clause A.5).
- preferably, 2 separate contiguous blocks of minimum 10 MHz plus 2 separate non-contiguous blocks of 2 × 3 MHz for new NB and 2 × 3 MHz for new WB as indicated in table 1), minimum, dedicated to PSS and harmonized across Europe; the total of **additional** 16 MHz for each direction (uplink and downlink). The tuning range concept of ±12,5 % of the centre frequency applies to NB and WB, however not to BB. The BB spectrum designation may be located in separate spectrum range.
- Further additional spectrum for local use at the scene of an incident, which is expected to be located in a higher frequency band - a minimum of 2 x 10MHz will be required.
- If in the future voice is also to be carried over a BB network, replacing voice on narrowband networks, a further 3,2 + 3,2 MHz is estimated to be required.
- Additional frequency requirements separate from the NB, WB and wide area BB requirements will be needed for Broadband Air to Ground operation and Broadband Direct Mode operation. The bandwidth of these requirements has not yet been estimated.

- The four additional requirements for local BB coverage, voice, Air to Ground and Direct Mode also need to be harmonized across Europe, for reasons of interoperability and to create sufficient volume of equipment for a competitive market.

The above requirements are based on the following assumptions in a disaster relief scenario:

1) A mixture of NB, WB and BB channels.

2) Multiple WB channels (each up to 150 kHz) per site.

3) Use of 1 BB channel per site for wide area use (minimum 10 MHz wide depending on the choice of broadband technology).

4) Further high frequency allocations of at least 10 + 10 MHz for local support at the scene of an incident.

5) Extensive field data from a number of operating TETRA networks has shown that the frequency re-use factor for 25 kHz TETRA NB channels is 20 to 30. A detailed consideration on how the frequency reuse was derived is in clause B.3.3.

6) A simulation study [i.30] carried out by TC TETRA WG4 showed that the re-use factor for WB (TEDS) channels is at minimum a factor of 2 lower than the TETRA NB (25 kHz) channels (i.e. 10 to 15).

7) The additional NB demand is caused by increased multi-slot packet data usage in existing networks and caused by the additional demand for spectrum used for the avoidance of congestion of the control channel due to location data usage. This was reported by several European countries within ETSI TC TETRA. Clause B.3.3 also provides some information on why additional NB demand (high usage density situations, cross-border additional channel needs, to support higher mobility requirements, etc.) is necessary.

8) The frequency re-use factor of 1 to 3 has been reported by some of the BB technologies listed in [i.31], clause B.2.3.

Using the above assumptions table 1 shows that additional 2 × 16 MHz is about the minimum to serve the above scenario for wide area networks, with the additional 2 × 10 MHz for local usage. Further air to ground and DMO spectrum is not yet calculated.

Table 1: Derivation of Typical Future Spectrum Requirement

Channel Type	Number of Channels	Total Spectrum MHz (paired bands)
NB	120 (network wide) 10 (per site)	2 x 5 (existing allocation)
New NB	120 (network wide) 6 (per site)	2 x 3
New WB	20 (network wide) 2 (per site)	2 x 3
New BB	1 (network wide and per site)	2 x 10
New local BB	1 deployable at an incident	2 x 10
Cognitive Pilot Channel (CPC)	1 or more	Note 1
DMO and Air to Ground		Note 2
Total new requirement (excl. CPC)		2 x 16
NOTE 1: The mechanism for spectrum sharing, and any spectrum requirements for pilot channels or other solutions is for future study. NOTE 2: DMO and Air to Ground requirements are for further study		

- ETSI noted the decision of WGFM that the main focus will be on the broadband requirements (2 × 10 MHz), as the narrowband and wideband requirements should be covered within the tuning range 380 MHz to 470 MHz, as identified in the ECC Decision (08)05 [i.2].

As many factors affect the performance of radio terminal equipment (mobile nature of use) and if communications are lost and/or degraded only one user is affected, reduced performance due to use of a tuning range for NB and WB allocations may be acceptable, however, field trials will be needed to quantify actual degradation.

A detailed discussion about the consequences of larger tuning ranges can be found in [i.40].

Duplex spacing

It is assumed that NB/WB channels would have to work with the same duplex spacing as existing TETRA networks. Keeping the 10 MHz duplex spacing as in existing networks would be easiest to deploy new network and subscriber equipment.

For BB spectrum, the need is for enough spacing, which would need to be at least 20 MHz for a 10 MHz channel bandwidth, preferably higher to ease the requirements for base station and terminal duplex filtering. On the other hand, if the identified granted BB spectrum were at lower frequency, then too great a spacing starts to cause antenna performance fall off between Tx and Rx bands. In this case, adequate spacing needs to be discussed further on in the process.

It is to be noted that the use of TDD in the spectrum proposed to be assigned should not be ruled out. German studies presented during the ECC WGFM PPDR workshop outlined a possible asymmetry of the demand (see clause A.5).

Furthermore, the above spectrum requirement is in addition to any existing PSS spectrum to allow interoperability, full wide-area coverage for routine PSS operations and equipment cost and size considerations.

PPDR services have the primary duty of ensuring law and order as well as protecting the life, health and property of citizens. Spectrum requirements for PSS have to prevail over requests for non-PSS spectrum.

The current 2 × 5 MHz PPDR spectrum is extensively used in Europe for NB data and voice services and is in need of expansion to cater for emerging PPDR WB data services.

As indicated above any spectrum designation (as a result of the present document) requires at least one contiguous component as wide as one required broadband channel for the permanent terrestrial capability (minimum 2 × 10 MHz for data usage; in case of using MC voice over BB an extra 2 × 3,2 MHz for that voice capacity will be required: see annex G).

NOTE: Additional spectrum for Air to Ground and Direct Mode capability will also be required, but is not included in the summarized figures above.

A solution based on split or fragmented spectrum for the required channel is not viable because of:

- RF front end design complexities:

  A fragmented band for a BB channel requires using either multiple transmitters and receivers for the different parts of the channel or employing very wide bandwidth DAC and ADC devices with a very high dynamic range to allow protection against high interference within the fragmented band. In both examples the technology is complex, expensive or does not exist. Furthermore, guard bands and adjacent band compatibility would be a big challenge for fragmented BB spectrum.

As for the non-contiguous requirements for 2 × 2 × 3 MHz for Narrowband and Wideband ise, there are the following problems compared to:

- Protection requirements:

  A wider total guard band would be necessary because of the need for a guardband at each fragmentation edge to meet the PSS compatibility requirements. This reduces the overall efficiency in utilization of the spectrum compared to the non-fragmented scenario. Otherwise extremely strict, perhaps technically even not feasible ACR and ACP specifications would be needed.

- Wastage of spectrum due to additional guard bands:

  As seen from the above second bullet point, more and wider guard bands are needed, which results in more wastage of the spectrum.

- Difficulties with interoperability:

  With a fragmented spectrum there will be more likelihood of Administrations using different sub-bands for their public safety TETRA network hence making the task of a cross border or pan European interoperability much more difficult.

In any case, the fragmented scenario requires a more complex and time consuming compatibility analysis. The scarcity of additional spectrum resources within the 400 MHz range (e.g. between 406,1 MHz to 430 MHz and 440 MHz to 470 MHz) will make it difficult to fulfil requests in future for wideband and broadband PPDR networks. These frequencies are also heavily used by non-PPDR, PMR/PAMR networks. Furthermore, WRC 07 identified the band 450 MHz to 470 MHz for use by administrations wishing to implement International Mobile Telecommunications (IMT) [i.26]. This will make it even more difficult to find additional spectrum resources. Clearly, a lack of further availability of spectrum will put the fulfilment of the duties of PPDR services at risk by (among others):

- Inability to support new services requiring more data (e.g. video, identity cards, photographs, fingerprints).

- Lagging behind criminals who increasingly adopt advanced data applications.

- Inability to manage efficiently major disaster scenarios.

Even though the European PSS community welcomes and appreciates the spectrum already assigned for dedicated PSS use, this allocation is clearly insufficient for supporting the data applications as listed in annex A, detailed market information. Back in early 1990, when the estimation of future spectrum needs for PSS determined that 2 × 5 MHz was needed, features like GPS (or AVLS/APLS - Automatic Vehicle/ Automatic Personal Location Services) were not known. Today most terminals - mobiles and handsets - have a GPS receiver built-in and the users have a need to inform their control rooms of their location at any given time. This additional data traffic has not been calculated and is just one reason on why additional spectrum is required. One other example, PPDR in Europe has access to 2 × 5 MHz (in practice there is more, but not harmonized; see remarks in table 2) of dedicated spectrum whereas the Public Safety community in North America has access to more than 97 MHz spectrum - a significant difference. See table 2 reproduced from [i.18].

Table 2: European Harmonized Dedicated PSS Spectrum Allocation

	United States		**Europe**		
Frequency Band	**Tuning Range (MHz)**	**Available Bandwidth (MHz)**	**Frequency Band**	**Tuning Range (MHz)**	**Available Bandwidth (MHz)**
VHF Low band (see note 1)	25 to 50	6,3			
VHF High band (see note 1)	150 to 174	3,6	68 MHz to 87,5 MHz, 146 MHz to 174 MHz VHF band		(see note 4)
220 MHz band (see note 1)	220 to 222	0,1			
UHF band (see note 1)				380 to 385	5
	450 to 470	3,7		390 to 395	5
700 MHz band	764 to 776	12		*410* to *430*	20 (see note 2)
	794 to 806	12	UHF band	*450 to 470*	20 (see note 2)
800 MHz band (see note 1)	806 to 821	1,75			
	851 to 866	1,75			
NPSPAC band	821 to 824	3			
	866 to 869	3			
5 GHz band	4 940 to 4 990	50	5 GHz band	*5 150* to *5 250* alternatively: 4 940 to 4 990	50 (see note 3)
Total available bandwidth		**97,2**			**10**

NOTE 1: Denotes approximate available bandwidth.
NOTE 2: Shows non-dedicated bands in Europe, hence not included in the total available bandwidth.
NOTE 3: For local and temporary usage (PP2 and DR) only, hence not included in the total available bandwidth.
NOTE 4: Many European countries have national frequency designations for PPDR in the VHF frequency range which are not harmonized throughout Europe, hence not included in the total available bandwidth.

Furthermore, the spectrum available to PPDR in Europe is fully used by voice traffic and some data usage. Examples of such PPDR networks are Airwave (UK), ASTRID (Belgium), C2000 (Netherland) and VIRVE network in Finland, all using the spectrum shown in table 2. Some of these networks have been compelled to expand into locally available spectrum that is not harmonized for PPDR use to meet their capacity demands. The wideband ECC Decision [i.2] for 380 MHz to 470 MHz does give the PPDR community some extra data capability, but high utilization of the current does not permit the establishment of channels suitable for the use of high speed data as required for future enhancements of public investments.

The mission-critical PPDR communications requirement is exhibiting an urgent and growing need for inter-operable high-speed data services (see annex A). A number of PSS organizations in Europe have been conducting trials on PSS high-speed data in recent years (TS 102 181 [i.19]). These organizations clearly see a need for a nation-wide mission critical capability in the near future to allow the HSD services and applications (often mission critical) listed in clause A.1. The ETSI Special Committee EMTEL and project MESA have identified user requirements for future broadband mission critical PP1, PP2 and DR applications. The EMTEL document TS 102 181 [i.19] on requirements for communication between authorities and organizations during emergencies also lists situations and services for effective communication (as listed in clause A.1).

Some of these services could be supported e.g. by TETRA Release 2 technology today and in the future by further enhancements to the TETRA standard. The implementation of these services however has been inhibited by a lack of suitable radio channels in range 380 MHz to 470 MHz. For example, although the new NB/WB ECC Decision [i.2] provides a tunable facility over this band, few European countries are in a position to provide spectrum in this band within the foreseeable future. This is why the implementation of wideband PPDR networks is inhibited from taking off in Europe. A wideband PPDR network, when implemented, could also provide the complementary role of a core network for the BBDR deployments, interconnecting various "hot zones".

Considering the above points it is therefore natural to consider the next relevant spectrum opportunity, i.e. the "second digital dividend" band as an ideal solution to this vital problem, allowing a spectrum designation for these important networks close to the LTE bands to get maximum profit of using the world-wide LTE technology. This view is based on the fact that the PSS/PPDR market segment is relatively small and that there is a limited economic case for the high degree of terminal integration (different spectrum bands and different standards) that we see e.g. in the GSM / UMTS market segments.

As a longer term consideration, the Adaptive Spectrum Management (ASM) based on the use of Cognitive Radio is believed by many regulators to be the solution for spectrum congestion. As part of the proposal of the present document, clause B.4 considers the applicability of Cognitive Radio to PPDR users.

8.2 Considerations in selecting the PPDR spectrum

The current TETRA public safety networks operate in the 400 MHz band as the propagation properties are well suited to the network density and excellent coverage levels necessary for such applications while also maintaining appropriate infrastructure costs for tax-payer funded services. However the 400 MHz band has been used almost fully by the existing networks for NB user applications in many countries (mainly for mission critical voice communication). The potential second Digital Dividend which should arise from ITU WRC 2015 may provide a better opportunity in the 700 MHz spectrum region.

CEPT WGFM PT49 are studying the appropriate bands, and a report currently designated "Report B" [i.71] will recommend the most suitable spectrum for the PPDR service.

8.3 Use of Public Networks to fulfil PSS requirements

NOTE: The present clause 6.3 has been introduced on request from ECC Working Group FM on *"the use of public networks to fulfil the PSS requirements should be considered"* in relation to providing justification to the PSS spectrum request covered by the present document.

8.3.1 What can Public Network offer to PS organizations

In recent years the Public Safety Agencies have been involved in pilot schemes and implementation of data services via public mobile networks. However these applications have been in "routine" operations primarily to increase the efficiency of the personnel by eliminating repeated travel from the field to the headquarters. For example the UK Police have improved their performance considerably using PDAs and smart-phones for access to:

- Police National Computer (PNC)
- National Voter's Register
- Vehicle Licence Agencies

This has helped the officers to obtain vital data and photographic records on e.g. missing persons, crime alerts, web view of duty schedules, etc. British Transport Police have been also able to locally print out forms and penalty notices using such devices.

8.3.2 Service Shortcomings of Public Networks as a total solution

Apart from the above being limited to routine operations, mainly in urban environments, the permitted level of "security" over-the-air to smart phone devices has been limited to the lower levels. Hence the mandatory services and facilities required by public safety organizations can only partially be provided on networks designed for commercial use since these organizations cannot base all their mission critical communication on commercial networks.

In many commercial networks data is sent at lower priority than voice traffic, where a common infrastructure is used for voice and data (as in public cellular networks). This could be a significant problem for the public safety users who often find themselves in areas where voice services are being used intensively (i.e. at an "incident") - thus data services could be degraded when most needed.

Even if a commercial network was designed to meet the needs (see clause 6.3.3) - operational, resilience, QoS, etc. of PPDR users - many governments would still need to ensure that ownership of the operator would be under control (selling the shares to unwanted parties is not considered acceptable in many countries). Alternatively they may require continued guaranteed financial viability of the operator; options to take management control of the operator when needed. All existing specialized operators of that type (UK, Portugal, Austria and Denmark) have this type of legal constraints. Further requirements can include unlimited liability clauses, open book accounting, most favoured customer status (the government customer should always receive the lowest contract prices), escrow copies of network software, security cleared personnel and the requirements for detailed auditing of detailed financial and operational records. These constraints may not be possible to impose on a traditional telecom operator, who, in theory, can be sold to investors who have no interest in the requirements of public safety. Many Governments feel they need to retain control over the spectrum to achieve that level of control.

Excessive reliance on commercial services has also security implications (i.e. risk of eavesdropping, impersonation, and lack of resilience in the event of disasters or attacks on base sites, etc.).

8.3.3 Public Safety specific Requirements

The most important factor is to understand and differentiate the needs of public safety networks from public mobile networks [i.21]. The relevant items include:

- Control over security implementation and other operational aspects of the network.
- Redundancy of components on cell sites (e.g. transceivers, site controllers, antennas, etc.), redundancy of UPS power supply capability, including battery and generator powered supplies, and a high degree of network resilience based on overlapping coverage from multiple cell sites in the same area.
- Fallback strategies to allow stand alone operation of sites disconnected from the rest of the network. In addition, most PSS networks have a number of fully transportable base stations that can be set up quickly in required locations to provide communication in case of a BS site loss or for additional coverage.

- To balance the economic impact of meeting the high level of RF Coverage, System Availability/Reliability and GoS, the PSS community requires the provision of Direct Mode Operation (DMO) in all radio terminals. The use of DMO plus the associated repeaters and gateways provides RF coverage in difficult areas, communications in areas where base station RF coverage has been lost and additional capacity at major incidents.
- Use of multiple transmission links to sites using various topologies including redundant stars and rings.
- Operational requirements lead to a different distribution of switching centers together with a redundancy provision in the case of the PSS/PPDR networks compared to public mobile networks.
- Various other special functional requirements, specific to PPDR users. For example use of comprehensive group calls with dynamic group number assignment and use of many simultaneous group calls with each reaching group members in any cell within the network.
- A need for a fast communication set-up in combination with a much higher call set-up success rate, typically 99 % or even higher for PPDR compared to what is offered by public networks.
- A comprehensive suite of security functions and level of encryption algorithms far superior to any offered in public cellular networks including immunity against jamming.
- Use of dispatchers and centralized or distributed network management centers with access rights for network capacity control.

PPDR networks, in contrast to public mobile networks, constitute a private network that should provide command and control of safe data transfer and thus require highly reliable radio communications. It is not sufficient for a PPDR network to describe the call success by Monte Carlo models or other statistical simulations as in public mobile radio systems. Safety-relevant data transmissions require immediate real time access and cannot be transferred some time later as soon as the interference may have disappeared.

In spite of public mobile networks being a unique world-wide success story, it should be stated that public mobile radio networks basically cannot guarantee 99 % call success. The International Standardization bodies are very conscious of this fact and define the system availability within the traffic area by statistical Monte Carlo-simulations based on a call success probability of e.g. 95 %. This definition is sufficient for public mobile radio systems because standardization and operators are not in a position to guarantee a 99 % call success. However, based on permanent user movement and permanently changing traffic situations, the residual 5 % of users are a short time later in a position to launch their calls. In this way operators can basically offer the wanted service to 100 % of the customers.

It is a fact that for PPDR systems, statistical probabilities for call success are totally unsuited since each break by interference constitutes an unacceptable interruption of radio links. It should be stated that the operational conditions of PPDR networks and the efforts of their network planners, are very different from public mobile networks since the reliability of PPDR networks is important for the safety of the PPDR users. Furthermore, the transferred information and the technical investments of Administrations also vary significantly from that of typical public systems.

The security aspects for these PPDR systems are multi-facetted as they form part of the essential communication structures for government agencies:

- The operators security processes and procedures need to be such that they can be approved by the national security audit organization; i.e. all staff needs to be security cleared.
- The operators financial viability needs to be proven regularly potentially leading to governments taking control of the operator.
- All physical locations are typically declared confidential and the base stations not listed in the national database of transmitter sites.

In conclusion, it is not the functions and facilities as such that are the primary challenge for public safety HSD, but the way they are made available from a commercial operator. Commercial operators make their service available driven by their business cases, whereas PPDR organizations have needs for service at places where there typically are no business case to support deployment. One could argue that the PPDR organizations could buy that extra service (coverage, availability, resilience, uptime etc,) from an operator. That however, leads to a problem with choosing the "right" operator and placing a contract without being challenged to spend government funding to distort the normal competitive situation. Even if a way could be found to use a commercial operator - that one operator would be the de-facto sole supplier to PPDR for 10+ years and that situation would have an impact on the operator ability to be remain agile and competitive in its normal market space. Commercial operators who have looked at today's PPDR requirements have been reluctant to commit to the legal conditions imposed by the PPDR organizations.

It is for the above reasons that PPDR networks in Europe rely dominantly on the TETRA technology today, and are operated independently from public mobile networks.

8.3.4 Example of PPDR network Design Goals

The typical design goals for a PPDR network, based on information provided by ASTRID (National PSS network in Belgium) and the National Policing Improvement Agency (NPIA) in the UK, are consolidated as follows.

RF Coverage:

- Population: 99 %
- Land Mass Area: 95 %
- Handportable: Urban Areas
- Mobile: Urban and Rural Areas
- In Building: Specified Establishments
- Underground: Selected tunnels and underground areas
- Cross Border: 25 km minimum beyond national border
- Special: Air-Ground-Air communications

System Availability and Reliability:

- Base Station Sites:
  - Main/Standby Base Stations and Controllers
  - Standby Power Supplies
  - Automatic Trunked Operation if bearer circuit fails
- Bearer Circuits:
  - Route diversity to/from major base station sites and control/switching centres
- Control/Switching Centres:
  - Fully redundant control and switching centre equipment
  - Separate physical locations for main and standby control and switching centre equipment and databases

Grade of Service (GOS):

Besides provisioning base station sites with sufficient channel capacity during the busy hour (Erlang C traffic theory) to support the anticipated traffic and radio users the network also needs to provided a number of Services and Facilities to optimize the GoS, such as the following examples:

- FIFO/Priority Level Call Queuing with Automatic Call Back when System Busy.
- Preferred Site Operation.

- Different User Priority Levels including multi-level precedence and pre-emption. This also includes voice call priorities without using too long waiting queues leading to pre-emption of other existing call requests.
- Dynamic Call Duration Timers.
- Recent User Priority (entries on SIM-cards would need changes via air interface).
- Dynamic Group Call Membership (entries on SIM- cards would need changes via air interface).
- Handover for all situations (not possible for listeners when using a downlink channel only in a public network for attending a group call).
- Dynamic call group sizes.
- Authentication during registration (not during call setup) for listeners-only
- Fast call set up (300 msec).

