EMPhAtiC: Progress towards standardization and regulation

Reconfigurable Radio Systems potentialities for the civil security domain

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I. INTRODUCTION

The EMPhAtiC project has explored technical solutions based on Filter-Bank approach with application to the domain of Professional Mobile Radio (PMR) and more specifically for the coexistence between narrowband PMR systems and broadband PMR systems in the same frequency band in a spectrum efficient manner. In the frame of the project a lot of techniques for achieving this target have been studied, simulated and developed, notably a flexible fast convolution filter-bank based waveform processing method.

The present paper will show the standardization actions that have been carried out by the EMPhAtiC project and more particularly by the two main industrial partners of the project, AIRBUS Defence and Space (ex-Cassidian) and Thales Communications and Security (TCS). In the frame of these actions, an approach for the introduction of a PMR broadband system in the 400 MHz band where narrowband PMR systems used today for different usages, civil PMR, public safety PMR, PMR for defence purpose, are already deployed. This approach, using the Filter-Bank technology studied in EMPhAtiC project, enables to deploy the broadband PMR system while fully preserving the pre-existing incumbent narrowband PMR systems and provides an additional broadband capacity and capability. This approach permits to provide new services to Public Safety users and to improve the spectrum efficiency in the corresponding frequency bands, notably the 400 MHz band.

Chapter II will present the standardization and regulation bodies addressed by the EMPhAtiC project through the contributions of the main industrial partners of the project.

Chapter III will present the contribution of main industrial partners of the EMPhAtiC project to the standardization and regulation bodies.

Chapter IV presents the opportunities of lobbying through dedicated workshops, forums or meetings.

Chapter V is the presentation made during RRS workshop on December 3rd, 2014, in Sophia Antipolis, which gives the approach proposed for the introduction of a PMR broadband system in 400 MHz band.

Chapter VI.deals with the contribution to ETSI Technical Report 103 217.

Chapter VII gives a conclusion.

II. OVERVIEW OF STANDARDIZATION AND REGULATION BODIES ADDRESSED BY MAIN EMPHATIC INDUSTRIAL PARTNERS

A. 3GPP Radio Access Network (RAN) working groups

The two groups mainly involved in Radio Spectrum aspects are:

- RAN WG1: Radio Layer 1
- RAN WG4: Radio Performance and Protocol Aspects

3GPP RAN WG1 is responsible for defining the specifications of the physical layer of the Radio Interface for UE, Evolved UTRAN (LTE – Long Term Evolution) covering both FDD and TDD modes, as well as the physical layer of the Un Interface for Relay Nodes.

The work in RAN WG1 includes especially:

- Specification of physical channel structures,
- Specification of the mapping of the transport channels onto physical channels,
- Specification of the physical layer multiplexing, channel coding and error detection,
- Specification of the modulation,
- Specification of the physical layer procedures,
- Specification of definition of measurements and their provision by the physical layer to the upper layers.

RAN WG1 also carries out work related to handling of the physical layer related UE capabilities and to physical layer related parameters used in UE tests.

3GPP RAN WG4 is responsible for:

- Radio specification for the LTE Base Station, Repeater and Terminal,
- LTE Base Station and Repeater Radio Conformance test specifications,
- LTE Base Station, Repeater and Terminal EMC specifications,
- Radio Link requirement specification,
- Cell selection/reselection performance requirement specifications,
- Performance requirements in support of Radio Resource Management,
- Specification of the accuracy of measurements offered by the physical layer to the upper layers Radio system scenario analysis and simulation.

B. European Telecommunications Standards Institute (ETSI)

The Technical Committee in charge of PMR subjects is TC TCCE (Technical Committee TETRA and Critical Communications). This committee was formerly called TC TETRA.

More specifically, ETSI TCCE WG4 is in charge of broadband PMR subjects and matters.

Another group will also be considered: ETSI ERM (Electromagnetic and Radio Spectrum Matters) TGDMR (Technical Group Digital Mobile Radio), which is in charge of coexistence standards for PMR systems.

The tasks addressed are:

- Develop and maintain, upon the request of TC-ERM, standards and technical reports, ensuring the efficient use of the radio frequency spectrum, primarily for private/professional land mobile radio systems.