8.3.5 System Cost

Some of PPDR data applications may not require a high quality of service. In these cases using commercial infrastructure is an option. For those applications, the issues to consider are mainly the costs of using commercial infrastructure for the intermittently heavy data traffic envisaged.

For other, mission- critical applications, the design goals described in clause 6.3.4 apply.

Considering these and related issues is thus the overall cost of a service to achieve a given level of functionality, which is deemed necessary for an individual State's public safety applications, which should be evaluated. Cost should be considered closely for, as previously noted, these are tax payer funded services even if the networks are managed by commercial organizations.

As explained it is not necessarily the case that using a commercial system is the best option if that system cannot provide the complete and integrated solution.

Using a public mobile network for PPDR purposes would require many changes in the public network. So far, such technical changes have only been demonstrated in limited local projects but no country-wide implementation has occurred. This places a public safety organization considering the usage of mobile networks always in a difficult situation since it has to deal with subjects such as:

- What are the real investment costs for additional infrastructure and specific terminal equipment (new terminal equipment to be developed)?
- What will be the additional operating costs over the lifetime of the network?
- Lack of any references or proven network operations in other countries.
- Availability and reliability of the network for PSS use can hardly be determined due to public usage.
- There is likely to be only one provider for the technical solution (no multiple vendorship/operatorship).
- The operator will always put all assumed connections costs for PSS usage in upfront subscription fee per PSS device.
- Specific security for the network and its operations incur additional cost to the operator.

8.4 Views from European PSS User Groups

In December 2008 the new radio communication expert-group RCEG) from the LEWP (Law Enforcement Working Group) of the EU Police Co-operation Council issued an Interim Report [i.28] stating:

- "Lack of a sufficient level of interoperability between different law enforcement authorities.

- Growing operational needs for data exchange between the authorities on the ground and their representatives in control rooms.
- Need for development of a single standard for high-speed data transmission.
- Need for a dedicated, harmonized and interoperable means of radio-communication to answer the mission critical and security requirements.
- A proposal to be prepared for a Council Recommendation to task the European bodies responsible for managing frequencies with allocating additional frequencies to the security and emergency services."

Meanwhile there is an official Council recommendation [i.33] and also the expert group has made progress [i.43]. The Swedish presidency has sent a letter December 2009 to CEPT-ERO with the request to find a harmonized frequency band for mobile data applications [i.41] and a letter to ETSI to ask for a mobile data technology solution [i.42].

PSCE (Public Safety Communications Europe) Forum has been established in recent years with the support of European Commission to facilitate consensus building in the area of PS communication and information management systems. The following statements were made during a presentation by this Forum to the EU Radio Spectrum Policy Group in November 2008 [i.29].

- "Need for a public safety and security sector for national and regional radio-communications interoperability and harmonized spectrum.
- Need for dedicated networks on dedicated spectrum for mission critical operations."

Public networks do not meet PS user requirements such as coverage, availability, security, resilience and interoperability.

Operational needs for broadband applications (including video and web-based) are a reality today (not a future speculation). These needs cannot be met by current PMR technologies, hence, there is a growing need for developing a dedicated broadband inter-operable network for PS and mission critical services.

9 Regulations

ECC Decision (08)05 [i.2] addresses the harmonization of bands within the frequency range 380 MHz to 470 MHz for the implementation of digital Public Protection and Disaster Relief (PPDR) narrow band and wide band radio applications in the mobile service (land mobile service).

Report ITU-R M.2033 [i.5] was developed in preparation for WRC-03 and defines the Public Protection and Disaster Relief (PPDR) objectives and requirements for the implementation of future advanced solutions.

ITU Resolution 646 (WRC-03, Geneva) [i.24] strongly recommends to use regionally harmonized bands for PPDR radio applications to the maximum extent possible.

ITU Resolution 647 (WRC-07, Geneva) [i.25] encourages administrations to consider global and/or regional frequency bands/ranges for emergency and disaster relief when undertaking their national planning and to communicate this information to the Radiocommunication Bureau of the ITU. A database system has been established and is maintained by the Radiocommunication Bureau.

In addition, the ECC Report 102 [i.4] identified Broadband Disaster Relief applications that are non-permanent, local hot-spot type services operating in limited time periods. BBDR applications have been described in TR 102 485 [i.9].

ECC Recommendation on Broadband Disaster Relief (ECC REC (08)04) was also developed in ECC in early 2008 [i.3] to cover local and temporary BBDR applications for so-called PP2 and DR applications as defined in Report ITU-R M.2033 [i.5].

The spectrum usage for these BBDR applications is going to be around 5 GHz [i.7], [i.9]. It is complementary to the proposal covered in the present document.

ECC Report 199 [i.70] identifies the need for a harmonized requirement of 10 + 10 MHz for PPDR Broadband spectrum, with national variations according to national requirements. A following ECC report (currently referred to as 'report B' in CEPT WGFM PT49) will provide a recommended frequency band.

10 Foreseen limits in the Harmonized Standard

The applicable Harmonized Standard for narrowband and wideband equipment is EN 302 561 [i.1]. The applicable harmonized standard for broadband technology is outside the scope of the present document.

Annex A: Detailed market information

A.1 Range of applications

At present, the operational PSS networks are only capable of supporting voice and NB data services. Hence the following important services that are of WB and BB nature cannot be supported by these networks [i.18].

- video conferencing;
- video streaming (CCTV on scene);
- full Satellite Navigation (AVLS works well on narrowband but not as comprehensive);
- passport and bio-metric checks (secure information) undertaken remotely as this requires data rates just above those available on narrowband;
- fire services on-line access to Gazetteer (provides information on what might be kept at premises that could be a problem e.g. propane gas bottles as well as other data that might be required) requires around 100 kbit/s;
- improved on-line access to contacts data base that can be shared to know all those organizations / people that should be contacted depending on, for example, the incident;
- full e-mail;
- intranet browsing;
- improved transfer of files (maps and pictures);
- improved transfer of medical information;
- ability to move the back office into the field; and
- increased over the air key programming downloads of new software updates. Allows the staff to be kept operational which could be a significant cost and operational benefit.

In recent years PSS organizations in the UK, France, Netherlands and others have been conducting trials on PSS high-speed data. There is clearly a need amongst these organizations to have in 2 to 3 years a nationwide network to allow the services listed above and to support mission critical applications such as:

- Sending detailed photographic images of children lost, people wanted to speak to officers in the field so they can act on the requests immediately. Currently with narrowband can only send small pictures and they are often not enough for identification.
- Relaying ad-hoc video camera and surveillance camera real time information to patrol cars responding to incidents so they are fully prepared when they arrive at the scene.
- Sending detailed maps and plans that can be used at an incident, e.g. a fire.
- Sending biometric data such as finger prints from an incident so it can be acted on at that time, rather than having to return to the office.

The ETSI Special Committee EMTEL and project MESA have identified user requirements for future broadband mission critical PP1, PP2 and DR applications [i.37]. The EMTEL document TS 102 181 [i.19] on requirements for communication between authorities and organizations during emergencies lists the following situations for effective communication:

- mobilization of the teams and people;
- updates on the emergency - situational reports;

- updates on requirements to other organizations so they can prepare e.g. informing hospitals on likely number of;
- casualties and individual patients and their needs;
- sending of command and control information to the incident area;
- requesting of information from the incident area e.g. building plans, chemical information; and
- sending of still and video images from the incident area.

The services required to support the above include:

- voice services (one to one and group calling);
- high level security encryption with multiple keys and Over The Air Re-keying (OTAR);
- video teleconferencing to assist in coordination between the services and also to provide information from the incident area back to the control rooms;
- data services (see table A.1 for the attributes of these services); and
- status monitoring and location services, including, for example, measuring exposure to environmental conditions, reporting PSS responders' vital signs and determining their physical proximity, all in real time.

Table A.1: Data services attributes from TS 102 181 [i.19]

Service	Throughput	Timeliness	Robustness
E-mail	Medium	Low	Low
Imaging	High	Low	Variable
Digital mapping / Geographical information services	High	Variable	Variable
Location services	Low	High	High
Video (real time)	High	High	Low
Video (slow scan)	Medium	Low	Low
Data base access (remote)	Variable	Variable	High
Data base replication	High	Low	High
Personnel monitoring	Low	High	High

The Law Enforcement Working Party (LEWP) of the EU has compiled a matrix of applications which will be needed in a PPDR environment, and has categorized the service characteritics of these. The applications are listed in table A.2.

Table A.2: Data applicationsDataapplications required by the LEWP

Type of application + services	
LOCATION DATA	**UPLOAD OPERATIONAL INFORMATION**
A(V)LS data to CCC	Incident information upload
A(V)LS data return	Status information + location
MULTI MEDIA	ANPR or speed control automatic upload
Video to/from CCC: following + intervention	Forward scanned documents
Low quality additional feeds	Reporting incl. pictures etc
Video for fixed observation	Upload maps + schemes
Low quality additional feeds	Patient monitoring (ECC) snapshot
Video on location to/from CCC - high quality	Patient monitoring (ECC) real time
Video on location to/from CCC - low quality	Monitoring status of security worker
Video on location for local use	**ONLINE DATA BASE ENQUIRY**
Video conferencing operations	Operational data base search
Non real time recorded video transmission	Remote medical database services
Photo broadcast	ANPR checking number plate live
Photo to selected group	Biometric (eg fingerprint) check
OFFICE APPLICATIONS	Cargo data
PDA PIMsync	Crash Recovery information request
Mobile workspace	Crash Recovery System update
DOWNLOAD OPERATIONAL INFORMATION	**MISCELLANEOUS**
Incident information download	Software update online
ANPR update hit list	GIS maps updates
Download maps	Authomatic telemetrics
Command & control information	Hotspot on disaster or event area
	Front office - back office applicaties
	Alarming / paging
	Traffic management system
	Connectivity of foreign force to local ccc

This set of applications is further used in the analysis of spectrum required in Annex F of the present document.

A.2 Expected market size and value

The most appropriate methodology to determine market size and value is to use indicators based on factual information and data provided under the following sections:

1) Existing and planned deployment of Narrowband PSS networks in Europe

2) Planned Deployment of Wideband PSS networks in Europe

3) Number of Independent Manufacturers of Infrastructure and Terminals

4) Application Providers

5) Number of PSS Contracts for Narrowband and Wideband PSS Products let in Europe

6) Expected use of the range of applications described in clause A.1

7) Attractiveness of the PSS Market

8) Export Potential outside Europe

1) Existing and planned deployment of Narrowband PSS networks in Europe

The vast majority of countries in Europe, have already deployed, or in the stages of deploying, narrowband TETRA or Tetrapol networks, with most of these completed and in operation. Figure A.1 shows the list and locations of natiowide projects, both fully deployed and those in rollout phases.

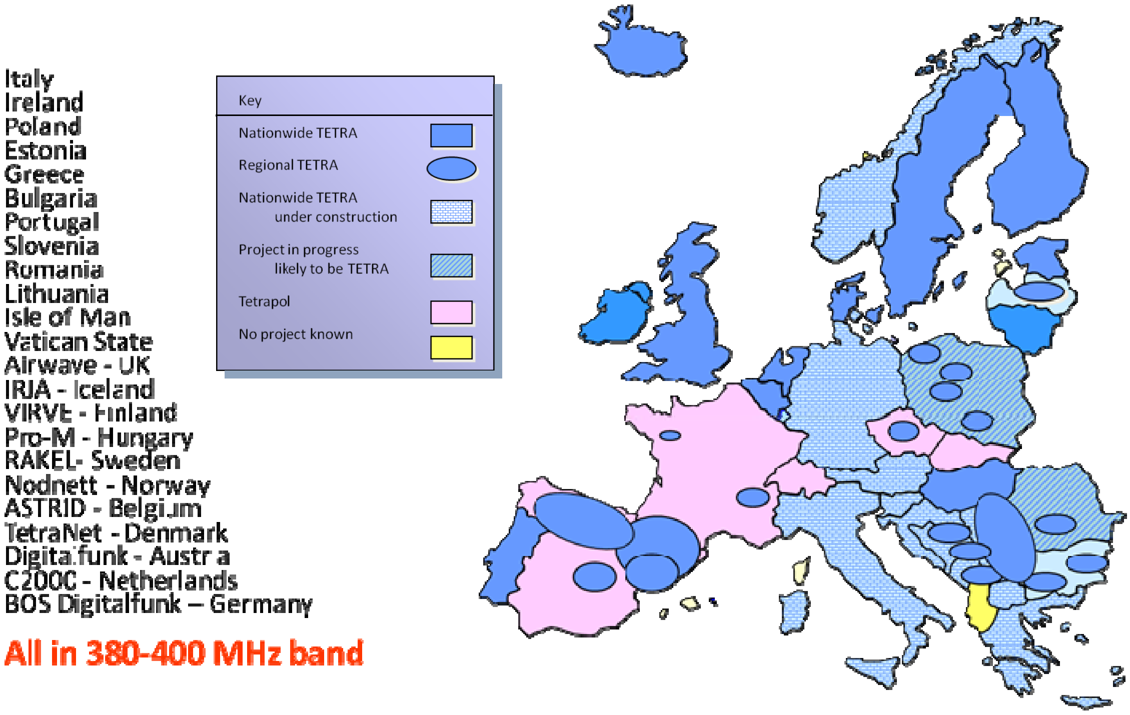


Figure A.1: PPDR TETRA and Tetrapol deployments in Europe

2) Planned Deployment of Wideband PSS networks in Europe

Because of limited spectrum availability and/or upgrade difficulties with existing networks, TEDS wideband data is planned in fewer countries.

3) Number of Independent Manufacturers of Infrastructure and Terminals

A positive indicator to the size and attractiveness of the PSS TETRA market is the number of independent TETRA manufacturers of narrowband infrastructure and terminals, of which some are listed in table A.3.

Table A.3: Manufacturers of Infrastructure and Terminals

Manufacturer	Infrastructure	Terminals
Artevea	√	
Cassidian	√	√
Cleartone		√
Damm	√	
Eastcomm	√	
ETELM	√	
Frequentis	√	
Hytera	√	√
Motorola	√	√
Piciorgros		√
Rohill	√	
Selex	√	√
Sepura	√	√
Teltronic	√	√
Thales	√	√
Unimo Technology		√
Team Simoco	√	

In total there are at least 17 manufacturers of infrastructure and/or terminals, which have led to a thriving competitive market. As the assumed broadband technology solution is 3GPP LTE, it is likely that the manufacturing and supplier base addressing the market will change. Even so, the market size for broadband solutions will be significantly large enough to attract several independent manufacturers thus maintaining the important PSS user benefits of competition and second source security.

4) Application Providers

The architecture of a TETRA network, combined with its core narrowband voice and data services, has attracted a large number of independent Application Providers, Peripheral and Component manufacturers who provide additional voice and data applications. A list of Application Providers , Peripheral and Component manufacturers that are currently listed as members of the TETRA and Critical Communications Association in 2013, are provided below.

- American International Radio Inc.
- Antennentechnik Bad.
- APD communications Ltd.
- Asia Pacific Satellite-Communications Inc.
- Etherstack Ltd.
- Eurofunk Kappacher GmbH.
- GenCore Candeo Ltd.
- Insta Defsec Oy.
- Mentura Group Oy.
- Portalify Ltd.
- Prescom.
- Rheinmetall Defence Electronics GmbH.
- Roscom Ltd.
- SAIT Zenitel Netherlands B.V.
- Swissphone Telecom AG.
- Syntech Systems.
- Team Simoco Ltd.
- Testing Technologies.
- TetraNed vof.
- Zencus International Ltd.
- Zetron Inc.

In total there are 21 independent providers listed (and there will others who are not TCCA members). As the assumed broadband technology solution is3GPP LTE, it is likely that the Application Provider base addressing the market will change, and larger number of providers will emerge because of synergies with mainstream cellular usage (see also clause B.4.3 on this aspect). Therefore, the market size for broadband applications will be significantly large and will attract many independent Application Providers thus maintaining the important PSS user benefits of competition and second source security.

5) Number of PSS TETRA Contracts for Narrowband and Wideband PSS Products

In 2013, the TETRA and Critical Communications Association show that there are more than 250 TETRA systems in use worldwide by Governments for public safety, military and defence, and other public services.

NOTE 1: Because the TETRA market is highly competitive, suppliers of infrastructure and terminals do not disclose the actual value of contracts won and as a consequence it is difficult to put an exact value on the market in monetary terms.

6) Expected use of the range of applications described in clause A.1

From a previous survey conducted by Motorola and APCO (The Association of Public-Safety Communications Officials) of more than 200 public safety administrators and officers in the top 100 U.S. markets made several significant findings about current and future use of communications technology. According to the survey results:

- 72 % report using systems that enable cross-departmental communications;
- 72 % report using computer mapping technology to enhance response time;
- 68 % report using personal digital assistants to perform "back office" work in the field;
- 44 % report using traffic light sensors for approaching emergency vehicles; and
- 42 % report using mobile video systems and video surveillance devices in public places.

On the "wish lists" for future applications:

- 47 % of PSS officials believe tracking solutions such as satellite tracking of vehicles are necessary;
- 37 % of PSS officials want "recognition/identification" technologies including facial recognition;
- 41 % of PSS officials want automatic license plate recognition;
- 26 % of PSS officials want rugged notebooks;
- 30 % of PSS officials mobile video systems;
- 31 % of PSS officials want traffic light sensors;
- 35 % of fire departments would like more mapping technologies;
- 63 % of police officials want mobile video systems; and
- 51 % of police officials and 20 % of fire departments want improvements in interoperability of communications.

Taking all these requirements into consideration it can be reasonably assumed that around 50 % of all PSS mobile terminal users will require a broadband capable terminal.

NOTE 2: Although this survey was carried out in the USA, these requirements are considered sufficiently representative of the PSS user requirements in Europe.

7) Attractiveness of the PSS Market

Another positive indicator of the size and value of the PSS market in Europe is the widespread use of commercial 2G and 3G networks by PPDR users within most countries Europe for non mission critical applications.

8) Export Potential outside Europe

In 2011, the year in which the latest system data is available, 33 % of all TETRA systems were used by Public Safety users, with another 10 % by government and military users. Also in 2011, 50 % of TETRA system sales took place outside Europe. In 2012, the total terminal sales were known to have exceeded 3 million units by a considerable margin, and terminal volumes were seen to be increasing year on year. This success is considered to be due to a common standard, the use of harmonized spectrum in the public safety market in Europe, and the use of compatible spectrum allocations between Europe and other regions. This indicates that any broadband solution standardized that is compatible with TETRA will have considerable market opportunity outside Europe, in particular if the spectrum allocations are compatible.

Summary

From the above data it is reasonable to assume that the expected value of the PSS market in Europe for broadband infrastructure, terminals and applications is very large, albeit not as large as the commercial operator market using GSM, GPRS, EDGE, UMTS/3G technologies. However, this market will be significantly reduced and fragmented if the harmonized spectrum as requested in this SRDoc is not made available for the PSS community.

A.3 Deployment

The deployment of PSS broadband networks is expected to follow the same deployment as experienced by the uptake of narrowband TETRA and Tetrapol in Europe as shown in figure A.1. The timescale for deployment of first generation broadband technology solutions is dependent on two main factors these being spectrum availability and the broadband technology choice made by the PSS user community.

The assumed technology choice is 3GPP LTE, and ETSI TC-TCCE are working on application level standards to ensure that the required services can be provided. Once spectrum is made available and the standards have been completed, first generation broadband networks and terminals should be available between 18 and 24 months later for early adopters. Thus if spectrum is available within 2-3 years following a WRC 2015 decision, i.e. 2017-2018 broadband networks for PPDR use could become available before 2020.

A.4 High Speed Data requirements

A TETRA Future Vision Workshop staged on 25th February 2009 in Brussels had the objective of understanding future high speed data requirements.

The workshop objectives were outlined as follows:

- To demonstrate that the Manufacturing Industry is united in its vision to evolve TETRA towards a fully integrated and seamless ICT solution providing NB/WB/BB wireless communications.
- To reassure members of the TETRA Association and the industry in general about the planned evolution of TETRA towards BB.
- To agree a list of applications and their data rate/bandwidth/QoS requirements so that they can be used within TC TETRA to help select the optimum technology solution to support BB data.
- To confirm user requirements for BB data so that they can also be used within TC TETRA to help select the optimum technology solution to support BB data.
- To identify other areas that need to be considered in the selection and standardization of a BB solution.

The fundamental high speed data requirements of the workshop were summarized as follows:

- Same RF coverage as voice (no need for additional base station sites).
- Instant access at all times (Perfect Grade of Service).
- Never goes wrong (100 % Reliability).
- Able to support all non-voice applications (real time and other).
- Air-Ground-Air (500 kph).
- Local Communications Independent of Network Infrastructure.

Even though these requirements can be provided trade-offs in the interest of economics could be made, such as:

- Use of ad-hoc HSD "Hot Spot" networks.
- RF coverage only in high density urban areas.

- Rapidly deployable HSD base stations.
- Commercial/Public Networks in rural areas (loss of "mission critical" communications accepted in major incidents).

A.5 Results from recent National studies

The German Ministry of the Interior commissioned a study that was presented during the ECC WGFM PPDR workshop on 11th to 12th March 2010. The conclusions of the study can be summarized as follows:

- Exclusive frequency usage by PPDR is seen as the preferred solution in the future.
- There is a need to study the symmetry (or asymmetry) of the demand. The results in Germany showed an asymmetric distribution (40 MHz in the uplink and 20 MHz in the downlink). These numbers are for the year 2025.
- Within the first 30 minutes of a disaster, mission critical communication means are needed to be available. A minimum communications capacity needs to be available on a permanent basis; Dutch studies also showed that public networks cannot provide this needed "immediate" capacity. A full short-term, temporary assignment of capacity is not considered to be realistic.
- More than 60 % of the mission scenarios (use cases) are considered as "mission critical" and more than 90 % of all scenarios require high usage requirements (extreme high availability and low latency).
- It is expected that more than 65 % of the future scenarios need a bandwidth of greater than 1 Mbps, more than 40 % even more than 10 Mbps in the future.
- More than 60 % of all scenarios require a coverage of larger than 10 km operating distance.
- The greatest bandwidth demand has been calculated in the categories "demonstration, special event, and natural disaster". These are temporary and mostly local events such as described under the BBDR regulations. For this case however, the probability of occurrence of the maximum bandwidth requirement is very low.
- Mission-tactical prioritization of the bandwidth usage leads to better usage efficiency.
- The calculations included a reduction factor of 2,5 in the German studies in order to take into account technological advances.
- The recommendations include expansion of the BBDR regulation to an additional 50 MHz on top of the existing 50 MHz in 5 150 MHz to 5 250 MHz.

An interpolation of the Dutch demand presented during the workshop for the year 2025 shows an even greater demand compared with the German study.

In the US, 80 MHz in the 700 MHz frequency range ("D-block") are under discussion, although the PPDR user density in some regard is lower than in European metropolitan areas.

Annex B: Technical information

B.1 Detailed technical description

At present the only European standard capable of HSD operation is TETRA 2 [i.10]. This standard includes:

- 25 kHz channels using π/4-DQPSK modulation for NB Voice plus Data (V+D) services.
- 25 kHz, 50 kHz, 100 kHz and 150 kHz channels using various QAM and phase modulation schemes to provide IP based WB (HSD) data services. The HSD capability has been provided by an in-house development of the TEDS technology.

Table B.1 gives an estimate of the maximum Internet Protocol (IP) packet data throughput for the various RF bandwidths and modulation types, where it is assumed that there are no message errors.

Table B.1: Estimated IP throughputs (kbit/s) on TETRA packet data channels

Modulation type and coding rate	RF channel bandwidth (kHz)							
	25		50		100		150	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
π/4-DQPSK, r = ⅔	15	15						
π/8-D8PSK, r = ⅔	24	24						
4-QAM, r = ½	10	10	24	26	49	55	77	86
16-QAM, r = ½	19	20	47	51	98	110	153	173
64-QAM, r = ½	29	30	71	77	146	164	230	259
64-QAM, r = ⅔	39	40	94	103	195	219	306	345
64-QAM, r = 1	58	60	141	154	293	329	459	518
NOTE: The estimated rates are given in kbit/s assuming that transmission occurs in all four TDMA slots in 17 out of 18 frames and assuming that there are no message errors.								

Note that the gross bit rates of TETRA channels are higher than the figures given in table B.1.

For details of TEDS technology refer to the TEDS Designer's Guide [i.11]. The details of the current TETRA standard which incorporates TEDS are given in EN 300 392-2 [i.10].

B.2 TETRA Evolution

B.2.1 General

As described above TETRA today supports two types of modulation, namely Phase Shift Keying (PSK) for narrowband 25 kHz channels and Multi Carrier (MC) Quadrature Amplitude Modulation (QAM) for wideband channels, scalable bandwidth between 25 kHz and 150 kHz. The PSK modulation forms the basis of the TETRA voice, data, and control services, while QAM modulation extends the bit rates for packet data services.

Both the PSK and QAM modulations use a root raised cosine pulse shaping function to provide a sharp roll off of the spectrum in the neighbouring channels while maintaining immunity to delay spread caused by multipath propagation. This adds some complexity to the implementation but is done in order to enable coexistence between TETRA and other narrow- or wide-band technologies existing in the same frequency band.

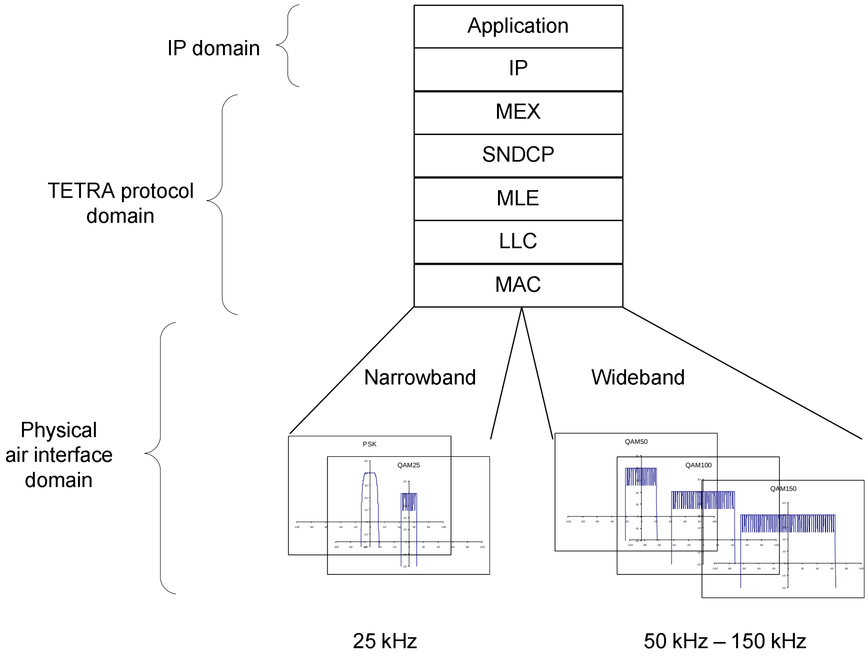


Figure B.1: Current TETRA access methods

The TETRA air interface thus allows for a wide variety of access methods, covering narrowband and wideband operation (figure B.1), all deployable in the spectrum currently designated for public safety. The TETRA standard has been designed to allow seamless selection of the best-suited technology when service is requested. That is, the different access methods appear transparent to the end user.

The TETRA air interface is, however, constantly evolving. The development of the TETRA standard in the near future will focus on:

- Optimization of the existing narrowband air interface (voice and data), adding new services when market need arises, and improving performance and capacity of the air interface.
- Optimization and extended scalability of the relatively new wideband air interface. The standard will be adapted and expanded as development and deployment of the wideband air interface progresses.
- Addition of a broadband air interface, which can be integrated with existing narrow and wideband services, maintaining end user transparency.

The integration between broadband and TETRA will be studied in ETSI TC TCCE, but may include migrating the TETRA air interface to an IP based protocol. This will allow the added broadcast interface to support new multimedia / IP based services, while maintaining the capability of using TETRA services. Moreover, this will enable TETRA voice calls to span multiple air interface technologies. This means that the broadband air interface should maintain the same high level of security as the current TETRA air interface.

B.2.2 Wideband Evolution

The QAM air interface can be optimized in several ways. The following enhancements have already been identified as candidates for addition to the QAM air interface part of TETRA:

- Adding control channel capability to the QAM air interface, allowing more flexible deployment of wideband services.
- Further optimization of the channel coding and interleaving.
- MIMO and MISO.
- Frequency hopping.

- Further optimization of the TETRA protocol (overhead, header compression, etc.).
- TETRA voice services on wideband carriers - including spectrum efficient point to multipoint calls.
- Efficient voice over IP on wideband carriers (TETRA over IP, SIP/IMS, etc.).

In addition to this, the TETRA air interface utilizing the QAM modulation can be further scaled within the wideband regime if needed.

B.2.3 Broadband Evolution

The optimal outcome is a harmonized frequency band coupled with certainty about availability (time) and an indication of where (space) in the frequency band plans it will be allocated. Until those factors are going to be determined it will be unlikely that the technology choice for PSS Broadband communications will be made.

However, the majority of user requirements listed in the TETRA Release 2 HSD URS TR 102 021-2 [i.20] are still considered relevant for broadband evolution purposes and as such these user requirements will be updated as required by analysing the results of the Future TETRA Workshop held at the World Congress in Madrid in 2007 (TWC2007 Future TETRA Workshop Report TR 102 621 [i.17]), which clearly indicates that HSD capabilities similar to those offered by wideband and broadband commercial GPRS and 3G/UMTS operators and WiFi and WiMax access services are required by the PSS community. Further broadband user requirements are given in [i.18].

The technology choice for PSS broadband evolution will be based on evaluating a number of candidate technologies that best meet the user requirements balanced against any technology constraints that will be identified during the evaluation and selection process. To date, there are a number of possible wireless technologies offering broadband HSD rates, some of which are listed below:

- TEDS enhancement (broadband);
- 3GPP/HSPA/LTE;
- 3GPP2/ EV-DO (Rev 0, A, B, C (UMB));
- WiMax (IEEE 802.16e [i.53]);
- IEEE 802.16m [i.54] (enhancement to 802.16e currently in process).

As well as PSS user requirements, the evaluation of candidate technologies will also consider performance requirements such as:

- Performance at different propagation conditions and speeds.
- Spectrum efficiency.
- RF range performance.
- Encryption capability.
- Interference susceptibility.

B.3 Technical justification for spectrum

B.3.1 Current wideband justification

The technical justification for the only European wideband PMR technology is given in the TEDS SRDoc [i.12], which was used by the ECC for compatibility studies between TEDS and other technologies in the 400 MHz region of the spectrum [i.13]. Since those studies, there have been some minor updates in the wideband noise specifications of the TEDS standard which are unlikely to affect the results of those studies. The updated specifications are included in clause 6 of the TETRA 2 standard [i.10] in case new spectrum engineering work will be carried out in any new PPDR spectrum designation.

B.3.2 Proposed Broadband Spectrum Mask

As the technology selection for broadband evolution has yet to be made, the "notional" transmitter spectrum mask shown in figure B.2 is proposed here for Spectrum Engineering purposes where the scenario requires coexistence with other broadband technologies. The actual permitted spectrum mask will be dependent on the nature of the technology in use in adjacent spectrum, and a different mask is likely to be required where narrowband or wideband technologies are present in that adjacent spectrum.

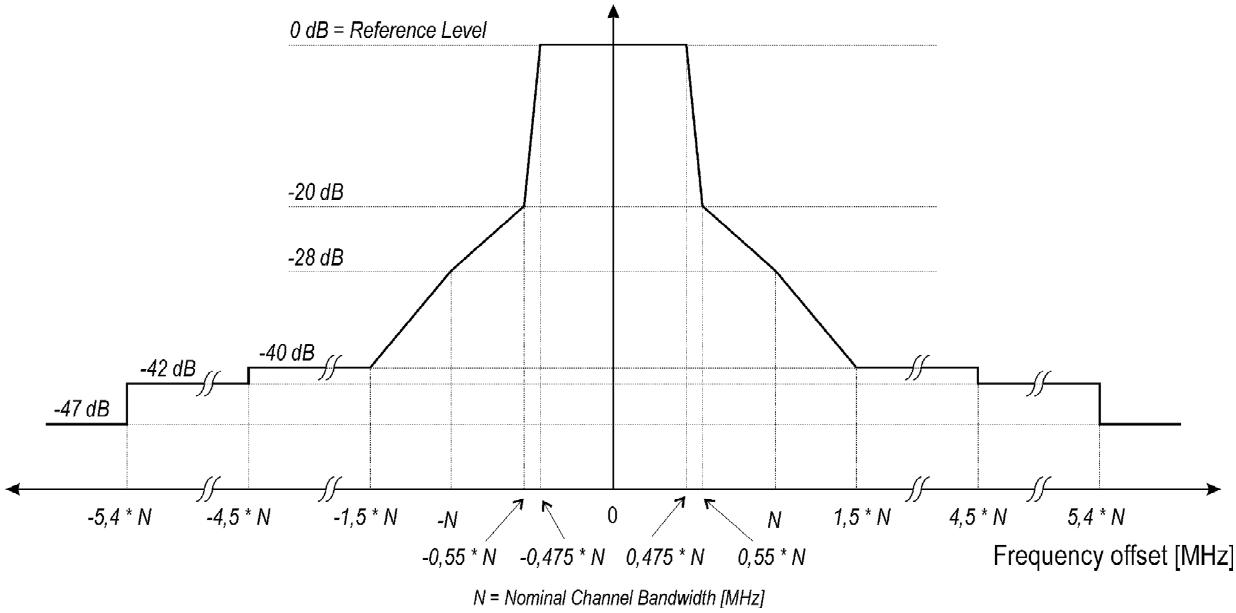


Figure B.2: Proposed spectrum mask for broadband service

This choice has been based on a number of preliminary considerations given below:

- Most BB technologies listed above, i.e. HSPA / LTE (3GPP), EV-DO Rev 0, A, B, C (UMB) (3GPP2), WiMAX and the IEEE 802.16m [i.54] are converging to OFDM carrier structure.
- TEDS carriers have multi sub-carrier structure and its evolution to wider carriers with more sub-carriers brings it more in line with the OFDM structure.
- The above mask is based on the IEEE 802.11 [i.55] standard with minor modifications to tighten the interference well away from the carrier.
- This modified mask is also proposed in the current ETSI draft Harmonized EN (HEN 302 625) for localized BB-DR service at 5 GHz [i.22].
- The mask is independent of carrier bandwidth, allowing e.g. to use more than one carrier bandwidth in the selected technology.

The Broadband Spectrum Mask is intended to accommodate known BB technologies.

B.3.3 Determination of the frequency demand, frequency reuse and fading

- The following illustrates the methodology and parameters to be taken into account for the determination of the spectrum demand.
- It is assumed that the PPDR is a cellular planar network requiring gapless coverage.

This can be seen in the equations (1) to (2):

$$\boxed{\text{ClusterSize} = \text{FrequencyReuse Factor}} \qquad (1)$$

Hence for a planar network (2):

$$\text{Required nb of channels per BS} = \frac{\text{Total nb of channels of the radio network}}{\text{ClusterSize}} \qquad (2)$$

Assuming a frequency reuse factor of X, the cluster size becomes Y.

Margins are needed for high density usage scenarios, highly mobile usage (more handovers) and cross-border coordination.

The frequency reuse factor depends mainly on the percentage of receiving locations. This itself requires a specified coverage probability. This means that in each location interval with a specified diameter the measured coverage level has to be verified with a probability value of at least a determined percentage. For an example PPDR radio network planning a value of 97 % may be used.

For the evaluation of the values the Recommendation ITU-R P.370-7 [i.39] is used, as shown in figure B.3.

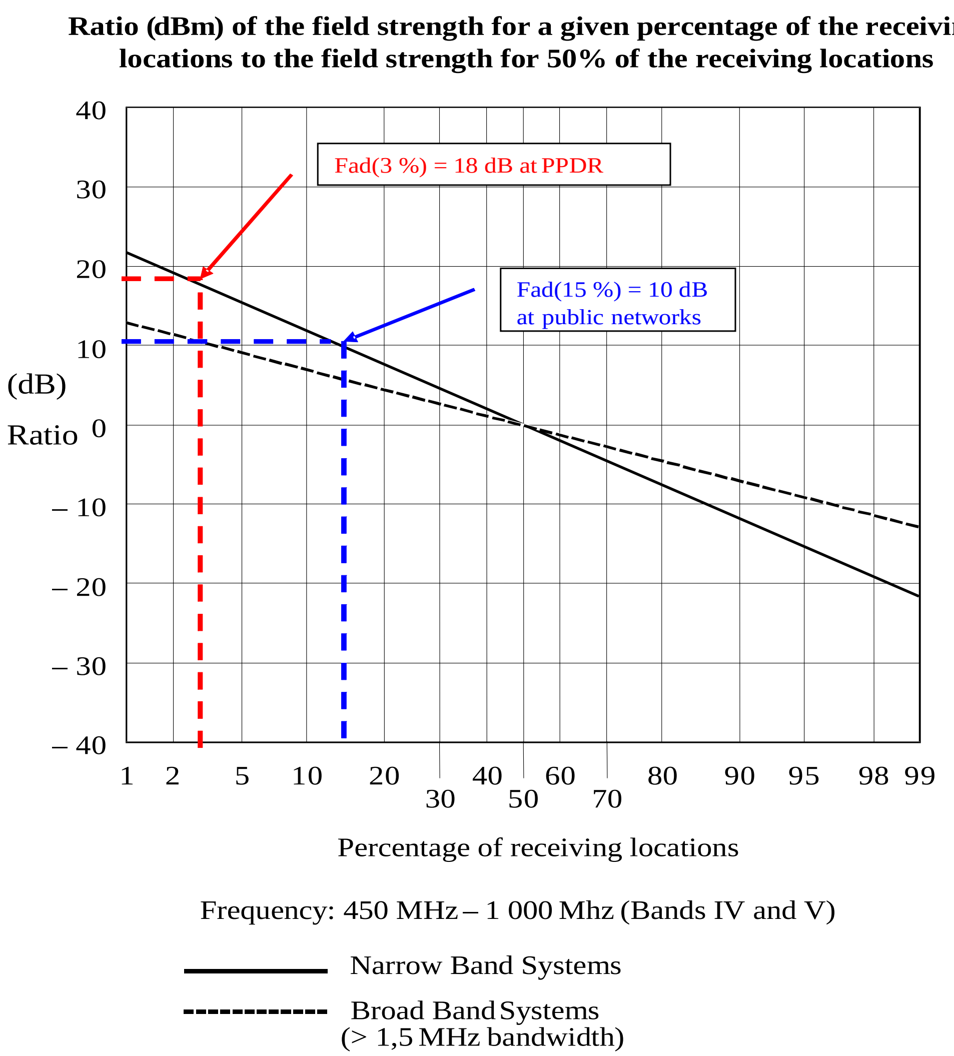


Figure B.3: Ratio (dB) of the field strength for a given percentage of the receiving locations to the field strength for 50 % of the receiving locations

A value of 97 % of probability is equal to a value of 3 % fading. The consequence of this is that an additional average margin of 18 dB is necessary. Taking into consideration this margin, the following equations are assumed:

Relation of fading, frequency reuse factor and data loss:

$$\boxed{F = c - \gamma \cdot \log(d)} \qquad (3)$$

Calculation of the received signal strength depending on the distance and according to the attenuation per decade of the ITU diagram:

$$\boxed{F_{car} - F_{Int} = c/i_{PPDR\text{-}System} + \sum Fad_{(x\%)} = \gamma \cdot \log\left(\frac{d_{Int}}{d_{car}}\right) = \gamma \cdot \log(\text{Frequency reuse factor})} \qquad (4)$$

and the frequency reuse factor is given by:

$$\boxed{\text{Frequency reuse factor} = 10^{\frac{c/i_{PPDR\text{-}System} + \sum Fad_{(x\%)}}{\gamma}}} \qquad (5)$$

$$\boxed{\sum Fad_{(x\%)} = Fad_{(x\%)car} \text{ und } Fad_{(x\%)Int} = Fad_{(x\%)user/interferer} \cdot \sqrt{2}} \qquad (6)$$

Key to symbols used in the equations:

- F = field strength.
- F_{car} = field strength of wanted carrier.
- F_{Int} = field strength of interfering signal.
- c = constant, includes data of the BS such as transmit power and antenna characteristics.

γ = propagation coefficient (ref ITU curves for UHF, approximately 50 dB/decade of distance; up to values of 35 dB/decade of distance; the calculations below use 50 dB/decade).

d = distance.

$Fad_{(x\%)}$ = Fading (in dB); there is a relation to the probability of location and hence the data losses, expressed as a percentage.

ΣFad = Fading; single fading events of the wanted and unwanted signals.

$c/i_{PPDR\text{-}System}$ = protection criteria of NB/WB/BB = 9 dB (see example).

NOTE: The TETRA NB/WB protection criterion is normally much higher and equals 19 dB (on average).

For PPDR applications a specified coverage probability 98 %, which is equal to 5 % of fading.

According to the formulas above, a frequency reuse factor can be calculated:

EXAMPLE Case 1: C/I=9 dB; Fading 2 %, which is equal to 19 dB, γ=50 dB, the frequency reuse factor is calculated 5,24.

B.3.3.1 Determination in the case of TETRA TEDS

NOTE: This clause does not use all the assumptions as outlined in the more generic clause B.3.3.

Based on the generic case in clause B.3.3, this clause discusses the methodology to be used for TETRA TEDS reuse evaluation. The methodologies presented here use SEAMCAT and MCL to calculate probability of co-channel interference. A few results of TETRA reuse is given here for illustration and validation of the methodologies.

Figure B.4 illustrates a basic reuse pattern using 7 frequency pairs. Each of the cells in the centre (with hexagons) uses a different frequency. The same frequency is then reused in the neighbour "clusters", so that all cells marked with the same number use the same frequency.

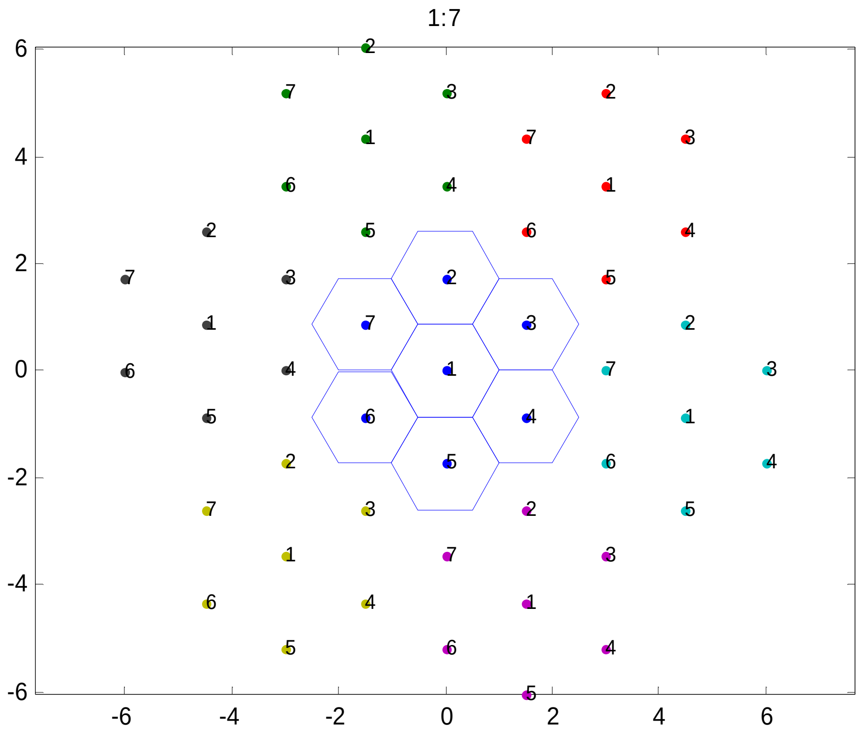


Figure B.4: Cluster

B.3.3.1.1 Methodology - SEAMCAT

The methodology presented here is that only the closest cells on the same frequency are considered for the reuse evaluation. That is, only cells marked with "1" in the above example. Therefore, any effects due to immediate neighbouring cells operation at different frequencies are ignored. This basically means that all TETRA / TEDS transmitter and receiver parameters relating to "off channel" behaviour can be ignored. Only transmit power, sensitivity, antenna configuration and C / I protection requirements are needed.