The following areas of work are covered:

- Data equipment, including digital speech equipment, Small land mobile radio systems, Citizen's Band equipment.
- Maintenance action on existing standards in the field of private/professional land mobile radio systems covers the following twelve standards: EN 300 086, EN 300 113, EN 300 296, EN 300 341, EN 300 390, EN 300 471, EN 300 753, EN 301 166, EN 301 391, EN 300 135, EN 300 433, EN 301 783.
- The task is to develop an ETSI Technical Specification (TS) for low cost, low complexity, digital mobile radio systems (DMR) complying with EN 300 113, with a 'polite' spectrum access protocol for channel sharing situations and using proven techniques.
- The task is to develop an ETSI Technical Specification (TS) for low cost, low complexity, digital private mobile radio system complying with EN 301 166, operating in peer-to-peer-mode (Digital PMR 446).
- The task is to develop a new harmonized standard for Broadband Disaster Relief applications to be used by emergency services in disaster situations.

The Technical Committee, ETSI RRS (Reconfigurable radio Systems), dealing with SDR (Software Defined Radio) and CR (Cognitive Radio) is of great interest for EMPhAtiC project standardization strategy since ETSI RRS addresses especially the reconfigurable and flexible approaches for better frequency spectrum usage and cognitive radio. This group is particularly targeted for introducing new ideas such as the ones studied in EMPhAtic project.

The ETSI Technical Committee on Reconfigurable Radio Systems (RRS) works on Cognitive Radio related aspects based on reconfigurable radios.

The RRS group has four working groups as mentioned below:

- WG-1: RRS System Aspect
- WG-2: Reconfigurable Radio Equipment Architecture
- WG-3: Cognitive Management and Control
- WG-4: RRS Public Safety

ETSI RRS WG4 is the group inside ETSI RRS that is of particular interest for EMPhAtiC project, which is addressing more specifically Public Safety PMR applications.

C. Conférence Européenne des Postes et Télécommunications (CEPT) - Electronic Communications Committee (ECC)

In Europe, the body in charge of frequency regulation is CEPT/ECC:

- WG FM (Frequency Management) is in charge of all frequency management aspects,
- More specifically, FM 49 group is in charge of frequency management matters for PPDR (Public Protection and Disaster Relief), which corresponds to PMR for Public Safety.
- WG SE (Spectrum Engineering) has in charge the frequency coexistence studies.
- More specifically, SE 7 group is in charge of compatibility and sharing issues of mobile systems, including PMR/PPDR.

D. International Telecommunication Union - Radiocommunication (ITU-R)

At ITU level, the WRC-15 (World Radio Conference – 2015) is currently under preparation.

There are different groups dealing PPDR related subject

- WG 5A: dealing notably with allocations for PPDR.
- WG 5D: dealing notably with WRC-15 agenda point 1.2 (organization of 700 MHz band).

III. CONTRIBUTION OF MAIN INDUSTRAL PARTNERS TO STANDARDIZATION AND REGULATION BODIES

A. AIRBUS DEFENCE AND SPACE

AIRBUS Defence and Space is involved in the standardization of PMR systems in ETSI TETRA and also in ETSI ERM TGDMR.

AIRBUS Defence and Space is especially involved in the standardization of future broadband PMR systems in ETSI TETRA WG4.

AIRBUS Defence and Space is also actively participating in 3GPP LTE standardization work (RAN, RAN1, RAN4, and also SA) in particular for PMR/PPDR functionalities.

AIRBUS Defence and Space, following the suggestion from CRS-I and from the project reviewers to the project EMPhAtiC, is also actively participating in ETSI RRS and ETSI RRS WG4.

Concerning frequency regulation activities, AIRBUS Defence and Space is actively participating in CEPT/ECC WG FM and especially in the group FM 49 dealing with Frequency Management for PPDR (Public Protection and Disaster Relief).

AIRBUS Defence and Space is focusing the standardization actions for EMPhAtiC project on ETSI RRS and ETSI RRS WG4.

In November 2012 the European Commission (EC) issued a mandate to European standardization organizations in the domain of Reconfigurable Radio Systems asking them to develop harmonized standards for Reconfigurable Radio Systems (RRS). The mandate (M/512) [1] aims to identify an approach and a number of issues where standardization should enable the development and use of RRS technologies in Europe. The EC mandate M/512 was formally accepted by ETSI in May 2013. The ETSI Technical Committee that is responsible for EC Mandate M/512 is TC RRS. Moreover, ETSI TC RRS and TC ERM have also agreed to create a task force, referred to as Joint Task Force ERM RRS (JTFER) with the aim to develop RRS related harmonized standards developed in response to the mandate. An overview of ETSI activities in relation with M/512 was presented during the 1st CRS-I Workshop by the ETSI Project Officer Andrea Lorelli.

The aim of Objective C of the M/512 is to explore potential areas of synergy among commercial, civil security and military applications, including:

- Architectures and interfaces for dynamic use of spectrum resources among commercial, civil security and/or military domains for disaster relief.
- Reconfigurable mobile device architecture for commercial and civil security applications.
- Other potential synergies to be identified.

The ETSI RRS WG4 Terms of Reference [2] have been refined in order to align with Objective C of the mandate M/512. ETSI RRS has adopted a Work Item in response to phase 1 (feasibility study) of Objective C:

- ETSI TR 103 217 [3]: Feasibility study on inter-domains synergies; Synergies between civil security, military and commercial domains.

This Work Item intends to explore the potential areas of synergies between commercial, civil security and military domains in the medium/long term (5-15 years) by providing:

- Definitions of use cases
- Definition of potential system requirements
- Discussion of feasibility and implementation obstacles of the use cases, which may include related market information
- Analysis and discussion on the regulatory implications

AIRBUS Defence and Space is regularly and actively contributing to RRS and RRS WG4 during face to face meetings as well as during conference calls.

AIRBUS Defence and Space delivered to ETSI RRS WG4 on September 23rd, 2014, during Mainz RRS04#16 meeting, a contribution on EMPhAtiC technical approach to ETSI TR 103 217, “Feasibility study on inter-domains synergies; Synergies between civil security, military and commercial domains”. This contribution was approved by ETSI RRS WG4 on December 4th, 2014, during Sophia Antipolis RRS04#17 meeting.

In parallel to the RRS#28 meeting in Sophia Antipolis RRS workshop took place on December 3rd and 4th, 2014. EMPhAtiC project made a demonstration during this RRS workshop.

During the same workshop, Philippe Mège from AIRBUS Defence and Space made a presentation [4] on December 3rd, 2014, based on EMPhAtiC work, on “Reconfigurable Radio Systems potentialities for the civil security domain”, see the presentation in § V below.

AIRBUS Defence and Space concentrates also actions on working group ETSI TETRA WG4. This TETRA WG4 working group is dedicated to the air-interface and is composed of the companies involved in TETRA and more generally PMR systems.

AIRBUS Defence and Space takes part in different "work items" like TEDS (TETRA Enhanced Data Service) and broadband PMR. TETRA WG4 is notably in charge of SRDoc Broadband, which is a document describing and specifying the frequency needs for Broadband PMR for Public Safety (PPDR: Public Protection Disaster Relief). WG4 is then considering technical aspects and frequency management aspects concerning Broadband for PMR PPDR systems.

B. TCS

TCS is involved in the standardization process of PMR systems and is taking actions in order to support the development of TCS future broadband PMR systems as well as more secure / robust implementations of the LTE system for critical applications.

TCS has been and is currently involved in several national and international research projects on PMR and PPDR systems. For instance, TCS is leading the Integrated FP7 ICT project ABSOLUTE on the use of LTE over balloons for setting up a PMR network on top of LTE in areas after a major disaster. In the context of this project TCS is also following the 3GPP standardization work.

As far as 3GPP is concerned, TCS has participated to several SA1 group meetings, where application requirements for direct and group communications were discussed. Currently, application requirements are fixed and discussions have started in RAN1 (followed by RAN2 and RAN3). TCS has made in the past joint contributions to RAN1.

TCS is also present or active in certain ETSI technical Committees; in particular TCS is attending plenary meetings of ETSI "Reconfigurable Radio Systems (RRS)" Technical Committee.

Concerning lobbying activities, TCS is active in the Wireless Innovation Forum (WInnF) on topics related to Software Defined Radio (SDR).

Concerning TCS activity in WInnF:

- TCS is Chair of "Coordinating Committee on International SCA Standards"
- Inside the Technical Committee on Software Defined Radio (TC - SDR), TCS is Chair of the Transceiver System Interface Task Group (TSI-TG).

IV. LOBBYING THROUGH DEDICATED WORKSHOPS, FORUMS OR MEETINGS

A. Public Safety Communication Europe (PSCE)

The aim of Public Safety Communication Europe (PSCE) is to foster, by consensus building, excellence in the development and use of public safety communications and information management systems as well as to improve the provision of public safety services and the safety of the citizens of Europe and of the rest of the world.