For the initial TETRA simulation, the following parameters are used as depicted in figure B.5.

```
BS antenna height: 30 m
BS transmit power: 44 dBm
BS antenna gain:   11 dB, Omni (perhaps a little high)
BS sensitivity:    -109 dBm
BS diversity gain: 4.77 dB (3x diversity, conservative)
MS antenna height: 1.5 m
MS transmit power: 30 dBm
MS antenna gain:   0 dB, Omni
MS sensitivity:    -103 dBm
Propagation:       suburban
Fade margin:       11.53 dB (90% contour)
C/I protection:      19 dB
Frequency:         400 MHz
```

Figure B.5: Cluster

Note that the BS sensitivity has been set slightly better than required in the standard, whereas MS sensitivity is set to the standard value. This is done as the planner typically would know the exact sensitivity of the deployed bases stations, whereas a "worst case" would have to be assumed for the MS population (at least in some systems).

Before simulation can begin in SEAMCAT with these parameters, the cell coverage radius and location of the neighbouring cells at the same frequency need to be established. With the above parameters, the system is uplink limited with a link gain of 155 dB. Using a contour reliability of 90 %, this gives a range of 9,2 km (suburban) (see note). The neighbour cells will then be placed according to selected reuse factor.

NOTE: The range will impact the results somewhat due to the additional loss in the Hata model [i.59] for distances above 20 km. At 80 km this additional loss is approximately 6 dB. That is, the result will improve as cell range increases, which again means that urban is the worst case environment.

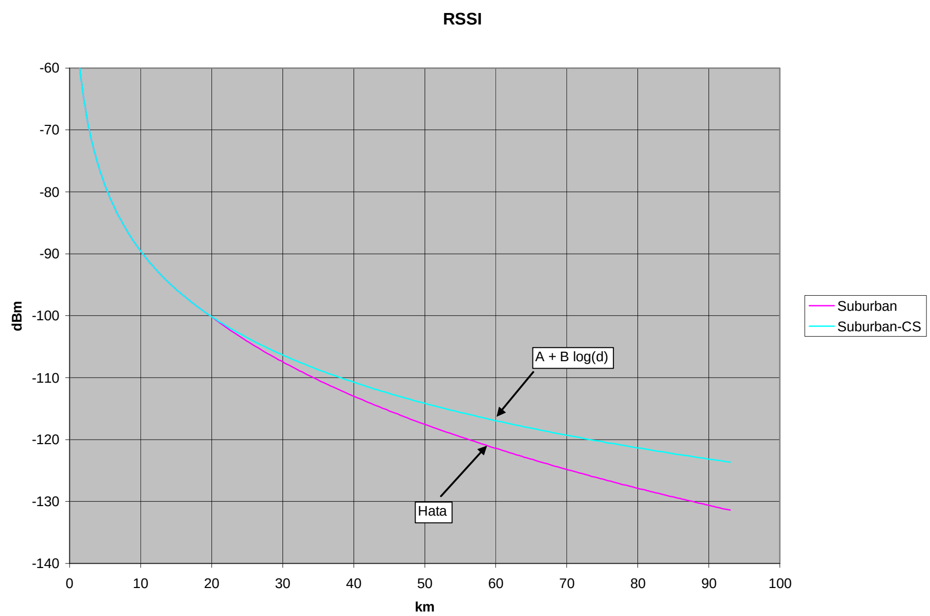


Figure B.5a

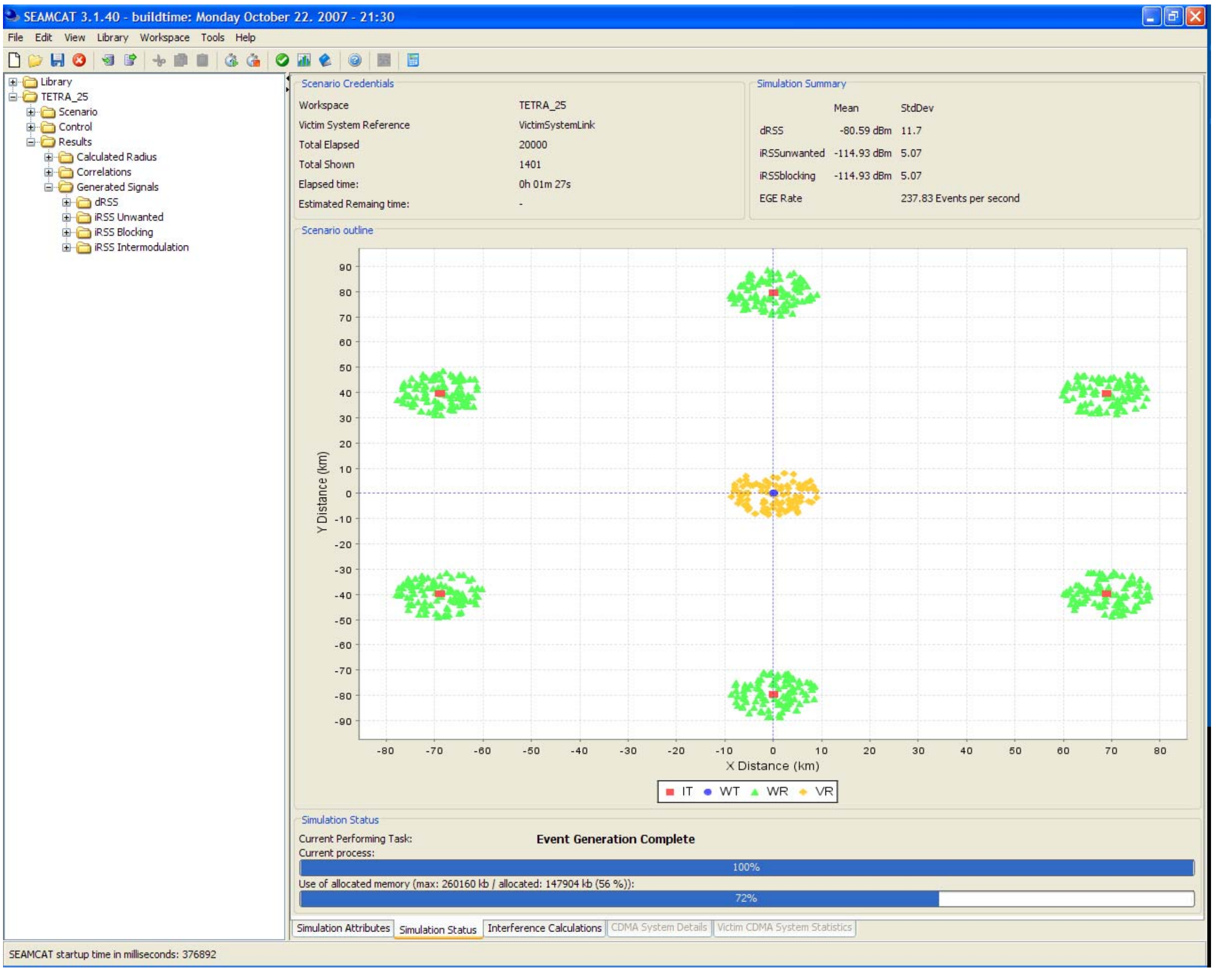
With this, all required parameters for SEAMCAT simulation has been established, and the scenario can be entered.

Results

For a reuse of 25, the co-channel BSs will be located at:

```
BS 1: x =   0.000 km y =  79.568 km
BS 2: x =  68.908 km y =  39.784 km
BS 3: x =  68.908 km y = -39.784 km
BS 4: x =   0.000 km y = -79.568 km
BS 5: x = -68.908 km y = -39.784 km
BS 6: x = -68.908 km y =  39.784 km
```

The example simulation is illustrated in figure B.6.



The probability of interference in this scenario is ~9 %.

Figure B.6: Simulation results

Two other scenarios have also been tested in SEAMCAT: reuse 12 and reuse 36. Results are shown in figure B.7:

Reuse	% interference
12	29
25	9
36	3,4

Figure B.7: Results

Note that these probabilities apply to the downlink direction only. However, unless the activity factor for the MS is somewhat below 100 %, this is not expected to be that different on the uplink (need validation).

Methodology Evaluation

SEAMCAT has been developed primarily to simulate inter-system interference scenarios. In such scenarios, the parameters for the simulation should be chosen conservatively so that if SEAMCAT results indicate that no interference problems exist, then really no interference problems exist.

However, SEAMCAT can also simulate intra-system interference scenarios (which is pointed out in the SEAMCAT help text). A major difference is here that the parameters now should be selected as "most likely" rather than "conservative". However, SEAMCAT does not allow the amount and nature of shadow fading to be controlled. One could therefore expect SEAMCAT results to be on the pessimistic side.

Another observation is the apparently self contradicting scenarios that are simulated in SEAMCAT: each "event" represents a draw from the possible MS positions in the simulated system. Each "event" is then taken as a static scenario - i.e. the MS does not move - however, at the same time C/I results for an MS moving at 50 km/h is used.

For voice calls, this is an acceptable "mix". However, for non-real time data transfers, packets are not lost but instead retransmitted later. If the correlation distance is 20 m and the MS speed is 50 km/h, the correlation time is ~1 sec. Using retransmissions to address "shadow fades" of this duration does not seem unreasonable. If on the other hand the MS is not moving, then interference really means loss of service. However, in this case it does not seem right to use the dynamic C/I protection level - static C/I protection level should be used instead (taking extra variation due to multipath into consideration). That is, either a higher interference probability (which is usually unacceptable for voice) should be used, or a lower value of the C/I protection should be used.

B.3.3.1.2 Methodology - Alternative MCL

The "MCL" approach to reuse calculation can be found in ERC Report 52 (from 1997) [i.68]. The method was later refined in ECC Report 42 (from 2004) [i.69]. Equation (9) in ERC Report 52 [i.68], refined to equation (4.3-1) in ECC Report 42 [i.69] gives the following formula for the reuse of any technology:

$$NR = 1 / 3 \, [M \, K \, A \, (C/I)_T]^{2/\alpha} \qquad (7)$$

Where M is the slow fading margin (not present in ERC Report 52 [i.68] - 8 dB in ECC Report 42 [i.69]), K is the "geometry" factor (set to 6 in ERC Report 52 [i.68] - 7 in ECC Report 42 [i.69]), A is the system load or activity (set to 0,5 in ERC Report 52 [i.68] - 1,0 in ECC Report 42 [i.69]), α is the exponent from Hata and $(C/I)_T$ is the required dynamic co-channel interference ratio.

Results

Using formula (7), the following calculations can be made for TETRA.

C/I	M	K	A	alfa	NR	
19	0	6	0,5	3,5	7,61	ERC 52
19	8	7	1	3,5	35,37	ECC 42

The ECC Report 42 [i.69] results can be said to somewhat match the SEAMCAT results above, whereas ERC Report 52 [i.68] is in disagreement.

The results for TEDS using this methodology are:

C/I	M	K	A	alfa	NR	
14	8	7	1	3,5	18,32	4-QAM
19	8	7	1	3,5	35,37	16-QAM
23	8	7	1	3,5	59,87	64-QAM 1/2
27	8	7	1	3,5	101,34	64-QAM 2/3

Assuming these numbers are correct, this means that the efficiency of TEDS compared to TETRA is:

- 4-QAM: approximately same bit rate per Hz, half the number of frequencies used, i.e. ~2 ×

- 16-QAM: approximately twice bit rate per Hz, same number of frequencies used, i.e. also ~2 ×
- 64-QAM 1/2: approximately three times bit rate per Hz, twice the number of frequencies, i.e. ~1,5 ×
- 64-QAM 2/3: approximately four times bit rate per Hz, three times the number of frequencies, i.e. ~1,3 ×

However, if take adaptive modulation into account, one could say that we a) can use half the frequencies while b) still have four times bit rate in a large percentage of the cell area - approaching 8x efficiency, but in practice a bit lower.

Methodology Evaluation

The MCL method is fast, but seems very dependent on input parameters. Especially the margin M can be difficult to set. The two CEPT reports states the TETRA reuse to be 7 or 36, which illustrates this difficulty. The method can be used for quick evaluation though - but the parameter choice should be validated against "real world" experience.

B.3.3.1.3 Simulation results using proprietary tool

This clause will present results using a proprietary tool. The tool is basically a number of MATLAB scripts, implementing the scenario generation and Hata propagation model (the same as used in SEAMCAT). The advantage of the proprietary tool is that all aspects of the scenario generation can be controlled and that basic parameters of the propagation model can be tuned to appropriate values.

In addition to this, we have obtained the SEAMCAT propagation source code, which makes it possible to control the basic parameters of the propagation model used in SEAMCAT.

This clause will discuss some parameters and present initial results. All results for now assume same conditions as given in clause B.3.3.1.1.

Log Normal Fading

The sigma for log normal fading is one of the crucial parameters for reuse evaluation. The value in SEAMCAT depends on the distance between the transmitter and receiver - however, for distances above 600 m, the value remains fixed at 9 dB [i.57].

Actual measurements are sparse but can be found in the literature:

- Jakes [i.56]: Refers to measurements made by other authors at various frequencies - no real consistency in measurements, except that range is from 5 dB to 12 dB.
- Curves reproduced from Okumura et al [i.58] suggest that sigma is increasing with frequency and that @400MHz the values are 6 dB for TU and 7,5 dB for SU.

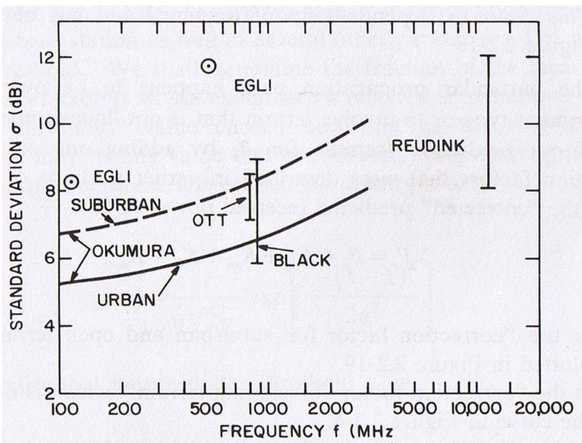


Figure B.8: Measurement results

- Algans et al [i.60]: Measurements @1,8 GHz in Denmark (Århus, Gistrup) and Sweden (Stockholm) finds sigma of 6 dB for SU, between 7,3 dB and 8,5 dB for TU, and 10 dB for BU.

- Perahia et al [i.61]: Measurements @1,9 GHz in the US (Mountain View, Scottsbluff) finds sigma of between 2 dB and 7,7 dB for "relatively flat" SU, and between 3,7 dB and 10 dB for "undulating hills" rural area. They find no correlation between shadow fading from multiple BS.
- Zayana et al [i.62]: Measurements @900 MHz in France (Mulhouse) finds sigma of 5,5 dB. They find significant correlation between shadow fading from multiple BS.
- Elfadhil et al [i.63]: Measurements @900 MHz in Oman finds sigma of 3,2 dB for open area.
- Weitzen et al [i.64]: Measurements @1,9 GHz in the US (Boston, Cambridge). No results for sigma given, however, a histogram of the log normal fading suggests a value in the order of 2 dB to 3 dB. The main objective of the paper is to show that there is no correlation between shadow fading from multiple BS.

The results reported above are not entirely consistent - some results seem to point in opposite directions. The only thing that really can be concluded is that the results show that the actual sigma will vary as a result of local factors, and that it is difficult to settle on one specific value of sigma.

The proposed conclusion on sigma is to state results for four different values of sigma:

1) 4 dB, representing optimal local conditions
2) 6 dB, representing most likely local conditions
3) 8 dB, representing difficult local conditions
4) 10 dB, representing bad local conditions

A nationwide network may consist of areas with different local conditions.

Mobility / Macro Diversity

The references in the previous clause contained 3 references to results relating to the correlation of shadow fading from multiple BS [i.61], [i.62] and [i.64]. The results are unfortunately contradicting, but for now, the assumption is that there is no correlation.

Now, with this assumption of no correlation and with the sigmas given in the previous clause, this means that there will be a significant probability that the geographically closest BS will not be the BS with highest RSSI. With the parameters in clause B.3.3.1.1 (and 9 dB shadow fading), this probability will be above 40 %.

This is illustrated in figure B.9, where green dots indicate MS positions where the geographically closest BS is not the one with highest RSSI.

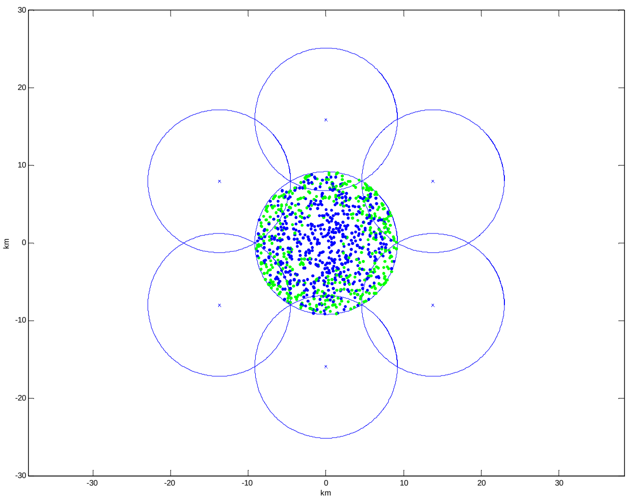


Figure B.9: MS positions (1)

To address this, the tool can use two mobility models:

- MS is using geographically closest BS. This is essentially the same method as used in SEAMCAT.
- MS is using neighbour BS with highest RSSI if this is above that of the geographically closest cell by more than X dB. This is not quite the algorithm used in the TETRA standard, but close. If a neighbour cell is chosen, the map is "shifted" so that the selected BS again becomes the BS located at (0, 0).

The second option is illustrated in figure B.10 for X = 6 dB, where red dots indicate MS positions where the initial BS was not selected, and green dots indicate MS positions where the geographically closest BS is not the one with the highest RSSI but the 6 dB difference is not met.

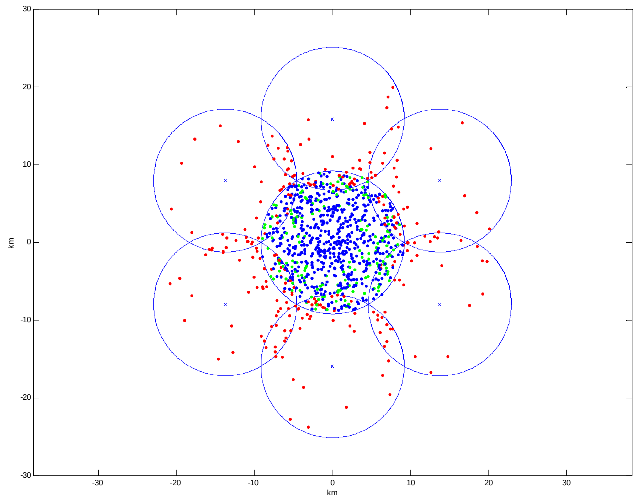


Figure B.10: MS positions (2)

The distribution is ~25 % red, ~15 % green and the rest blue.

C/I Numbers

EN 300 392-2 [i.10] gives the C/I protection ratio needed for 4PSK and QAM:

- 4PSK: 19 dB
- 4-QAM R1/2: 14 dB
- 16-QAM R1/2: 19 dB
- 64-QAM R1/2: 23 dB
- 64-QAM R2/3: 27 dB

However, all of these numbers include a fair amount of implementation margin. This implementation margin is, however, a bit different from the implementation margin assumed in the MS and BS noise figures, in the sense that meeting the C/I performance is largely unaffected by the RF parts of the receiver. Instead, the C/I performance is assured by the all-digital parts of the receiver, and therefore not sensitive to production variations. One could therefore argue that most receivers are unlikely to utilize this margin.

Without margin, the numbers are (derived from internal data and [i.11]):

- 4PSK: 17,5 dB
- 4-QAM R1/2: 11,5 dB
- 16-QAM R1/2: 16,5 dB [i.11]
- 64-QAM R1/2: 21,5 dB

- 64-QAM R2/3: 24,5 dB

Results

With the tool introduction done, we are now ready to look at some results.

Tool Comparison

The first curve with results show the probability of interference for TETRA with the same parameters and assumptions as used in SEAMCAT in clause B.3.3.1.1 as a function of the reuse factor (labelled "SEAMCAT T1" as the SEAMCAT method is used). As the tool is based on a scripting language it is fairly easy to vary parameters, so result here are given for all reuse factors from 3 to 63 (see note 1).

NOTE 1: 3, 4, 7, 9, 12, 13, 16, 19, 21, 25, 27, 28, 31, 36, 37, 39, 43, 48, 49, 49, 52, 57, 61, 63.