PSCE provides a unique common platform for researchers, industry and users to meet and network, learn about communication technologies and information systems used for public safety and influence policy makers at European level. It was founded under the auspices of the European Commission (DG Infso) in 2006 and has now become an autonomous and non-profit organization.

PSCE stimulates the cooperation between providers and users (to be defined as the persons in charge of responding to crisis and safety missions: police, fire brigades, emergency services) for the use of public safety communication in order to ensure that the new technologies and tools to be developed fit the needs of the users.

Its work is two-fold:

- A Roadmap for the future emergency technologies which identifies key technologies items and their possible evolution from a short term to a long term perspective. These key components are the Citizen Warning Systems, the Interoperability issue, the Mobile High Speed Wireless, the Satellite and an IP based architecture.
- Harmonized user requirements in order to identify the needs of the different communities of users in public safety communication, based on scenario covering routine and major incidents for the mutual benefit of the users and of industry that will have a unified view of the needs and could generate economy of scale for the development of the necessary technology/equipment.

B. Wireless Innovation Forum (WInnF)

Established in 1996, the Wireless Innovation Forum™ is a non-profit "mutual benefit corporation" dedicated driving technology innovation in commercial, civil, and defence communications around the world. Forum members bring a broad base of experience in Software Defined Radio (SDR), Cognitive Radio (CR) and Dynamic Spectrum Access (DSA) technologies in diverse markets and at all levels of the wireless value chain to address emerging wireless communications requirements through enhanced value, reduced total life cost of ownership, and accelerated deployment of standardized families of products, technologies, and services. The Forum acts as the premier venue for its members to collaborate to achieve these objectives, providing opportunities to network with customers, partners and competitors, educate decision makers, develop and expand markets and advance relevant technologies.

V. PRESENTATION MADE AT RRS WORKSHOP ON DECEMBER 3RD, 2014 IN SOPHIA ANTIPOLIS

Philippe Mège from AIRBUS Defence and Space was invited to make a presentation at 2014 RRS Workshop on "Reconfigurable Radio Systems potentialities for the civil security domain" [4].

This talk was presenting the views of AIRBUS Defence and Space and the EMPhAtiC project for the introduction of Broadband PMR systems in frequency bands already used by Narrowband PMR systems.

This presentation is given in the following.

Reconfigurable Radio Systems Potentialities for the civil security domain

A. *Broadband needs for Public Safety*

The civil security domain is often called public safety. It is also known as PPDR (Public Protection and Disaster relief). This is the name that is used in regulatory bodies.

The aim of public safety is the protection of persons and goods.

Public Safety is composed of different organizations having similar operational constraints and contributing to the protection and the rescue of the public. These organizations are: Police, Fire Brigades, Ambulances, Military services for Public Safety, Customs …

They have common needs:

- Coverage of the full area under their responsibility
- National or Regional Coverage
- 100% availability: it shall work even if all other communication means are out of service, which has already happened several times when events such as natural disasters, industrial disasters, bombings, riots …. , are happening
- Fast Access
- Management of Priorities
- Fully Secured Communications

Current Public Safety systems in Europe (TETRA, TETRAPOL) are offering only Narrowband services:

- Speech and Low Data Rate communications

There is also a need for Higher Data Rate communications for Public Safety to improve the operational efficiency:

- Real-Time Video, Large File Transfer, Map Transfer, Data Base consultation, Telemedicine ….

The figure 1 shows the data throughput requirements evolution.

Figure 1: Data throughput requirements evolution

B. *Need for frequency resource*

The new broadband needs cannot be offered by existing narrowband systems because these systems (TETRA, TETRAPOL) are using very narrow bandwidth from 10 to 25 kHz only. This narrow bandwidth conbined with the requirement of large coverage reduced strongly the achievable data rates, that are in the range of maximum 10 kbit/s. This is clearly far below the need for broadband services.

Only broadband systems such as LTE can provide these new high data rate services.

Then one major problem occurs, the problematic of frequencies. In which frequency band a Broadband PMR system could be deployed?

Frequency matters are managed by national regulators and by international bodies.

At European level, CEPT/ECC FM 49, dealing with Frequency Management for PPDR, is currently working on the subject of frequencies for Public Safety systems (PPDR).

The PPDR users, regulators and manufacturers, in FM 49 working group, have specified the characteristics of the future frequency bands for broadband PPDR. A frequency band for PPDR has to be dedicated to this usage. This is the only way to ensure a full availability. The total amount of frequency needed for Broadband PPDR is 2x10 MHz.

This frequency band has to be below 1 GHz for economic reasons. Low frequencies are providing better propagation characteristics. It allows deploying large cells in rural areas as well as smaller cells in dense urban areas. This limits the number of sites required, and so the total deployment costs, to ensure a regional or national coverage.

FM 49 has issued ECC Report 199 [5] that deals with user requirements and spectrum needs for Broadband PPDR.

Without surprise, it is challenging to find frequency bands that meet these requirements.

It is difficult for Public Safety to get more spectrum, particularly in quite low frequency bands, due to the competition for accessing to the frequency spectrum, especially with commercial networks operators.

In its ECC Report 218 [6], FM 49 has identified two candidate frequency bands at the moment for broadband PPDR.

- The 400 MHz band. This is already a PMR Band.
- The 700 MHz band, in the frame of the second Digital Dividend.

Clearly frequency spectrum is a very scarce resource that is hardly accessible to users such as PPDR users.

So spectrum efficiency is a must in order to use efficiently the frequency resource and to save it. This implies better spectrum occupancy. This means that the band occupied by one system has to be as much as possible

usefully occupied. So the guard bands have to be minimized.

This implies better spectrum efficiency. This means that the number of communications provided, the data rate provided shall be optimized as a function of the available frequency spectrum and as a function of the total numbers of cells in the deployment.

This better spectrum usage has to be achieved while maintaining good radio coverage for economic reasons.

C. Use of Commercial networks for PPDR needs

Some countries (UK, Sweden …) are envisaging using commercial broadband mobile networks for providing PPDR broadband services.

The expected benefit would be to avoid the deployment of a specific and dedicated network and by so to save money.

There is no problem on a technical point of view: LTE is offering or will offer the necessary technical features for PPDR requirements (availability, fast access, priority management), as well as specific needs (push-to-talk group communications, direct mode …).

The real difficulty is of regulatory nature, as reported in SCF report of "Study on use of commercial mobile networks and equipment for mission-critical high-speed broadband communications in specific sectors" [7] issued for European Commission. The question is: will commercial operators really offer the level of service that PPDR users need, at a reasonable cost? For sure they can offer the service for non-mission critical services but obviously not for PPDR mission-critical communications because offering premium services to some users that could even mean to preempt other users' communications would be fully contradictory with commercial operators' business model.

D. Dedicated Networks and Frequency Resources

The LEWP (Law Enforcement Working Party), which is the European PPDR users group where Ministries of Interior and Ministries of Justice are represented, has clearly expressed PPDR need for a Broadband dedicated network. A dedicated network can be operated by a PPDR network operator or by the users themselves.

This excludes a solution based on a commercial network. A dedicated one is the only way to insure that PPDR users will be able to use the resource when they need it for mission-critical communications.

This means also dedicated frequencies for Broadband PPDR.

E. Mutualisation

The different PPDR organizations have their own geographical area under responsibility.

The PPDR network must cover all this area because the radio service has to be available anywhere were it can be necessary. This means that, at a given moment, the average traffic in a PPDR network can be very low but, depending on events, the traffic can grow rapidly locally anywhere under the coverage of the network.

So there is clearly an advantage to have several PPDR organizations in the same network in order to get a better traffic usage of it.

There is a great benefit of mutualisation on a PPDR network. The mutualisation can de between different PPDR organizations as:

- Police
- Fire Brigades
- Ambulances
- Military services for Public Safety
- Customs
- …

The mutualisation can be also with other PMR users that are having similar needs and operational constraints, e.g. as:

- Transports (Urban, Trains, …)
- Energy (Electricity plants, Nuclear plants, Pipelines, …)
- Infrastructures (Motorways, Airports, Ports, …)
- Utilities
- Security of Military Bases
- …

This mutualisation would have also benefit on the effective cost of the network for the users.

F. Coexistence between Narrowband PMR systems and Broadband PMR systems

Today, PPDR speech communications are provided by narrowband PMR networks (TETRA, TETRAPOL) in Europe. Since the lifetime of a PMR system is very long and since investments have to be optimized, the Narrowband networks will last for long at least until 2030.

So Narrowband PPDR networks and Broadband PPDR networks will have to coexist for a long time.

Even if 3GPP work includes Push-To-Talk speech group communications for PPDR, the migration from Narrowband to Broadband, in particular for speech communications, will take place but only on long term.