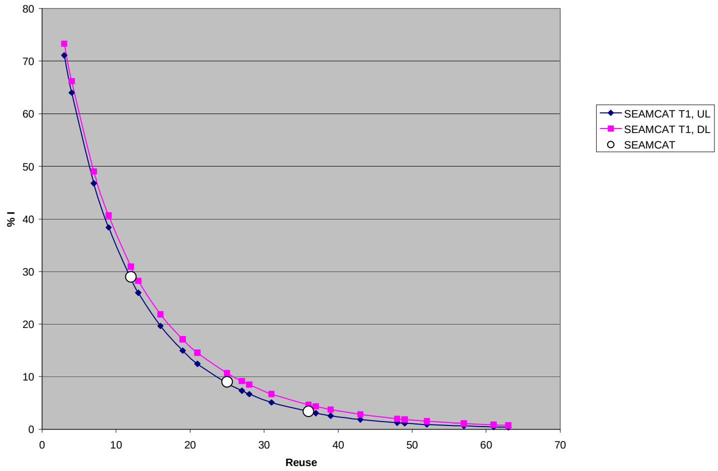


Figure B.11: Comparison

The results obtained by use of SEAMCAT in clause B.3.3.1.1 have been added to the graph as well (labelled "SEAMCAT" indicated by white dots) - as can be seen, there is an excellent match of results, although SEAMCAT seem to be slightly more optimistic (DL was simulated in SEAMCAT).

Now, since the interesting part of the curve is the area with low probability of interference, the y-axis has been scaled on figure B.12 (and all following figures) to ease reading the graph.

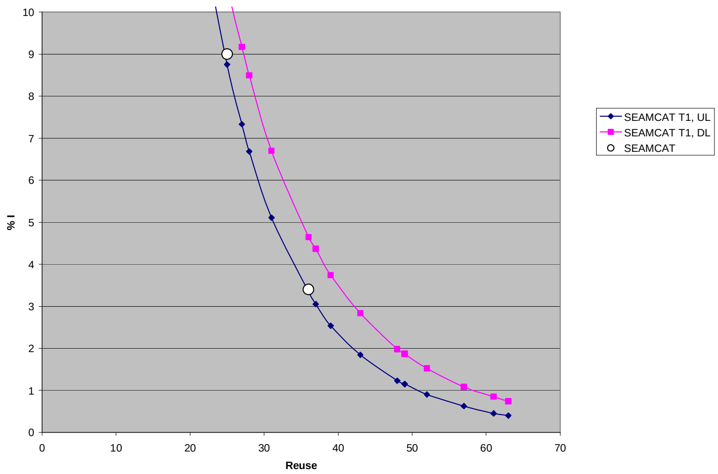


Figure B.12: Results

TETRA Results - Log Normal Sigma Sensitivity

The curves below show the effect of changing sigma. Some of the values have been calculated using SEAMCAT with modified propagation model parameter (white circles - corresponding to a sigma of 6 dB, 8 dB and 9 dB).

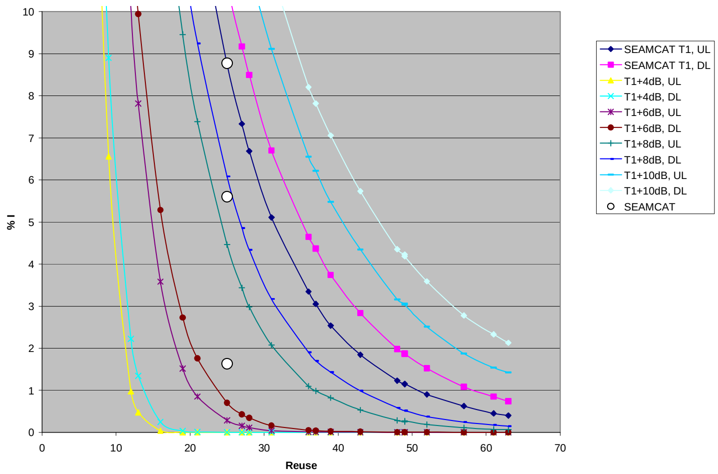


Figure B.13: Propagations

As can be seen, the value of sigma has a dramatic effect on the results.

TETRA Results - Mobility / Macro Diversity Sensitivity

The curves below show the effect of including mobility / macro diversity for some different values of X (0 dB, 2 dB, 4 dB, 6 dB and 8 dB).

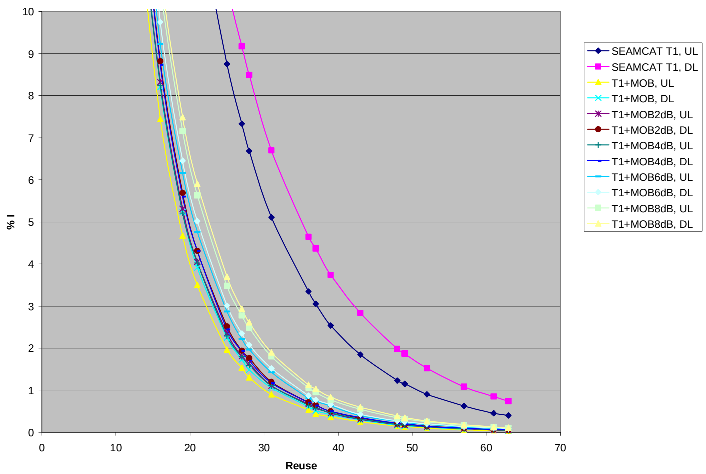


Figure B.14: Diversity

This shows that the mobility will contribute to increasing the received RSSI (and therefore indirectly increase C/I) and therefore improve the reuse. However, the impact is not as sensitive to values of X as one might initially think.

The use of the strongest BS also results in the area reliability increasing to close to 100 %. The cell size could therefore be increased beyond that of a single cell system; however, this has not been done here.

TETRA Results - Selected Curves

The curves below show the effect of some of the changes to the simulation proposed above.

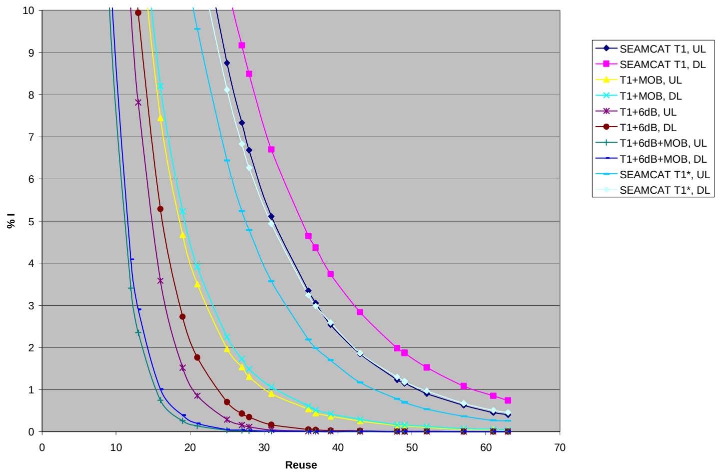


Figure B.15: Results

The curves are:

- "SEAMCAT T1" - basically the same curves as presented in Tool Comparison.
- "T1+MOB" - mobility as described in clause B.3.3.1.3 added (X = 0).
- "T1+6dB" - sigma in log normal changed from 9 dB to 6 dB.
- "T1+6dB+MOB" - sigma in log normal changed from 9 dB to 6 dB, and mobility as described in section Mobility / Macro Diversity section added (X = 0).
- "SEAMCAT T1*" - C/I margin reduced from 19 dB to 17,5 dB.

The curves show that that the reuse factor is strongly affected by the assumptions on mobility and sigma. The reuse for TETRA can therefore only be given as a range of possible values.

NOTE 2: All curves assume 100 % UL activity and no UL power control.

B.4 Cognitive Radio & Spectrum Management

B.4.1 Cognitive radio requirement

Cognitive radio is a tool for use in adaptive spectrum management to enable an efficient use of spectrum in an intelligent way. The following list provides examples of features that may need to be incorporated in cognitive radios:

- Frequency agility;
- Dynamic frequency selection;
- Adaptive modulation;
- Adaptive bandwidth;
- Transmit power control;
- Location awareness (its own and that of other devices operating in the same spectrum);

- Interference cancellation.

Modern HSD digital mobile technologies such as TEDS networks and radios are already utilizing a degree of reconfigurability in provision of link adaptation to changing propagation conditions. A dynamic reconfiguration of TEDS Physical/MAC layers parameters such as adaptive modulation, coding rate and channel bandwidth as well as transmit power are features already included in the present document in line with the technology of cognitive and software-controlled radios.

An idea being promoted currently in discussions of "Reconfigurable Radio Systems" is a cognitive control channel. This channel could be used to identify other wireless systems in operation. It would provide information about band occupation, power levels or Transmit-Power-Control settings of active radio systems. With this information, PPDR systems could adapt themselves to a radio environment which might otherwise be difficult to measure, for the purposes of band-sharing. Likewise, other spectrum sharers could be obliged to provide the same information on such a channel that is provided by the PPDR system if they like to use the spectrum (under the assumption that pre-emption would take place, if spectrum is needed by the PPDR network). Another interesting aspect is that such a channel would be part of the PPDR network and therefore, under control of the PPDR network operator. The concept of a "cognitive control channel" discussed above is already in use in TETRA albeit for internal network purposes. Nonetheless, this concept should be carefully investigated in sharing spectrum between the PPDR and other networks to ensure that more severe requirements in terms of fast communications set-up, availability and reliability exercised by the PPDR network are fulfilled.

Furthermore, from the perspective of a PPDR network sharing spectrum with other users, it is important to have a strict pre-emption capability as part of the sharing arrangement to ensure the required performance from the PPDR network is achieved at times of disaster (see further, clause B.4.2.3).

It is clear that a co-operation criterion has to be established between the technologies sharing the spectrum. Implementing these techniques does rely on contiguous blocks of spectrum under the control of a PPDR network infrastructure, which makes the opportunity of the digital dividend band ideal for implementing this advanced cognitive concept. However as explained below the nature of the pan-European emergency communication dictates a fully secure primary spectrum allocation. A cognitive radio deployment of future PPDR radio in an opportunistic spectrum usage could be envisaged in non mission-critical (routine) operations.

B.4.2 Emergency communication and adaptive spectrum management based on cognitive radio

It is generally understood that spectrum availability for emergency communications should be given a high priority by regulatory authorities. Furthermore, the national and regional security dictates a permanent harmonized band, which could be effectively utilized across national boundaries at times of calamity. Such a spectrum allocation should not be governed by costly auction procedures that are best suited for high-user-density commercial networks.

It is feasible in the future that if technology permits, spectrum sharing may be a possibility to fulfil some of the PPDR requirements, provided that adequate priority and pre-emption capabilities are given to the PPDR users, and the response times in clearing the spectrum of other users is adequate in a sudden unplanned emergency. The digital dividend bands are possible candidates for this purpose, although only following the clearing of broadcast TV stations from the band, as TV transmitters generally are high powered and have high locations, and would cause excessive interference to co-channel mobile networks.

In a quest for a more-efficient spectrum utilization the Wireless Access Platform for Electronic Communications Services (WAPECS) concept is currently under serious consideration by European regulators. WAPECS is defined [i.15] as "a framework for the provision of electronic communications services (ECS) within a set of frequency bands to be identified and agreed between European Union Member States in which a range of ECS may be offered on a technology and service neutral basis, provided that certain technical requirements to avoid interference are met, to ensure the effective and efficient use of the spectrum, and the authorisation conditions do not distort competition". However, the EU Radio Spectrum Policy Group (RSPG) recognized that "The use of bands by services pursuing particular general interest objectives (e.g. Service of General Economic Interest, safety-of-life services, etc.) ***require special consideration***. Member states may have to fulfil some obligations relating to such services, even when they fall under the WAPECS scope, and to safeguard some spectrum for them". CEPT Report 19 addressed such questions in the context of WAPECS [i.28].

There are several challenges in adaptive use of spectrum, such as the means for determining whether the spectrum is available for use, and the means for prioritizing one user over another with enough speed. Spectrum sensing is unlikely to be sufficient alone, and a location database approach is being pursued within CEPT. Beacons indicating availability and use of spectrum is another possibility, although the ownership of and source of up to date information for such beacons would need careful study.

For PPDR users, use of unlicensed spectrum with a sharing approach would be unlikely to give the necessary degree of control and response time. An alternative where PPDR users owned (were licensed) the spectrum, and granted access to approved devices for other purposes may be a solution in the future.

The possibility of spectrum sharing for PPDR users should be allowed only under a strict pre-emption regime with no risk of interference to the PPDR service and availability of sufficient spectrum for mission critical part of the PPDR service. Therefore, PPDR designated spectrum needs an exclusive "core" radio spectrum for PP1 and PP2 services plus sufficient shared spectrum (with a ruthless pre-emption arrangement) for occasional DR applications. The sharing arrangement is proposed to be facilitated by using a cognitive channel being provided by the PPDR system (see also clause B.4.1). Table B.2 shows the optimal and sub-optimal options under a shared scenario.

Table B.2: Network and spectrum sharing options

		Spectrum	
		Dedicated	**Shared**
Network	**Dedicated**	Optimal.	Possible for Mission Critical applications if provided on primary basis and using pre-emption. Possible for non-mission critical applications.
	Shared	Suboptimal: Possible with clearly defined rights and duties. Network should be robust, reliable, and available to accommodate PSS users.	Not possible for Mission Critical applications.

The allocation of preemptable spectrum for PPDR use would be in addition to core dedicated, exclusive spectrum, and would only be accessed in certain limited circumstances. Preemption can only work in one direction with sharer networks taking advantage of spectrum dedicated to PPDR communications, and with PPDR being able to "ruthlessly" invoke emergency use at the expense of other users. It is to be noted that DR services, have "average" or long-term spectrum requirements which are very different from the peak requirements that arise during major incidents. However, dedicated does not necessarily mean that the entire designated spectrum has to remain exclusive to PPDR all the time. Hence there is likely to be benefits in a combination of dedicated and shared use spectrum, where the shared spectrum is used to cater for the peaks as and when they arise. Furthermore, since the occasional peak spectrum requirement is highly localized, the locations outside the incident area do not have to invoke the pre-emption arrangement.

B.4.3 Synergies between BB-PPDR and other broadband applications

BB-PPDR and for example railway radio applications (such as currently used in GSM-R) may use the same technical framework and equipment in the future (e.g. based on LTE). Some railway applications have similar requirements in terms of predictability and availability of the communications and can also be considered as mission-critical (e.g. the European Train Control System (ETCS) and other signalling application). There may be a possibility of having a common set of technical parameters for spectrum access.

Coordination and the associated broadband applications' demands will be dealt with on a national level, e.g. whether certain broadband applications with similar technical requirements use their own networks, share a common dedicated network or are delivered within public mobile networks; but still using a common technical framework.

To find such synergies amongst broadband applications from specific market sectors is also in the interest of spectrum authorities who may find it difficult to provide dedicated spectrum to a variety of specific market sectors.

This is also recognized in the RSPG Report on Sectoral Spectrum needs [i.76], approved by RSPG in November 2013, that recognized that the provision of PPDR services, including the associated radiocommunications facilities is a sovereign national matter, and that the broadband PPDR needs of Member States may vary to a significant extent. Therefore, the future harmonization of the broadband PPDR sector in Europe needs to be flexible enough to respect national sovereignties and different national circumstances such as; the amount of available spectrum and the type of network deployed and used which may be dedicated, commercial or a hybrid solution (a mixture of dedicated and commercial networks). There are requirements to ensure adequate interoperability between the different countries. Also the possibilities of maximizing the benefits from the economies of scale should be taken into account.

This is seen as a basis for future considerations on synergies amongst broadband applications which can use the same technical framework.

The main difference is seen in the authorization regime for accessing the spectrum. For government use, or assimilated, covering various domains (defence, civil aviation, maritime & waterways, public safety, meteorology, science or some part of the public transport infrastructure, etc.), the rights of use are usually limited to the rights described in the National Table of Frequency Allocations (NTFA). No individual authorizations with limited duration are granted. Governmental users, or assimilated, need access to frequency bands so as to perform their own duties. Their access to spectrum resources should be subject to regular review with Administration/NRA. It is usually given for well identified radio services and on a shared basis. The ability of one entity having access to a frequency band to effectively deploy radio networks and use the spectrum will obviously also depend upon the nature of spectrum rights given to other entities sharing the band. Other non-governmental use would than share the spectrum by means of individual authorizations. To find synergies, e.g. between BB-PPDR and e.g. a future railway wireless application that follows GSM-R, it would therefore very important to find a common technical framework and it is proposed that the ECC should have a look on this.

Synergies may be found in areas such as:

a) Recognizing the right of Member States how to organize and use their radio spectrum for PPDR, a possible harmonization of frequency spectrum for broadband PPDR should not limit individual Member States from using that spectrum also for commercial wireless broadband;

b) Interoperability and roaming between different PPDR networks, as well as commercial networks is also being considered. For hybrid networks this may be essential.

c) Roaming between countries would be beneficial for future broadband PPDR networks for cross-border co-operation;

d) Frequency bands for use by broadband PPDR services supported by commercial mobile broadband equipment (user terminals, base stations, chipsets etc.) would also enable PPDR users to benefit from economies of scale available when using commercial products and from possible synergy with technology development in the commercial sector;

e) Dedicated frequency bands offer the opportunities to roll out dedicated networks responding to national security requirements and enable to provide the specific PPDR services and needed reliability while benefitting from synergy with standards developed for the commercial mobile broadband.

f) Interoperability between radio equipment of different manufacturers of user equipment and infrastructure is required to make roaming possible.

Annex C: Expected sharing and compatibility issues

C.1 Current ITU allocations

PPDR is considered as a radio application under the Land Mobile Service or under the Mobile Service.

Due to the broad range of frequencies covered, an excerpt of the European Common Allocation Table [i.7] is not reproduced here. Please see [i.7] for further details.

C.2 Coexistence issues

The following coexistence issues should be studied with the following systems in the band 300 MHz to 790 MHz:

- SAP/SAB (PWMS systems, including multichannel radiomicrophone receivers);
- TV Broadcasting (DVB-T);
- PMR/PAMR systems (narrowband and wideband);
- Military radio applications;
- radio astronomy service.

Special attention should be paid to the wideband noise characteristic of broadband systems for PPDR. However using the assumption that PPDR broadband services will be based on 3GPP LTE technology, many of the existing studies of compatibility between LTE and other uses of the UHF band for the first Digital Dividend will be applicable.

The density of dedicated PPDR networks (both infrastructure and users) is likely to be lower than commercial networks employing 3GPP technology. This should be factored into compatibility studies. Should the frequency band 694 MHz to 790 MHz (see note below) be adopted for co-primary mobile use following WRC 2015, placement of PPDR networks at the lower part of the released band is one solution to minimize the level of interference between domestic TV reception and broadband mobile users.

NOTE: The lower frequency limit of the second digital dividend release for mobile usage will be determined by WRC 2015, and is not yet confirmed.

Annex D: Public Safety Frequency Statements from 18 Countries

D.1 To WG FM Workshop in 2010

To the WG FM Workshop on Spectrum Harmonisation for Public Protection and Disaster Relief (PPDR) 11-12 March 2010 - Mainz (Germany)

The Police Corporation Working Group (PCWG) under The European Council started in 2008 the Radio Expertgroup as an initiative to assure future high-speed mobile data information. That coupled with the Council Decision 2008/616/JHA of 23 June 2008 to improve cross-border cooperation, particularly in combating terrorism and cross-border crime (the "Prüm" Decision) [i.65] means that common spectrum and a common standard will be required.

The PCWG initiative is supported by the Ministers of Justice and Interior of all 27 Member States who at the JHA Council meeting in Prague 4-5th June 2009 approved the Council Recommendation 10141/09 [i.33].

NOTE: The PCWG name has subsequently been changed to 'Law Enforcement Working Party' (LEWP) but the activities from their Radio Communicatio Expert Group (RCEG) remains the same.

The Recommendation specifically RECOMMENDS that:

"The Electronic Communication Committee (CEPT / ECC) be tasked to study the possibility of obtaining sufficient additional frequency allocation below 1 GHz for the development of future law-enforcement and public-safety voice and high-speed data networks.

When needed and justified, and taking account of national arrangements for the distribution of spectrum, that Member States allocate additional frequencies at national level in a coordinated timeframe in cooperation with CEPT.

That ministries responsible for police and justice be encouraged to contact their counterparts responsible for spectrum policy to ask for their assistance with the above proposal, given the important role of the national frequency administrations."

The Swedish Presidency established end 2009 two expert subgroups from the Radio Expertgroup as result of this Recommendation.

The "Forerunner Group" (for the long term solutions) met in March 2010 to expand on the user requirements.

The present document is the first agreed output.

The Forerunner Group has following position:

1) The Group welcomed the initiative from CEPT/ECC to hold a workshop on Public Protection and Disaster Relief (PPDR) in Mainz 11-12 March 2010.

2) We recall that one of the objectives of the European Union is to strengthen operational cooperation between neighboring States in order to combat all forms of crime more effectively, thereby participating in the consolidation of the European Union.

3) We recall Council Decision 2008/616/JHA of 23 June 2008 on improving cross-border cooperation, particularly in combating terrorism and cross-border crime (the "Prüm" Decision) [i.65].

4) We recall Council Recommendation on improving communication between operational units in border areas, which was approved on 24 October 2008 (13796/08 ENFOPOL 181 COMIX 716) [i.66].

5) We recall that the Commission published on 5 March 2008, its Communication on "Reinforcing the Union's Disaster Response Capacity" [i.67]. The chapter on "Capacity building across Community policies and instruments" states that the enhancement of broadband and mobile communications for public protection and disaster relief services, as well as the opportunity to enable EU-wide interoperability, should be examined.

6) We note that the Spanish, Belgian and Hungarian Presidencies in their Justice and Home Affairs TRIO PRESIDENCY PROGRAMME from 4th January 2010 in section IX. Police and Customs cooperation states they will seek to enhance the interoperability between radio communication systems in the field of law enforcement. That demonstrates that the initiative taken by France and followed up by the Czech Republic and Sweden continues to receive good political support.

With that as a backdrop we note that:

1) Public Safety Service (PSS) organizations provide the community with indispensable police, fire and other emergency services. These services use spectrum for essential communication purposes. PSS organisations require reliable, high-availability and secure solutions provided by dedicated systems. Such systems should cover all necessary national geographic areas (local, regional, country) and allow PSS organizations to enable cross-border cooperation.

2) In order to fulfil their obligation to save lives and property, PSS organizations and their personnel require wireless access not only to voice and simple data services (narrowband) but also increasingly to wide-band and broadband data services. The ability to utilise these services requires more spectrum than the two 5 MHz-wide blocks currently harmonized across Europe.
Calculations in the present document show that approximately two additional 3 MHz-wide blocks are required for additional voice traffic, two 3 MHz-wide blocks are required for wide-band data traffic and two 10 MHz-wide blocks are required for future broadband data services.
These allocations should be Pan-European even though different parts of the same frequency bands might be utilised in each country.

3) PSS bring value to society by creating a stable and secure environment; this can only be done by building dedicated robust, secure and reliable modern Public Safety mobile communications networks.
Building these modern essential services requires a long project lead time, for example, today's national digital radio system for emergency services, often part of Critical National Infrastructure, typically have taken 10 years in planning before they became operational.

4) It is of utmost importance that CEPT/ECC decides that the PSS spectrum requirement - as a principle - will be met. A clear position to that question will establish the platform for the most cost effective solution.

5) Without trying to influence the work in CEPT/ECC, we want ideally to be able to re-use the antenna sites we have today for the existing narrow-band systems, also for future wideband and broadband systems. Spectrum in the lower end around 400 MHz will have a positive impact on cost of deployment.

Involved countries from the PCWG Radio Expertgroup gave permission to The Netherlands to bring the opinion described above to the attention of the PPDR workshop 11+12 March 2010 in Mainz.

This opinion is supported by Justice and Home affairs representatives from:
Belgium, UK, France, Spain, Finland, Italy, Poland, Portugal, Slovakia, Cyprus, Denmark, The Netherlands, Switzerland, Lithuania, Norway, Czech Republic, Austria, Germany (see note).

The Netherlands

8-3-2010

NOTE: In principle, Germany supports the initiative to increase the amount of spectrum available for PPDR services. The specific requirements on which the spectrum needs of the German PPDR are based have been identified in a study which will be presented at the workshop on 11-12 March 2010 in Mainz. Germany is in favor of identifying harmonized spectrum. Proposals will be elaborated in a second study.

D.2 To ECC, WG FM and WG FM PT49 in December 2012

Public Safety statement from Law Enforcement Working Party - Radio Communications Expert Group (RCEG)

Considering

- Council Decision 2008/616/JHA of 23 June 2008 on the stepping up of cross-border cooperation, particularly in combating terrorism and cross-border crime.

- Council Recommendation on improving radio communication between operational units in border areas; {FM38(10)35rev2 annexl}.
- The fact that the Law Enforcement Working Party (LEWP) of the Council established a Radio Communication Expert Group (RCEG) to work on relevant radio and spectrum matters.
- Letter from Swedish Presidency to ECC October 2009; {FM38(10)35rev2 annex 3}.
- Letter from Swedish Presidency to ETSI November 2009; {FM38(10)35rev2 annex 5}.
- Public Safety frequency statement from 18 countries to the WG FM Workshop on Spectrum Harmonization for Public Protection and Disaster Relief (PPDR) 11-12 March 2010 in Mainz (Germany); {FM38(10)35rev2 annex2}.
- Letter from Belgium Presidency to ECC November 2010 with LEWP-RCEGfrequency statement; {FM38(10)35rev2 annex 'LEWP'}.
- Progress Report from FM Project Team 38 dated 14 September 2010, including Questionnaire; {FM38(10)35rev2 annex 4a,4b}.
- ETSI's SRDoc on future spectrum needs for Public Safety; (note 1).
- Proposal for a Decision of the European Parliament and of the Council establishing the first Radio Spectrum Policy Program (recitals (18) and Article 7) + the RSPP text (note 2) with the conclusion that PPDR Broadband frequencies are needed.
- The new CEPT-FM-PT49 workgroup, especially set up for PPDR Broadband frequencies.
- Report from the LEWP-RCEG to PT49 with the progress report of the Radio Communications Expert Group June 2011. {FM49(1l)04}.
- The LEWP-RCEG Matrix made by the RCEG was input in the work of CEPT-FM-PT49; {FM49(1l)024}.
- The ETSI added calculation details and a calculation tool to this Matrix; {FM48(12)042}.
- The LEWP-RCEG'3-scenario document' which was presented to FM-PT49; {FM49(12)019}.

NOTE 1: ETSI SRDoc Additional spectrum requirements for future Public Safety and Security (PSS) wireless communication systems in the UHF frequency range (TR 102 628); the first published version of the present document.

NOTE 2: RSPP text: *"The Commission shall, in cooperation with the Member States, seek to ensure that sufficient spectrum is made available under harmonized conditions to support the development of safety services and the free circulation of related devices, as well as the development of innovative interoperable solutions for public safety and protection civil protection and disaster relief."*

LEWP-RCEG met on 24 October 2012 in Cyprus and reviewed the progress of activities initiated by Council Recommendation on improving radio communication between operational units in border areas.

The meeting noted the fact that ECC/CEPTWGFM-PT49 are working on an allocation for extra frequencies for new broad-band data.

LEWP-RCEG noted that it encourages the work of ECC/CEPT-WGFM.

The existing mobile radio networks are in some countries typically being used by the police, but in most countries also deliver services to all other PPDR organizations.

For the ongoing study on Broadband data LEWP-RCEG will, in cooperation with other PPDR organizations, continue to provide ECC/CEPT WGFM-PT49 on their request with extra information on user needs, operational scenarios etc. to get an overview of the PPDR high speed data needs. The LEWP-RCEG Matrix and the LEWP-RCEG '3-scenario document' are examples from already provided inputs.

LEWP-RCEG has in parallel asked each Member State, insofar as this is deemed appropriate, to contact their national spectrum administration to inform them of this statement and to ask support for it in ECC/CEPTWGFM.

LEWP-RCEG asks ECC/CEPT WGFM to take into account the PPDR needs for a mission critical Broadband solution and for this purpose to allocate harmonized frequencies.

LEWP-RCEG will continue to support CEPT WGFM-PT49 in their activity to find a solution and asks PT49 to take into account the information provided by the user representatives in the FM-PT49 meetings

D.3 LEWP-RCEG statement on RSPG draft opinion on Wireless Broadband

LEWP-RCEG statement on RSPG draft opinion on Wireless Broadband

The Radio Communications Expert Group (RCEG) of the Law Enforcement Working Party (LEWP) of the Council of the European Union, representing the radio communication interests of the European Public Protection and Disaster Relief Organisations, takes notice of the draft opinion of the RSPG on Strategic Challenges facing Europe in addressing the Growing Spectrum Demand for Wireless Broadband.

The LEWP-RCEG respects both the intermediate target in the Radio Spectrum Policy Programme (RSPP) to make 1200 MHz of spectrum available for Wireless Broadband and the respective long term objectives of the Digital Agenda for Europe. In addition the RCEG seeks to ensure that the requirement of the European PPDR organisations for sufficient harmonised spectrum for their future PPDR broadband solutions is met.

In this respect the RCEG has elaborated the commonly agreed European PPDR Requirements regarding future broadband data applications, known as the so-called MATRIX of the LEWP-RCEG. The user requirements described in this MATRIX served as one of the main inputs for the current work of the project team 49 (PT 49) of the ECC of the CEPT, which is dealing with the European harmonisation of spectrum suitable for the European PPDR. The draft of the first output report of PT 49 clearly indicates that European PPDR will need dedicated harmonised spectrum, at a minimum of 2 X 10 MHz, for their future interoperable broadband solutions. However different national needs could lead to varying national spectrum demands.

Against this background LEWP-RCEG is kindly requesting the RSPG to take into account the dedicated specific wireless broadband frequency demand of the European PPDR and to advise the European Commission accordingly. The LEWP-RCEG kindly requests that this requirement to identify dedicated spectrum for broadband PPDR is reflected in the RSPG Opinion. As spectrum saves lives, the European PPDR dedicated spectrum demand is critical and at least as equally important as the role played by commercial mobile radio communication.

Mick McDonnell

Chairman (Irish Presidency)

LEWP-RCEG.

19 April 2013

Annex E: Information on recommendation on improving radio communication

Recommendations submitted by the Swedish Presidency:

"The Swedish Presidency of the EU would like to inform the ETSI that the Council in June 2009 approved Council Recommendations on improving radio communication between operational units in border areas.

In these recommendations, the European standardization bodies are invited to start producing a European standard satisfying law-enforcement and public-safety services' operational requirements regarding high-speed data communication and roaming functionality in the medium term. In the long term, after the life cycle of the current TETRA and TETRAPOL systems has ended, a fully integrated solution could be envisaged."

Annex F: Spectrum Requirements Calculations based on LEWP Applications Matrix

F.1 Introduction

In 2011, the EU Council's Law Enforcement Working Party Radio Communications Expert Group (LEWP RCEG) generated a matrix of user applications that would be required for Broadband for Public Protection and Disaster Relief (PPDR). TC TETRA WG4 held joint meetings with the LEWP RCEG in late 2011 to provide an analysis of these requirements to support the case for acquisition of harmonized spectrum for PPDR. Following this work, the Matrix was extended to calculate a data rate and spectrum requirement. This Annex describes the methodology and the results of this work.

This work includes data applications over a wide area network, but does not include speech requirements, nor Air to Ground nor DMO.

The work has also been used in CEPT WGFM PT49 in their analysis of spectrum requirements for PPDR. The contents of this Annex are also largely captured in ECC Report 199 [i.70].

F.2 Spectrum calculation process

The method of calculation made use of the user requirements matrix provided by the LEWP RCEG and assessed the user application requirements in joint meetings with TC TETRA WG4.

The method consisted of the following steps:

- Describe the applications used in the peak busy hour in normal conditions and in emergency situations.
- Estimate the number of users in a cell using an application, and the number of transactions per user for that application in both peak busy hour normal conditions and during an emergency or incident. The cell is assumed to be in a busy area (e.g. in a major city).
- Estimate the data requirements for each application.
- Apply the data requirements to scenarios.
- Estimate the spectral efficiency of an appropriate technology such as LTE in the scenarios.
- Calculate the spectrum needed in each scenario from the above inputs.

These steps are described in detail in the following clauses of this Annex.

F.3 Methodology

F.3.1 User applications

The applications required for a broadband network to serve the PPDR community were tabulated in the Matrix by the LEWP RCEG.

F.3.2 Number of users in a cell or sector

The number of users in a cell or sector during a peak busy hour condition and during an emergency incident in an urban environment in a large city was estimated in joint meetings between the end user community, represented by the LEWP RCEG, and technical experts from ETSI TC TETRA WG4 using those users' experience to make a generic model of load conditions.

As usage of applications can be asymmetrical between the uplink and downlink (e.g. several users send video concerning an incident to a control room, but video is only sent back to one supervisor in the field), the number of users making use of the application on the uplink and downlink were estimated separately.

F.3.3 Use of groups

In some cases, the same information can be sent to many members of a single group. Therefore for the use of applications on the downlink, the number of different groups whose members would receive the same sets of data was estimated.

NOTE: The purpose of this was to enable alternative calculations of downlink spectrum requirements if the technology adopted can provide a true group addressed service, as opposed to a technology which requires the same information to be sent individually to each group member.

F.3.4 Transactions per user

For each application, the number of transactions per user in a peak busy hour in normal conditions was estimated using the end users' experience.

A multiplication factor for emergencies was also estimated, as use of some applications will increase during an emergency, and use of some others (for example those associated with more routine operations) will decrease.

F.3.5 Data requirements for each application

For each application, the size of a data transaction was estimated both for the uplink and the downlink. These were estimated either as the data requirement for each discrete transaction (number of bytes of information required), or as the bit rate of a streamed application.

To estimate the data requirements per hour per user for transactional applications, the data size for each transaction is multiplied by the number of transactions per user per hour. For streaming applications, the number of minutes per hour that each user would need to make use of that application was estimated, and then the resulting fraction of an hour was multiplied by the data rate.

F.3.6 Network data loading per application

For each application, the data loading was then calculated by the Matrix for uplink and downlink and in normal peak busy hour conditions and emergency conditions.

For normal peak busy hour conditions, the number of users for each application is multiplied by the application data requirements for each of uplink and downlink. Where an application can use a true group addressed service, an alternative calculation is made where the same data is sent to groups rather than individuals. A group addressed transmission may have an increased overhead compared with an individually addressed transmission as extra forward error correction may be needed if individual selective retransmission is not possible in the normal way; therefore an extra factor is used to estimate the increased loading caused in a group addressed transmission.

NOTE: Not all group addressed services will incur an extra overhead; for example real time video transmission will be sent with an amount of forward error correction, but the receiving codec mitigates for lost data rather than requesting a retransmission. This will be the same whether the transmission is individually addressed or group addressed, hence there would be no overhead for groups with this service.

For emergency incident conditions, the same calculations are made. However the multiplication factor is also taken into account to allow for an increase or reduction in the use of that application in emergency conditions.

F.3.7 Spectrum efficiency in scenarios

The spectrum requirements calculation for each scenario were then made using the Matrix.

During an incident or emergency, some users will be located at the incident scene; others will be spread out across the cell as part of the background load. Those at the incident will incur a spectrum efficiency for their data exchanges depending on their distance from the centre of the cell. Those spread out across the cell can be averaged out with an average spectrum efficiency. It is therefore important to recognize which applications are incident centric and which are used by users distributed throughout the cell.

For each application, a decision was taken as to whether it was incident centric, or a background application spread out across the cell.

The spectrum calculations then consisted of:

- For background applications spread out across the cell, multiply the data demands for uplink and downlink by the average spectrum efficiency of the technology. This provides the non incident related load on the cell.

- For applications centric to an incident, multiply the data demands by the spectrum efficiency estimated for the incident.

In both cases, a separate spectrum efficiency is estimated for the uplink and the downlink (see clause F.4.3).

F.3.8 Variations in spectrum efficiency

Variations were made in the spectrum efficiency applied in the matrix in order to consider both the effects of user distribution for different applications, the effects of group calls, and the effects of network planning.

F.3.8.1 Effects related to different applications

A modification was made in the event of applications which are normally spread out across the cell and which have low numbers of users utilizing that application, specifically video used in a chase scenario. In this case it is assumed that one user will from time to time require to use the application at a different (lower) spectrum efficiency than the average spectrum efficiency of the cell as the user will travel to and across the cell boundaries, and therefore allowance is made for one user to receive a different spectrum efficiency for these specific applications.

F.3.8.2 Bandwidth limitations in edge of cell conditions

If a streamed user application demands a high bandwidth where spectrum efficiency is low, i.e. at the edge of a cell, a simple calculation may result in an unrealistic demand for spectrum. In practice, the handset may simply not have sufficient output power on the uplink to be able to transmit across the bandwidth required; and instead in practice the application will be forced to drop to a lower bit rate (thus reducing the spectrum demand). On the downlink, the base station may simply not be able to deliver the quality of service requested by the application, and again the application will be forced to lower its bit rate. These aspects have been taken into account in the Matrix by imposing a spectrum cap on both uplink and downlink video transmissions so that the maximum spectrum which can be demanded by any one instance of the application is limited to a preset figure.

F.3.8.3 Effects of group call technology

As decribed previously, group calls may provide a more efficient means of distributing the same information to multiple users on the downlink than individual unicast transmissions. However the implications for the technology are not yet known. If one user is close to the cell edge or in poor reception conditions, then an adaptive group call will have to account for this worst case situation, and will incur a low spectrum efficiency figure. It is also possible that a future group call in a technology such as LTE may not be able to dynamically adapt the transmission according to the user with the worst link budget (as this will vary from time to time between different users) and the solution may simply transmit with a constant spectrum efficiency which may be that appropriate to the edge of a cell. The Matrix therefore allowed group call spectrum efficiency to be determined independently of individual call spectrum efficiency, and has typically been set to the edge of cell figure. As a result of this, in some scenarios individually transmitted downlink transmissions for a few users may be more spectrally efficient than a group call. Therefore where group call is used, the Matrix compares the overall spectrum demand of a group call with that of an individual call per user on a per application basis, and selects only the most efficient figure of the two as an 'optimised' group call result.

F.3.8.4 Effects of network planning

A network may be planned with large cells, which has the advantage that there will be fewer base stations and so lower cost but the disadvantage that throughput at the cell edges will be relatively low, or with small cells which permits better cell edge throughput at the expense of greater network cost. The Matrix was used with different cell edge spectrum efficiencies to show the effect of this variation with network planning. The technology used in the network such as Multiple Input Multiple Output (MIMO) antenna technology, beamforming antenna technology and so on will also affect the spectrum efficiency, with the more complex technologies yielding improvements in both cell edge throughput and spectrum efficiency.

F.3.9 Limitations

The method used averages out demand over a one hour period. In practice there will be higher peak demands that estimated here, however this can be mitigated by intelligent applications, and by reducing the throughput of non time critical applications in times of peak load. Also, in a real situation, users operating close to each other will achieve different spectrum efficiencies, and this may alleviate the worst case scenarios at the edge of cell. Protocol overheads are generally not taken into account in this mechanism, although for the most demanding applications (mainly video) they will have relatively small effect.

F.4 Spectrum calculations

F.4.1 Spectrum calculation scenarios

Spectrum calculations can be based on peak business as usual traffic, sometimes described as PP1 scenarios, or on major incidents either planned or unplanned which are known as PP2 scenarios.

The original LEWP-ETSI Matrix assumed a generic worst case set of conditions for either peak busy hour in a cell in a big city, or a generic emergency incident situation (such as an aeroplane crash or terrorist attack) in the same big city cell environment. These figures were used for the first sets of scenarios, which were calculated with different spectrum efficiencies.

Two scenarios based on real life events were then taken, where the user numbers and applications were provided as inputs. In each case, the numbers of users for each application and the application data requirements (if different from the generic requirements) were modified in the Matrix to match the data provided in each scenario. In each case, the background data load was left almost unchanged from the generic LEWP input as the users assume that there will still be other load in the cell or sector which continues independently of the emergency. The scenarios are listed in the following paragraphs.

The London Riots in 2011 was used as the first scenario. The number of users and the broadband applications which would be required was taken from discussions with the Metropolitan Police in November 2012. A summary of the communication needs is as follows, based on the use of two sub Bronze commanders each commanding 300 users who report to a single Bronze commander in an operational area, and who could all be operating within a single cell:

- 2 high quality video streams - one from each sub Bronze Command area - being fed back to Gold and Silver Command. The video would be used to help manage the situation and would be recorded remotely for evidential purposes.
- Bronze and Sub bronze commanders receive regular GPS based location updates of the officers under their command.
- Interactive maps are pushed to officers on the ground to help them navigate to where they needed to be and also which areas/streets they should avoid. Particularly important as many of the officers deployed to contain and quell the rioting were not familiar with the area in which they were working.
- An infrared video feed from a helicopter is fed to fire fighters on the ground to help them tactically fight large fires.
- A video feed from a helicopter is fed back to Gold and Silver Command.
- Numerous still pictures captured by police officers are transmitted back to Gold and Silver command to help manage the situation and to be recorded remotely for evidential purposes.

The British Royal Wedding in 2011 was used as the second scenario. The numbers of users and the broadband applications which would be in use if a BB PPDR network was available was taken from discussions with the Metropolitan Police in September 2012. The following communciations needs were based on dividing the route into 'sectors', where in the worst case two sectors could be in the coverage area of a single cell.

- 1 video stream from the Royal Coach.
- 2 video streams from each side of the road from close protection officers lining the route - i.e. 4 streams/sector in total. This assumes video cameras on the 500 officers in each section lining the route on the lookout for suspicious activity directly facing the public can be switched on and off remotely as the royal coach makes it way along the route - hence there would be 2 video streams per side.
- 1 high resolution picture sent per minute from the helicopter to the coach and each of the bronze commanders managing each section. Frequency of updates would increase in the event of an incident.
- Selected still pictures from the helicopter and fixed cameras along the route would be sent to the two covert teams mingling with the crowd as and when felt necessary.
- The 60 officers of the two covert teams in each sector provide GPS based location updates every 5 seconds.

All of the three scenarios can be considered to be examples of PP2 scenario, although the Matrix also includes a background load of PP1 business as usual traffic of applications not associated with the PP2 incidents.

F.4.1.1 Generic LEWP matrix - users and applications

Table F.1 provides the LEWP users' estimates for the number of users in a cell for each application under peak busy hour and incident/emergency conditions in a heavily loaded cell in a heavily populated urban environment (such as London). This data is input to the matrix for the generic peak busy hour and incident situations.