Then PPDR speech communications will remain for a long time in 380-385/390-395 MHz band where European narrowband PPDR networks are mainly located.

G. The preferred frequency band options for Broadband PPDR

400 MHz band is the preferred option for nationwide coverage PPDR networks. 400 MHz band is a frequency band that is already dedicated to PMR.

Propagation characteristics in the 400 MHz band are particularly interesting and suited for minimizing the number of sites in a national deployment.

The 400 MHz band is sub-divided in 3 sub-bands:

- 380-385/390-395 MHz: dedicated today to narrowband PPDR
- 410-420/420-430 MHz: used for different civil, public safety and military PMR applications
- 450-460/460-470 MHz: used for different civil, public safety and military PMR applications

FM 49 considers the two sub-bands 410-430 MHz and 450-470 MHz as bands for Broadband PPDR.

After CEPT SE 7 studies, the conclusion is that Broadband PPDR can be deployed:

- in 450-457/460-467 MHz (3 MHz guard band from Digital TV - DTT)
- in 410-420/420-430 MHz

The figure 2 illustrates the schemes proposed by CEPT FM 49 for the deployment of Broadband PPDR in the 450-470 MHz band.

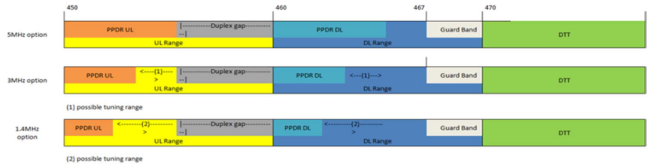

Figure 2: FM 49 options for dedicated PPDR spectrum in 450 - 470 MHz band

700 MHz is band of great interest for Broadband PPDR.

This can be an opportunity, in the frame of the second Digital Dividend in Europe, for getting more frequencies in a band that will be freed by Digital Broadcasting application. 700 MHz band has the advantage that, after release of Broadcasters, the band will be fully free contrary to 400 MHz band where incumbent narrowband PPDR and PMR systems are already present.

700 MHz would be more specifically suited for deployment in dense urban areas and for coverage extensions from a vehicular repeater.

The options considered by CEPT/ECC, and included in ECC report 218, about PPDR spectrum in the 700 MHz band are shown in figure 3:

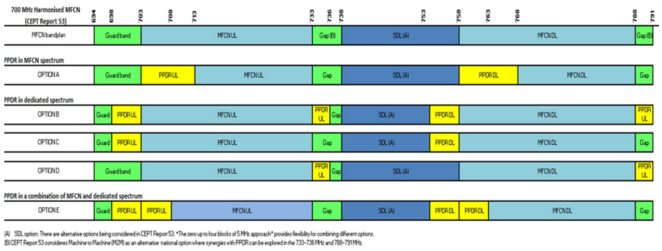

Figure 3: FM 49 options for dedicated PPDR spectrum in 700 MHz band

These options are enabling 2 times 5 MHz (698 – 703 / 753 – 758 MHz) plus 2 times 3 MHz (733 – 736 / 788 – 791 MHz) for dedicated spectrum for Broadband PPDR in the 700 MHz band.

H. The problematic of the 400 MHz band

In 400 MHz band, narrowband PMR incumbent communications are already present.

In 410-430 MHz and in 450-470 MHz sub-bands, there are a lot of PMR networks of very different sizes. All parts of the spectrum are used but in a quite sparse manner even in dense urban areas. So the effective spectrum efficiency is low in these bands.

The situation is different in 380-385/390-395 MHz sub-band since national Narrowband Public Safety (PPDR) networks (TETRA, TETRAPOL) are deployed in this band.

I. Need for a refarming

In 410-430 MHz and in 450-470 MHz sub-bands, a refarming of the band, this means a reorganization of the frequency channels used by all the systems in this band, will allow freeing a significant part of the spectrum for introducing Broadband PPDR.

As an example, it is estimated that, in France, at least 2 x 3 MHz could be freed with such a refarming. This would allow deploying a Broadband network using LTE technology in the 400 MHz band. This would be the first step for introduction of Broadband PPDR in this band.

CEPT/ECC SE 7 has carried coexistence studies of LTE in the 410-430 MHz and 450-470 MHz sub-bands for Broadband PPDR, notably with Digital TV and Narrowband PMR.