Table F.1: Applications and user numbers in generic LEWP matrix

Type of application + services	Transaction per peak hour per user	Multiplication factor in emergency	Uplink users per cell (peak) for this application	Uplink users per cell (emergency)	Downlink users per cell (peak) for this application	Downlink users per cell (emergency)	Groups per cell instead of users (peak)	Groups per cell instead of users (emergency)	User distribution: i: incident, s: spread over cell, x: ignore
LOCATION DATA									
A(V)LS data to CCC	240	1	500	2 000					s
A(V)LS data return	60	2			50	100			i
MULTI MEDIA									
Video to/from CCC: following + intervention	1	1	2	2	8	8	2	2	s
Low quality additional feeds	1	1	6	6	8	8			s
Video for fixed observation	1	0,5	5	5					s
Low quality additional feeds	1	0.5	20	20					s
Video on location to/from CCC - high quality	1	1	0	4		1			i
Video on location to/from CCC - low quality	1	1	0	10					i
Video on location for local use	1	1	0	20		10		1	x
Video conferencing operations	1	0,1	1	6	1	6			i
Non real time recorded video transmission	1	1	5	5	5		1		i
Photo broadcast	2	1			500	2 000	2	2	s
Photo to selected group	2	1			500	2 000	10	10	s
OFFICE APPLICATIONS									
PDA PIMsync	2	0,2	500	2 000	500	2 000			s
Mobile workspace	5	0,2	50	100	50	100			s
DOWNLOAD OPERATIONAL INFORMATION									
Incident information download	2	1			500	1 000	10	20	i
ANPR update hit list	1	1			300	1 200	1	1	s
Download maps	1	2			50	200	10	20	s
Command & control information	1	4			500	1 000	10	20	i
UPLOAD OPERATIONAL INFORMATION									
Incident information upload	1	4	50	200					i
Status information + location	5	1	500	2 000					s
ANPR or speed control automatic upload	50	0	30	30					s
Forward scanned documents	0,1	30	10	25					i
Reporting incl. pictures etc	1	0,1	100	100					s
Upload maps + schemes	1	4	10	20					i
Patient monitoring (ECC) snapshot	1	12	5	100					i
Patient monitoring (ECC) real time	1	1	5	10					s
Monitoring status of security worker	120	1	10	100					i
ONLINE DATA BASE ENQUIRY									
Operational data base search	2	0,1	300	1 000	300	1 000			i
Remote medical database services	2	2	10	100	10	100			i
ANPR checking number plate live	5	0,1	300	1 200	300	1 200			s
Biometric (eg fingerprint) check	1	0,1	300	600	300	600			i
Cargo data	1	0,5	10	50	10	50			s
Crash Recovery information request	1	0,5	10	50	10	50			i
Crash Recovery System update	0,1	0			10	50			i
MISCELLANEOUS									
Software update online					0	0			x
GIS maps updates					0	0			x
Authomatic telemetrics	60	1	100	100					s
Hotspot on disaster or event area									x
Front office - back office applicaties	3	0,1	300	1 200	300	1 200			s
Alarming / paging	1	1	100	100	100	100	15	15	s
Traffic management system	4	2			50	200	10	20	s
Connectivity of foreign force to local ccc									x

F.4.1.2 Riots scenario: users and applications

The data in table F.2 shows the number of users of each application required in the Riots scenario. To assist recognizing the difference with the generic matrix data, applications related to the incident are shaded orange, and changed figures are highlighted as **bold** text. Further notes relating to the use of applications are listed in table F.2. Note that there are no changes in the 'peak hour' figures and these are not used in the calculation; however these are left in the table to provide consistent positioning of data within the matrix.

Table F.2: Applications and user numbers in riot scenario

Type of application + services	Transaction per peak hour per user	Multiplication factor in emergency	Uplink users per cell (peak) for this application	Uplink users per cell (emergency)	Downlink users per cell (peak) for this application	Downlink users per cell (emergency)	Groups per cell instead of users (peak)	Groups per cell instead of users (emergency)	User distribution: i: incident, s: spread over cell, x: ignore	Notes
LOCATION DATA										
A(V)LS data to CCC	240	1	500	2 000					s	
A(V)LS data return	60	2			50	**1,5**			i	1
MULTI MEDIA										
Video to/from CCC: following + intervention	1	1	2	**4**	8	8	2	2	s	2
Low quality additional feeds	1	1	6	6	8	8			s	3
Video for fixed observation	1	0,5	5	5					s	3
Low quality additional feeds	1	0,5	20	20					s	3
Video on location to/from CCC - high quality	1	1	0	**1**		1			i	4
Video on location to/from CCC - low quality	1	**1**	0	**0**					i	5
Video on location for local use	1	1	0	20		10		1	x	6
Video conferencing operations	1	**1**	1	**1**	1	**1**			i	7
Non real time recorded video transmission	1	1	5	**0**	5	**0**	1		i	5
Photo broadcast	2	1			500	2 000	2	2	s	
Photo to selected group	2	1			500	2 000	10	10	s	
OFFICE APPLICATIONS										
PDA PIMsync	2	0,2	500	2 000	500	2 000			s	
Mobile workspace	5	0,2	50	100	50	100			s	
DOWNLOAD OPERATIONAL INFORMATION										
Incident information download	2	1			500	**300**	10	20	i	8
ANPR update hit list	1	1			300	1 200	1	1	s	
Download maps	1	2			50	200	10	20	s	9
Command & control information	1	4			500	**0**	10	**0**	i	5
UPLOAD OPERATIONAL INFORMATION										
Incident information upload	1	4	50	**300**					i	10
Status information + location	5	1	500	2 000					s	
ANPR or speed control automatic upload	50	0	30	30					s	
Forward scanned documents	0,1	30	10	**0**					i	5
Reporting incl. pictures etc	1	0,1	100	100					s	
Upload maps + schemes	1	4	10	**0**					i	5
Patient monitoring (ECC) snapshot	1	12	5	100					i	11
Patient monitoring (ECC) real time	1	1	5	10					s	
Monitoring status of security worker	120	1	10	**0**					i	5
ONLINE DATA BASE ENQUIRY										
Operational data base search	2	0,1	300	**0**	300	**0**			i	5
Remote medical database services	2	2	10	100	10	100			i	11
ANPR checking number plate live	5	0,1	300	1 200	300	1 200			s	
Biometric (eg fingerprint) check	1	0,1	300	**0**	300	**0**			i	5
Cargo data	1	0,5	10	50	10	50			s	
Crash Recovery information request	1	0,5	10	**0**	10	**0**			i	5
Crash Recovery System update	0,1	0			10	**0**			i	5

Type of application + services	Transaction per peak hour per user	Multiplication factor in emergency	Uplink users per cell (peak) for this application	Uplink users per cell (emergency)	Downlink users per cell (peak) for this application	Downlink users per cell (emergency)	Groups per cell instead of users (peak)	Groups per cell instead of users (emergency)	User distribution: i: incident, s: spread over cell, x: ignore	Notes
MISCELLANEOUS										
Software update online					0	0				
GIS maps updates					0	0				
Authomatic telemetrics	60	1	100	100					s	
Hotspot on disaster or event area									x	6
Front office - back office applicaties	3	0,1	300	1 200	300	1 200			s	
Alarming / paging	1	1	100	100	100	100	15	15	s	
Traffic management system	4	2			50	200	10	20	s	
Connectivity of foreign force to local ccc									x	

NOTE 1: Number of users in cell remains as for original LEWP matrix; this would include incident users.
NOTE 2: The intervention and fixed video users are unchanged as this is the assumed background load on the cell not connected with the incident. However, the helicopters have been added in here. We can assume that the helicopters never reach an edge of cell spectrum efficiency, hence adding them here rather than together with the incidents ensures that they are grouped with the 'average' spectrum efficiency.
NOTE 3: No change, as background load assumed to as LEWP scenario.
NOTE 4: One feed per incident per scenario.
NOTE 5: Not mentioned in scenario so reduced to zero.
NOTE 6: Not included in calculation as carried locally.
NOTE 7: Assume that at least one video conference needed per incident, for bronze commander to communicate with silver command. Factors here allow a single 10 minute call per incident, considered appropriate by LEWP experts.
NOTE 8: Incident users reduced to 300 per incident according to scenario. Download operational info is estimated to same data size as maps, therefore this is equivalent to the map + other info download to officers at the incident points.
NOTE 9: Background load download map load infomation unchanged; it is assumed that others in the cell need directions related to the incident (to reach it or avoid it, or other related purposes).
NOTE 10: Changed to 300 users per incident to upload operational information including pictures.
NOTE 11: Unchanged, as presumed to be still required by ambulance service.

F.4.1.3 Royal Wedding scenario: Users and applications

The data in table F.3 shows the number of users of each application required in the Royal Wedding scenario. To assist recognising the difference with the generic matrix data, applications related to the incident are shaded orange, and changed figures are highlighted as **bold** text. Further notes relating to the use of applications are listed in table F.3. Note that there are no changes in the 'peak hour' figures and these are not used in the calculation; however these are left in the table to provide consistent positioning of data within the matrix.

Table F.3: Applications and user numbers in Royal Wedding Scenario

Type of application + services	Transaction per peak hour per user	Multiplication factor in emergency	Uplink users per cell (peak) for this application	Uplink users per cell (emergency)	Downlink users per cell (peak) for this application	Downlink users per cell (emergency)	Groups per cell instead of users (peak)	Groups per cell instead of users (emergency)	User distribution: i: incident, s: spread over cell, x: ignore	Notes
LOCATION DATA										
A(V)LS data to CCC	240	1	500	**2 240**					s	1
A(V)LS data return	60	2			50	**1**			i	2
MULTI MEDIA	-	-	-	-	-	-	-	-	-	
Video to/from CCC: following + intervention	1	1	2	2	8	8	2	2	s	3
Low quality additional feeds	1	1	6	6	8	8			s	3
Video for fixed observation	1	0,5	5	5					s	3
Low quality additional feeds	1	0,5	20	20					s	3
Video on location to/from CCC - high quality	1	1	0	**4,5**		**0**			i	4
Video on location to/from CCC - low quality	1	1	0	**10**					i	5
Video on location for local use	1	1	0	20		10		1	x	
Video conferencing operations	1	**0,5**	1	**1**	1	**1**			i	6
Non real time recorded video transmission	1	1	5	**0**	5	**0**	1		i	7
Photo broadcast	2	1			500	2 000	2	2	s	
Photo to selected group	2	1			500	2 000	10	10	s	
OFFICE APPLICATIONS						-	-	-	-	
PDA PIMsync	2	0,2	500	2 000	500	2 000			s	
Mobile workspace	5	0,2	50	100	50	100			s	
DOWNLOAD OPERATIONAL INFORMATION	-	-	-	-	-	-	-	-	-	
Incident information download	**6**	1			500	**60**	10	**1**	i	8
ANPR update hit list	1	1			300	1 200	1	1	s	
Download maps	1	2			50	200	10	20	s	9
Command & control information	1	**60**			500	**1,5**	10	**1**	i	10
UPLOAD OPERATIONAL INFORMATION	-	-	-	-	-	-	-	-	-	11
Incident information upload	1	4	50	**300**					i	
Status information + location	5	1	500	2 000					s	
ANPR or speed control automatic upload	50	0	30	30					s	7
Forward scanned documents	0,1	30	10	**0**					i	12
Reporting incl. pictures etc	1	**1**	100	**160**					s	7
Upload maps + schemes	1	4	10	**0**					i	13
Patient monitoring (ECC) snapshot	1	12	5	**5**					i	
Patient monitoring (ECC) real time	1	1	5	10					s	7
Monitoring status of security worker	120	1	10	**0**					i	
ONLINE DATA BASE ENQUIRY	-	-	-	-	-	-	-	-	-	
Operational data base search	2	0,1	300	**0**	300	**0**			i	7
Remote medical database services	2	2	**10**	10	10	**10**			i	14
ANPR checking number plate live	5	0,1	300	1 200	300	1 200			s	
Biometric (eg fingerprint) check	1	0,1	300	**0**	300	**0**			i	7
Cargo data	1	0,5	10	50	10	50			s	
Crash Recovery information request	1	0,5	10	50	10	**0**			i	7
Crash Recovery System update	0,1	0			10	**0**			i	7

Type of application + services	Transaction per peak hour per user	Multiplication factor in emergency	Uplink users per cell (peak) for this application	Uplink users per cell (emergency)	Downlink users per cell (peak) for this application	Downlink users per cell (emergency)	Groups per cell instead of users (peak)	Groups per cell instead of users (emergency)	User distribution: i: incident, s: spread over cell, x: ignore	Notes
MISCELLANEOUS										
Software update online					0	0				
GIS maps updates					0	0				
Authomatic telemetrics	60	1	100	100					s	
Hotspot on disaster or event area									x	
Front office - back office applicaties	3	0,1	300	1 200	300	1 200			s	
Alarming / paging	1	1	100	100	100	100	15	15	s	
Traffic management system	4	2			50	200	10	20	s	
Connectivity of foreign force to local ccc									x	

NOTE 1: The number has been increased to allow for the 120 covert officers sending data every 5 seconds. The original number allowed 2 000 users sending data every 15 seconds, therefore the covert users will send 120 x 2 = 240 more updates per 15 seconds than other users.

NOTE 2: If there are two sub bronze commanders per section, then we need 1 per incident (as incident is mapped to section).

NOTE 3: The intervention and fixed video users are unchanged from the matrix as this is the assumed background load on the cell not connected with the incident.

NOTE 4: Four feeds per section, plus one feed on the coach. As the coach only keeps one feed where it moves between sections, 'half' a feed becomes one feed in the two section scenario. This will only contribute half a feed at an edge of cell if one section is at the edge of a cell - but it is probable that of the four other feeds, not all will be worst case, so this will somewhat compensate for that. No downlink feed identified in the scenario.

NOTE 5: Scenario calls for individual feeds from up to 500 officers to be selected for high quality use. We assume that a number of low quality feeds will be required so that the commander/control room know which to select to high quality. Therefore the LEWP proposed 10 low quality feeds per incident have been retained.

NOTE 6: Assume that at least one video conference needed per incident, for bronze commander to communicate with silver command. The multiplication factor can determine the length of the call: 0,5 allows 5 minutes.

NOTE 7: Not mentioned in scenario so reduced to zero.

NOTE 8: Incident users are included as the covert users who receive pictures from helicopters and fixed cameras as necessary. 60 covert users per sector used for the number of users. Assumed one picture every 10 minutes per user. Also assumed that all users in the same section receive the same information, i.e. only 1 group is needed per section.

NOTE 9: Background load download map load infomation unchanged; it is assumed that others in the cell need directions related to the incident (to reach it or avoid it, or other related purposes).

NOTE 10: The scenario calls for one high resolution picture per minute to the coach and to the bronze commanders. This is captured here. As with the camera feeds, the coach has been divided between the two incident/bronze commanders, which will reduce the effect at the edge of cell somewhat.
If a group call, only one group would be needed.
The data will be increased from 50 kbytes to 1 Mbyte for a reasonably high resolution picture."

NOTE 11: Changed to 300 users per incident to upload operational information including pictures; this will cover the uploads from fixed cameras, and could also be used to identify which cameras to switch to video stream.

NOTE 12: Incorporates load from helicopters on UL.

NOTE 13: The number of users in the scenario has been reduced to 5, the same as the LEWP peak busy hour figure, as in this incident, medical issues will be mainly small incidents (fainting, etc.) in the crowd. The multiplication factor allows 1 snapshot per 5 minutes, same as LEWP emergency case.

NOTE 14: As with patient data, the number of users has been reduced to the same as peak busy hour numbers from LEWP, as this is a peaceful incident. The multiplication factor allows 4 transactions per hour, same as LEWP emergency case.

F.4.2 Load in each scenario

F.4.2.1 LEWP Matrix generic scenario

Table F.4 shows the offered load in the scenarios incorporated into the generic Matrix:

Table F.4: Offered load using generic LEWP matrix

	Data Load (kbps)		
	Uplink	Downlink	Downlink with Group call (individual+multicast)
LEWP Matrix 121130			
Peak busy hour	3 561	7 297	2 287
Background load during incident	2 641	7 688	2 111
Load per incident	4 038	1 557	917

The 'Uplink' and 'Downlink' figures show the offered data load assuming all use is unicast (individual transactions for each user). The 'Downlink with Group call' column shows the reduced data load where any transaction that can be sent more efficiently with a group call uses multicast transmission, and then the remaining transactions use unicast: i.e. the table shows the sum total of unicast and multicast transmission data rates on the downlink.

The background load includes video from two chase situations. A reduced background load was also adopted where data load from a single chase only was included, to examine the effect in the worst case scenario with two incidents.

Table F.5: Reduced incident load using LEWP matrix

	Data Load (kbps)		
	Uplink	Downlink	Downlink with Group call (individual+multicast)
LEWP Matrix 121130			
Reduced background load during incident	1 873	4 616	1 343
Load per incident	4 038	1 557	917

F.4.2.2 Royal Wedding scenario

Table F.6: Offered load in Royal Wedding scenario

	Data Load (kbps)		
	Uplink	Downlink	Downlink with Group call (individual+multicast)
Royal Wedding Scenario			
Background load during incident	2 985	7 688	2 111
Load per 'sector' (= incident)	4 257	266	294

The increase in uplink background load in this scenario compared with the generic LEWP matrix was due to the scenario applying an increased rate of personal location transmissions to a set of covert users above the rate set in the matrix.

F.4.2.3 London Riots scenario

Table F.7: Offered load in London Riots scenario

	Data Load (kbps)		
	Uplink	Downlink	Downlink with Group call (individual+multicast)
London Riots Scenario			
Background load during incident	4 177	7 688	2 111
Load per incident	1 078	922	864

The increase in uplink background load was due to the scenario adding in a number of video feeds from helicopters. These were added as background rather than incident load to ensure that they always caused a load at average spectrum efficiency, even if incidents took place at edge of cell.

F.4.3 Spectrum efficiencies applied

Spectrum efficiency figures were applied for an 'average' location in a cell and for edge of the cell. The figures adopted were chosen in consideration of TR 136 912 [i.78] and those in Recommendation ITU-R M.2198 [i.77] which included performance reports on LTE for an IMT technology, applied in a macrocell condition (considered a likely PPDR solution).

It is assumed that a spectrum efficiency of 1,5 bps/Hz is achievable on average in a PPDR network on the downlink, and 1,0 bps/Hz on the uplink.

Two edge of cell spectrum efficiency figures are used to provide a sensitivity analysis. The more pessimistic is a spectrum efficiency of 0,1 bps/Hz uplink and 0,15 bps/Hz downlink (similar or slightly optimistic compared with TR 136 912 [i.78]). The more optimistic assumes that the network is designed with smaller cells to provide a higher bit rate at the cell edges, and has been rounded to 0,3 bps/Hz for both uplink and downlink.

The figures above were applied in both individual and group downlink cases.

F.4.4 Spectrum demand results

The results from the calculations of spectrum in the various scenarios are given in the following clauses. In each case, the table lists uplink and downlink spectrum demands calculated by the Matrix for the various scenarios as the number and position of incidents is varied. The tables also show variation in results with more optimistic and more pessimistic spectrum efficiency values.

F.4.4.1a LEWP Matrix 121130 - pessimistic edge of cell spectrum efficiency

Table F.8: Spectrum demand using generic LEWP matrix with pessimistic edge of cell spectrum efficiency

	Spectrum requirements (MHz)		
	Uplink	**Individual Downlink**	**Optimized Group DL**
Edge of cell spectrum efficiency:	0,1 bps/Hz	0,15 bps/Hz	0,15 bps/Hz
Average spectrum efficiency:	1 bps/Hz	1,5 bps/Hz	1,5 bps/Hz
Peak busy hour	4,4	4,9	4,7
1 incident at average position	7,5	8	7,2
1 incident at edge of cell	17,1	14,3	9,4
2 incidents at average position	11,5	9,1	8
2 incidents, 1 at edge of cell	21,2	15,3	10,2
2 incidents, 1 at edge of cell, reduced background load	20,4	13,2	6,6

F.4.4.1b LEWP Matrix 121130 - optimistic edge of cell spectrum efficiency

Table F.9: Spectrum demand using generic LEWP matrix with optimistic edge of cell spectrum efficiency

	Spectrum requirements (MHz)		
	Uplink	**Individual Downlink**	**Optimized Group DL**
Edge of cell spectrum efficiency:	0,3 bps/Hz	0,3 bps/Hz	0,3 bps/Hz
Average spectrum efficiency:	1 bps/Hz	1,5 bps/Hz	1,5 bps/Hz
Peak busy hour	3,9	4,9	4,6
1 incident at average position	7,1	7,8	5,9
1 incident at edge of cell	10,2	11,4	7,7
2 incidents at average position	11,1	8,9	6,5
2 incidents, 1 at edge of cell	14,3	12,5	8,3
2 incidents, 1 at edge of cell, reduced background load	13,5	10,4	5,8

F.4.4.2a Royal Wedding scenario - pessimistic edge of cell spectrum efficiency

Table F.10: Spectrum demand in Royal Wedding scenario with pessimistic edge of cell spectrum efficiency

	Spectrum requirements (MHz)		
	Uplink	**Individual Downlink**	**Optimized Group DL**
Edge of cell spectrum efficiency:	0,1 bps/Hz	0,15 bps/Hz	0,15 bps/Hz
Average spectrum efficiency:	1 bps/Hz	1,5 bps/Hz	1,5 bps/Hz
1 'sector' at average position	8,1	7,2	6,6
1 'sector' at edge of cell	16,3	8,8	7,9
2 'sectors' at average position	12,3	7,4	6,7
2 'sectors', 1 at edge of cell	20,6	8,9	8,1

F.4.4.2b Royal Wedding scenario - optimistic edge of cell spectrum efficiency

Table F.11: Spectrum demand in Royal Wedding scenario with optimistic edge of cell spectrum efficiency

	Spectrum requirements (MHz)		
	Uplink	**Individual Downlink**	**Optimized Group DL**
Edge of cell spectrum efficiency:	0,3 bps/Hz	0,3 bps/Hz	0,3 bps/Hz
Average spectrum efficiency:	1 bps/Hz	1,5 bps/Hz	1,5 bps/Hz
1 'sector' at average position	7,6	7	5,3
1 'sector' at edge of cell	10,5	7,7	5,9
2 'sectors' at average position	11,9	7,1	5,5
2 'sectors', 1 at edge of cell	14,8	7,8	6,1

F.4.4.3a London Riots scenario - pessimistic edge of cell spectrum efficiency

Table F.12: Spectrum demand in London Riots scenario with pessimistic edge of cell spectrum efficiency

	Spectrum requirements (MHz)		
	Uplink	**Individual Downlink**	**Optimized Group DL**
Edge of cell spectrum efficiency:	0,1 bps/Hz	0,15 bps/Hz	0,15 bps/Hz
Average spectrum efficiency:	1 bps/Hz	1,5 bps/Hz	1,5 bps/Hz
1 incident at average position	6,1	7,6	7
1 incident at edge of cell	9,1	10	9,1
2 incidents at average position	7,1	8,2	7,7
2 incidents, 1 at edge of cell	10,2	10,6	9,7

F.4.4.3b London Riots scenario - optimistic edge of cell spectrum efficiency

Table F.13: Spectrum demand in London Riots scenario with optimistic edge of cell spectrum efficiency

	Spectrum requirements (MHz)		
	Uplink	**Individual Downlink**	**Optimized Group DL**
Edge of cell spectrum efficiency:	0,3 bps/Hz	0,3 bps/Hz	0,3 bps/Hz
Average spectrum efficiency:	1 bps/Hz	1,5 bps/Hz	1,5 bps/Hz
1 incident at average position	6,1	7,4	5,8
1 incident at edge of cell	6,6	9,3	7,5
2 incidents at average position	6,7	8	6,4
2 incidents, 1 at edge of cell	7,7	9,9	8,1

F.4.4.4 Average results across the three scenarios - pessimistic spectrum efficiency

Table F.14 averages the results using pessimistic edge of cell spectrum efficiency across the three scenarios, with the various different combinations of incident number and positioning. Whereas an average in this way does not relate to any individual scenario anymore, it can serve to give a single indication taken from a range of situations. The final rows in the table provide further averaging of all results within the table for the different positioning of incidents.