J. Advanced Narrowband-Broadband coexistenc: Need for intelligent refarming

It is possible to go further. Better spectrum efficiency can be achieved through a better coexistence management better Narrowband and Broadband communications.

The very simple coexistence scheme, described in § V. paragraph I, is based on a disjoint frequency allocation of Narrowband and Broadband PPDR. This works but this is not the most spectrum efficient way to coexist.

It is possible to deploy a Broadband network, in a more spectrum efficient manner, in the same band as pre-existing Narrowband systems without impacting their service and coverage.

This is possible by shutting down some sub-carriers of the Broadband signal corresponding to the channels used by narrowband signals. In LTE, this is possible to do so by shutting down the respective Resource Blocks (RB).

Figure 4 illustrates the shutting-down of some resource blocks in an LTE signal.

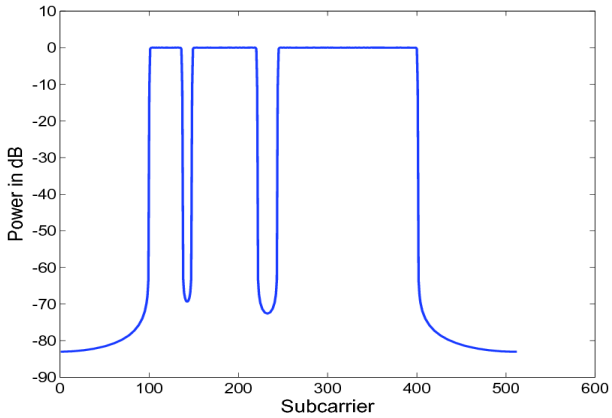

Figure 4 : LTE signal with some Resource Blocks shut-down

There is, here again, a need for a refarming because if a whole Resource Block, which corresponds to 180 kHz, has to be shut down when a narrowband channel is present then, with the current usage of the frequency sub-bands, almost all Broadband Resource Blocks should be shut down.

An intelligent refarming can reduce the number of impacted broadband Resource Blocks by grouping the narrowband channels in order to limit the impact on Broadband Resource Blocks. This has to be done by using frequency planning tools and processes. Only the Narrowband cells close to the Broadband Cell have to be taken into account, so for a regular deployment only the serving cell and the 6 surrounding cells have to be taken into account.

In fact, up to 6 TETRA channels (25 kHz) can fit into one broadband Resource Block (180 kHz), as shown in Figure 5.

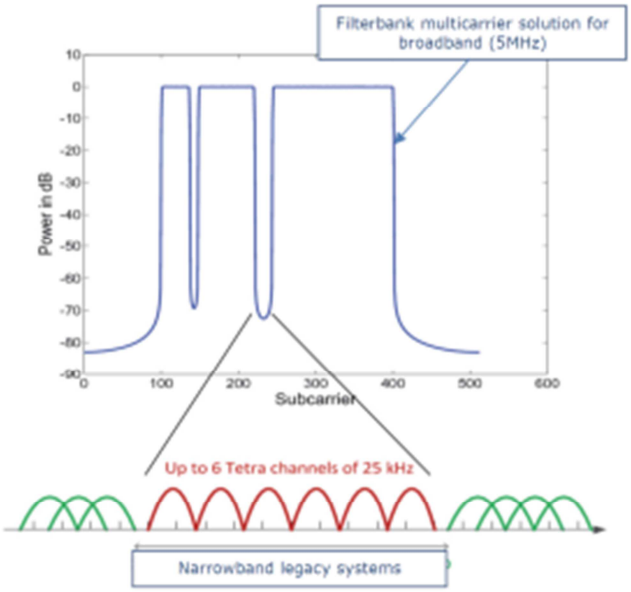

Figure 5: TETRA Channels and LTE Resource blocks

This approach implies

- A flexible reconfigurable approach (shut down of some RBs)
- A global frequency planning of all the radio systems deployed in the same frequency band (NB and BB systems)

This is the condition for a spectrum efficient coexistence between Narrowband and Broadband PMR systems.

This approach enables to add BB capability with no impact on NB systems. It provides new BB services while maintaining NB services and it improves spectrum usage and spectrum efficiency.

As it has been said, this advanced approach can be done using LTE, but LTE has limitations. The LTE spectrum is decreasing very slowly due to the CP-OFDM (and SC-FDMA) multi-carrier scheme used. This means that a significant guard band is necessary for coexisting with another service, as example:

- LTE 1,4 MHz uses only 1,08 MHz for useful signal,
- LTE 3 MHz uses only 2,7 MHz for useful signal,
- LTE 5 MHz uses only 4,5 MHz for useful signal,

The rest is guard band for protecting neighboring services.