Table F.14: Average spectrum demand across three scenarios with pessimistic edge of cell spectrum efficiency

	Spectrum requirements (MHz)		
	Uplink	**Individual Downlink**	**Optimized Group DL**
Edge of cell spectrum efficiency:	0,1 bps/Hz	0,15 bps/Hz	0,15 bps/Hz
Average spectrum efficiency:	1 bps/Hz	1,5 bps/Hz	1,5 bps/Hz
1 incident at average position	7,2	7,6	6,9
1 incident at edge of cell	14,2	11,0	8,8
2 incidents at average position	10,3	8,2	7,5
2 incidents, 1 at edge of cell	17,3	11,6	9,3
Average 1 incident	10,7	9,3	7,9
Average 2 incidents	13,8	9,9	8,4

F.4.4.5 Average results across the three scenarios - optimistic spectrum efficiency

Table F.15 provides average results, as for the previous table, except with the more optimistic edge of cell spectrum efficiency.

Table F.15: Average spectrum demand across three scenarios with optimistic edge of cell spectrum efficiency

	Spectrum requirements (MHz)		
	Uplink	**Individual Downlink**	**Optimized Group DL**
Edge of cell spectrum efficiency:	0,3 bps/Hz	0,3 bps/Hz	0,3 bps/Hz
Average spectrum efficiency:	1 bps/Hz	1,5 bps/Hz	1,5 bps/Hz
1 incident at average position	6,9	7,4	5,7
1 incident at edge of cell	9,1	9,5	7,0
2 incidents at average position	9,9	8,0	6,1
2 incidents, 1 at edge of cell	12,3	10,1	7,5
Average 1 incident	8,0	8,4	6,4
Average 2 incidents	11,1	9,0	6,8

F.4.5 Discussion of results

The spectrum demands are dependent on a number of factors, both related to the technology and use of group call services, and the network planning, and also to the scenario. Large incidents at the edge of cell create the greatest spectrum demands.

F.4.5.1 Uplink demand

Uplink demand in peak busy hour is considered distributed evenly across the cell, and is relatively insensitive to the cell edge spectrum efficiency. The LEWP Matrix scenario for peak busy hour uplink demand changed from 4,4 MHz to 3,9 MHz when the spectrum efficiency was improved from 0,1 bps/Hz to 0,3 bps/Hz. Similar results are seen where incidents take place in average cell positions; for example the Royal Wedding scenario demand only changed from 12,3 MHz to 11,9 MHz when two 'sectors' (incidents) are located in average positions and spectrum efficiency is similarly improved.

Uplink demand is obviously very sensitive to cell edge spectrum efficiency where an incident is located at the edge of a cell. In the LEWP Matrix scenario with two incidents, one at edge of cell, the spectrum demand increased from 14,3 MHz to 21,2 MHz with the change from 0,3 bps/Hz to 0,1 bps/Hz. Similar effects are seen in the other scenarios: The Royal Wedding scenario demand increases from 14,8 MHz to 20,6 MHz, and the Riots scenario demand increased from 7,7 MHz to 10,2 MHz.

If the more optimistic spectrum efficiency for the uplink is assumed with appropriate network planning, the demand with two incidents, one at edge of cell, varies from 7,7 MHz (London Riots scenario) to 14,8 MHz (Royal Wedding scenario). If only one incident takes place in the cell but at the cell edge, the demand reduces to 10,5 MHz in the Royal Wedding scenario (the worst case of the scenarios investigated).

In all cases, a background load is incorporated into the results. Where the background load was reduced in the LEWP Matrix scenario with two incidents at edge of cell, there was a reduction in spectrum demand of approximately 800 kHz, reducing the demand by 4-6 % for pessimistic and optimistic spectrum efficiency cases respectively. It can be seen that the reduction is not particularly significant compared with the remaining load.

The average spectrum demand for the uplink was 13,8 MHz for two incidents with the pessimistic spectrum efficiency of 0.1 bps at edge of cell, falling to 11,1 MHz for the more optimistic 0,3 bps/Hz figure.

F.4.5.2 Downlink demand

Downlink demand is similarly sensitive to edge of cell spectrum efficiency where incidents occur at the edge of cell. However the use and technology associated with a group call also has a heavy influence.

Considering individual call only scenarios, the demand for the worst case conditions with two incidents where one is at the edge of the cell, varies from 12,5 MHz to 15,3 MHz in the LEWP Matrix (worst scenario) and from 7,8 MHz to 8,9 MHz in the Royal Wedding scenario (best scenario) when the spectrum efficiency at edge of cell is changed from 0,1 bps/Hz to 0,3 bps/Hz. On examination of the offered load in the scenarios, this is because of the dominant nature of the background load in each scenario, where background load is considered to be evenly distributed across the cell.

Use of optimized group call, where the use of group call is chosen only where it has an advantage over a set of individual calls, reduces the demand for spectrum. In the LEWP Matrix scenario, the reduction is from 15,3 MHz to 10,2 MHz for the two incident case and 0,15 bps/Hz edge of cell spectrum efficiency, and from 12,5 MHz to 8,3 MHz with 0,3 bps/Hz spectrum efficiency, with similar reductions in other scenarios.

The sensitivity to background load was also examined by reducing the background load in the LEWP Matrix scenario with two incidents at the edge of cell. The reduction is around 2 MHz in the individual downlink case (16-20 % depending on edge of cell spectrum efficiency); and greater (30-35 %) in the group call case. The effect is therefore greater than that seen on the uplink; however the uplink has the dominant demand in any case.

The average spectrum demand for the downlink for two incidents with pessimistic 0,1 bps/Hz edge of cell spectrum efficiency was 9,9 MHz, falling to 9,0 MHz with the optimistic 0,3 bps/Hz figure. When group call is used, the demand fell to 8,4 MHz and 6,8 MHz respectively.

F.4.5.3 Summary of spectrum demands from scenarios

During incident conditions, the demand varies as follows, where the range of demands spans one or both incidents in average position, to one at edge of cell.

Table F.16: Summary of uplink spectrum demands

Uplink spectrum requirement (MHz)						
	Optimistic spectrum efficiency			Pessimistic spectrum efficiency		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Peak Busy Hour (see note)	-	-	4,4	-	-	3,9
1 incident						
	6,1	10,5	8,0	6,1	17,1	10,7
2 incidents						
	6,7	14,8	11,1	7,1	21,2	13,8
NOTE: Only one set of calculations was performed for peak busy hour, which used the generic LEWP matrix scenario, and is listed as the 'Average' result in this table.						

Table F.17: Summary of downlink spectrum demands

Downlink spectrum requirement (MHz)						
	Optimistic spectrum efficiency			**Pessimistic spectrum efficiency**		
	Minimum	**Maximum**	**Average**	**Minimum**	**Maximum**	**Average**
Peak Busy Hour (see note)						
Individual only	-	-	4,9	-	-	4,9
Group+Individual	-	-	4,7	-	-	4,6
1 incident						
Individual only	7,0	11,4	9,3	7,2	14,3	9,3
Group+Individual	5.3	7,7	6,4	6,6	9,4	7,9
2 incidents						
Individual only	7,1	12,5	9,0	7,4	15.3	9,9
Group+Individual	5,5	8,3	6,8	6,7	10.2	8,4
NOTE: Only one set of calculations was performed for peak busy hour, which used the generic LEWP matrix scenario, and is listed as the 'Average' result in this table.						

If 10 MHz was available for uplink, many but not all scenarios could be accommodated. If the network were designed for the optimistic spectrum efficiency at edge of cell, the spectrum available would be within 10 % of the average demand (which is probably within the bounds of error of the method used).

If 10 MHz was available for the downlink, most scenarios can be accommodated using an individual call, and if group call downlink is optimally used, then all scenarios can be accommodated.

F.5 Conclusions

From the analysis, it can be seen that most scenarios can be accommodated within 10 MHz of uplink spectrum especially where the network is designed for improved throughput at the edge of cells. In practice, there may be other techniques such as relay stations which could be used to improve edge of cell performance If the network is designed for maximum coverage, the uplink demand exceeds 10 MHz in many scenarios, and therefore other techniques such as relays, local coverage enhancements in incidents and restriction of application data rates may be necessary. It seems unlikely that a spectrum provision of less than 10 MHz will satisfy the demands.

The downlink can be satisfied with 10 MHz in just about all scenarios if the technology allows a true efficient group call to be used. If group call is not possible, then other techniques will be needed to alleviate the demands, as in the uplink.

Therefore an allocation of 10 + 10 MHz is a good basis for supporting PPDR wide area broadband communications on a harmonized basis. Clearly different national situations will have different requirements, and the matrix could be used as a means of estimating the demand in the various different environments.

Some of the scenarios indicate that over 20 MHz will be required on the uplink, and at least 15 MHz on the downlink. This indicates that additional spectrum local to the scene of the incident is likely to require at least another 10 + 10 MHz, probably on a higher frequency, to manage the peak demands of incidents. The Matrix deliberately did not estimate all traffic needs local to an incident, and therefore the actual demand may be higher.

Note that this analysis does not cover Air to Ground (except for some limited allowance), nor DMO, nor voice scenarios; and spectrum required for these would be in addition to the values calculated for data applications above. An estimation of voice requirements is made in Annex G of the present document.

F.6 Matrix

The spectrum calculating matrix is contained in archive tr_102628v010201p0.zip which accompanies the present document.

Annex G: Spectrum Calculations for Voice

G.1 Introduction

The purpose of this Annex is to estimate the relative spectrum efficiencies of TETRA group call speech with a solution based on LTE MBSFN, and to use this to estimate the amount of broadband spectrum that would be required to carry PPDR speech. The same calculation has been published in an Annex to ECC Report 199 [i.70].

The main calculation uses a 10 + 10 MHz bandwidth LTE channel, and a similar result for a 1,4 + 1,4 MHz channel is shown in clause G.8.

G.2 Architecture of LTE multicast transport

Group voice is assumed to be transported using the multicast-broadcast channel contained in specific sub-frames called MBMS sub-frames. The MBMS sub-frames may be transmitted synchronously by several base stations, offering a simulcast capability over a MBSFN area.

However, not all sub-frames can be allocated to multicast-broadcast traffic and this allocation is semi-static. Some information on the DL control channel indicates the change of multicast-broadcast configuration from time to time, and the mobile terminals monitor such information to maintain an up-to-date configuration information.

In the case of a FDD channel, the maximum number of sub-frames than may be allocated to multicast broadcast is 6 sub-frames every frame (i.e. 6 out of every set of 10 consecutive sub-frames).

G.3 Architecture of a voice over LTE channnel

For the purposes of this analysis, we will assume that MBSFN "macro-cell" is made of 4 synchronously transmitting elementary cells (or micro-cells). As the frequency reuse pattern is equal to one, it is clear that two neighbouring cells not belonging to the same MBSFN area, i.e. not transmitting the same information, cannot use the same sub-frames due to interference. It is thus necessary to define a time-multiplexed sequence with a reuse pattern to make sure that:

- All micro-cells inside a macro-cell (MBSFN area) use the same set of MBSFN sub-frames belonging to a time multiplexed sequence to transmit the same information
- The various neighbouring cells of a cell not transmitting the same information do not transmit conflicting information at the same time and thus use a different time multiplexed sequence

It is therefore possible to use a time pattern reuse pattern similar to a frequency reuse pattern in this case with a pattern repeat of 4 macros cells as shown in figure G.1.

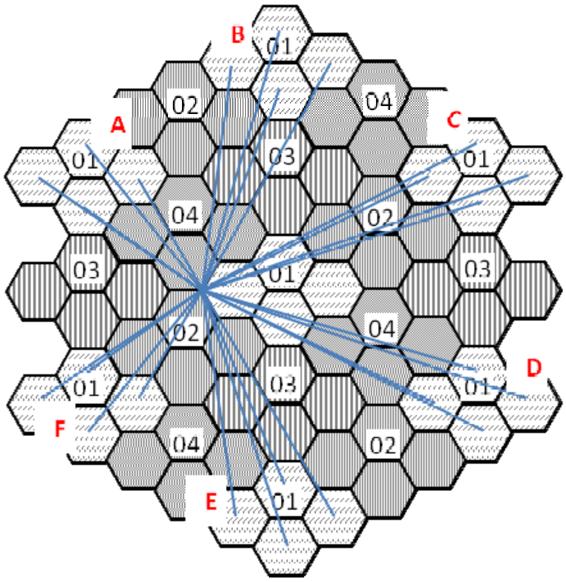


Figure G.1 Reuse pattern of MBSFN time multiplexing sequence

As can be seen in figure 1, each macro cell is therefore surrounded by six other interfering macro cells, in each of which four cells contribute interference according to their distance from the wanted point in the wanted cell. Assuming a worst case situation where an MS is on the extreme edge of a macrocell, each of the interfering cells contribute interference that is attenuated by distance. Using a 35 dB/decade law, the summed interference from these 6 × 4 interferers gives a C/I ratio of 13,3 dB.

For successful MBSFN area operation, the modulation which may be chosen for the transport of the multicast-broadcast blocks should have a SNR equal to the corresponding (summed) attenuation of the interfering signals minus an appropriate slow fading margin (6 dB to 8 dB), i.e. 5,3 dB to 7,3 dB.

G.4 Implication for LTE channels

An MBSFN broadcast channel can take one 1 msec sub-frame per 10 msec frame in its simplest form. Other variations, such as one sub-frame per mulitple frames, or multiple sub frames per frame, are possible; however for the purposes of this Annex, one sub frame per 10 msec frame will be assumed.

MBSFN channel performance is given in the simulation results from R4-101492 [i.73], which provides an estimate of performance, but without an implementation margin. These simulations can be taken and compared with the UE specification for MBSFN reception in TS 136 101 [i.74] to work out this implementation margin, and then with the coding rates of the different Moduation and Coding Schemes (MCSs) for the different available CQI (Channel Quality Information) sets given in TS 136 213 [i.75], the appropriate CQI can be chosen, hence the number of bits available per subframe can be estimated.

For a 10 MHz channel using QPSK 1/3, the more pessimistic of the curves in R4-101492 [i.73] indicate that 1,8 dB SINR is needed for 1 % BLER. If the voice channel can operate in 3 % BLER conditions, approximately 1dB SINR is needed from the curve. The specification in Table 10.1.1-2 of TS 136 101 [i.74] specifies 4,1dB SNR for 1% BLER, therefore indicating that there should be an approximately 2,3 dB implementation margin above the more pessimistic curve in R4-101492 [i.73]. This implies that the actual SINR required for 3 % BLER is approximately 3,3 dB.

Rate 1/3 coding would be achieved with a CQI=4 (coding rate 308/1 024 bits), and would require approx 3.3dB SINR as stated previously. As 5,3 dB SINR is available from the interference pattern, QCI = 5 can be chosen. The transport block size - how many bits can be transmitted per sub-frame - is given in Table 7.1.7.2.1-1 of TS 136 213 [i.75]. In a 10 MHz channel, which supports 50 resource blocks of 180 kHz each, 4 392 bits are available. If one sub-frame per frame is used for the MBSFN, 439 kbps throughput can be supported.

Each MBSFN macro cell is part of a four cell repeat pattern, and so the MBSFN complex is consuming 4/10 of the resources of the 10MHz channel, giving it an equivalent consumption of 4 MHz of spectrum. The spectrum efficiency is therefore 439/4 000 = 0,11 bps/Hz.

The spectrum required for a speech channel will depend on the speech codec used. A codec rate of 10 kbps should allow the TETRA or equivalent quality codec to be used taking the various overheads for channel management and networking (e.g. IP) into account. A higher rate would give the end users an improvement in audio quality.

A 10 kHz codec rate will have an equivalent spectrum demand of 91 kHz per voice 'channel' as 44 voice channels can be supported in 4 MHz. A higher equivalent bandwidth may be demanded if better speech quality was desired.

G.5 Spectrum efficiency for TETRA

Annex B of the present document makes some comparisons with previous results for the reuse factor possible in TETRA, based on ERC report 52, ECC report 42 and some other calculations. If we adopt a C/I requirement of 17 dB (similar to that suggested in Annex B, and a figure closer to practice than the 19 dB maximum limit in the TETRA specification) with an 8 dB slow fade margin and a geometry factor of 7, then the method of ECC report 42 with a path loss factor of 3,5 indicates a practical frequency repeat pattern of 28 cells.

The TETRA codec requires 4,567 kbps for one speech channel, and this occupies an equivalent of 6,25 kHz bandwidth (as four channels are contained in 25 kHz). The effect of the frequency repeat pattern will cause this to scale to one channel in $6{,}25 \times 28 = 175$ kHz.

G.6 Spectrum efficiency comparison

If we compare these two results, the LTE MBSFN in a 10 MHz channel will be more efficient than TETRA by 175/91 = 1,9 x.

G.7 Spectrum requirement for group call voice over LTE

Existing TETRA networks require at least 5 + 5 MHz to provide group call services in large urban areas. In some cases additional spectrum of up to 2 + 2 MHz is utilized, although the total spectrum includes air to ground and Direct Mode use, which will reduce the trunked mode wide area requirement to a maximum of 6 + 6 MHz

If we assume that the LTE network is 1,9x as efficient for group calls than a TETRA network, then spectrum required for group call voice over LTE will be of the order of 3,2 + 3,2 MHz

G.8 Sensitivity analysis

The method above has been repeated with variations in the cell repeat pattern and LTE channel bandwidth.

A 3×3 cell pattern could use less capacity in an LTE carrier for MBSFN use, as only three sub-frames would need to be reserved for group call use.

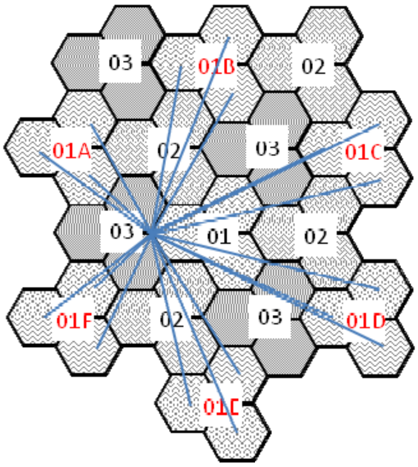


Figure G.2: 3x3 Macro cell repeat pattern

However, the closer nature of the cells increases the interference, and the edge of the MBSFN macro cell only achieves 7,5 dB SINR. With the slow fading margin, only 0 dB SINR is likely to be achieved. This reduces the CQI to 2, and 222 kbps throughput - i.e. approximately half of the throughput for a saving of only ¼ of the bandwidth of the channel. Therefore the 4 × 4 pattern is more efficient.

Larger patterns of 5 or 7 cells per macro cell with a 3 macro cell repeat pattern improve the performance; the 5 cells per macro cell achieves similar spectrum efficiency to the 4 × 4 cell pattern, and the 7 cell per macro cell case achieves better spectrum efficiency. However the larger the macro cell cluster, the greater the chance that the MBSFN area does not match the operational area of a group; and inefficiencies in this will reduce the overall spectrum efficiency of the system. Therefore the 4x4 cell pattern used here seems to have the optimum efficiency.

The 4x4 pattern was repeated for 1,4 MHz LTE. In this case, the curves in R4-101492 [i.73] suggest a 4,2 dB SINR as required for 1 % BLER, which when compared with the 6.6dB SINR requirement in Table 10.1.1-2 of TS 136 101 [i.74], implies a 2,4 dB implementation margin. For the 3 % BLER case, the curves indicate approximately 3 dB SNR, which implies that the pattern needs to provide 5,4 dB SINR. As the result for the pattern with slow fade margin gives 5,3 dB, a CQI of 4 can be used, providing 408 bits per block, or 41 kbps/sec; thus supporting 4 voice channels in effectively 560 kHz (4/10 of a 1,4 MHz channel). This gives a spectrum efficiency of 140 kHz/voice channel, 1,25x improved compared with TETRA. In this case, 6 + 6 MHz of TETRA spectrum would require 4,8 + 4,8 MHz of LTE spectrum.

The 4 × 4 pattern was also checked to see whether a second and third tier of interfering cells would influence the result. The difference in adding in the next 12 macro cells (hence 48 interfering cells) made 0,3 dB difference to the SINR, and so was neglected.

Annex H: Bibliography

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History

Document history		
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