K. Further improved Narrowband-Broadband coexistence: The FilterBank approach

AIRBUS Defence and Space (France) is a partner in the European Project EMPhAtiC with CTTC (Spain), CNAM (France), Technical University of Tampere (Finland), Technical University of Munich (Germany), Université Catholique de Louvain (Belgium), CTI (Greece), Ilmenau Technical University (Germany), SINTEF (Norway), University of Novi Sad (Serbia) Thales Communications and Security (France), Bitgear (Serbia), Magister (Finland).

The EMPhAtiC project is dealing with Filter-Bank approach as an improvement of classical OFDM with application to Professional Mobile Radio.

The interest of Filter-Banks is that the compactness in the frequency domain is much better than for classical OFDM systems as LTE. With Filter Banks (FB-MC), the spectrum decay is much faster. This enables to reduce guard bands and to improve spectrum occupancy and spectrum efficiency.

Figure 6 shows the compared spectrum of a sub-carrier with classical OFDM technology of LTE and with FB-MC technology.

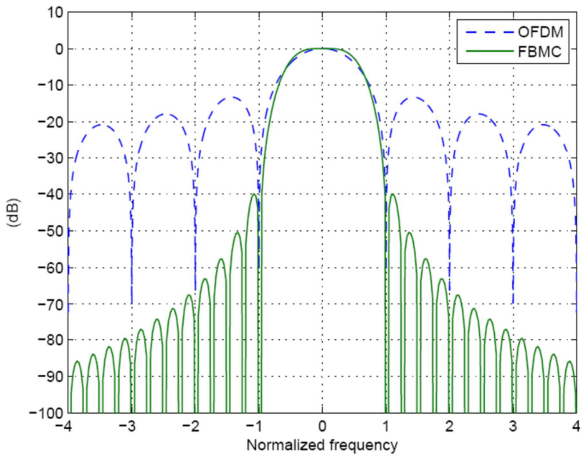

Figure 6 : Comparative spectra of OFDM and FB-MC sub-carriers.

Also, the rejection in shut-down RBs is much better than with OFDM.

The protection of Narrowband communications will be enhanced. This will enable a perfect coexistence of Broadband with TETRA and TETRAPOL narrowband communications. Narrowband services will be preserved all over their radio coverage. New Broadband services will be introduced.

Figure 7 shows the rejection achieved in shut-down Resource blocks respectively for OFDM technology and for FB-MC technology.

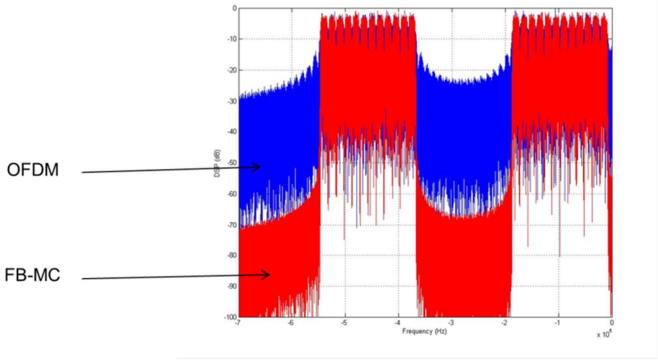

Figure 7: Compared rejection in shut-down RBs between OFDM and FB-MC

L. Expected benefits

By using flexible and reconfigurable capabilities of Broadband Radio equipment and with an intelligent refarming of the 400 MHz sub-bands, it is possible to deploy a Broadband system in a band already occupied by Narrowband systems without any impact on the Narrowband Communications and adding Broadband capabilities.

Even in the 380-385 / 390-395 MHz sub-band, fully occupied today by narrowband TETRA or TETRAPOL systems for mission-critical voice and low rate data, a broadband system can be deployed with a capacity roughly equivalent to 2/3 of the capacity of a Broadband system deployed in a fully free spectrum.

The same kind of approach can also be used in 410-430 MHz and 450-470 MHz sub-bands.

Filter Bank approach will be an important element for fulfilling an efficient and strong protection of the narrowband services and to achieve the global purpose.

M. Comparison with other spectrum sharing schemes

The most usually considered and used spectrum sharing schemes are:

- « White Space » notably for in Digital Terrestrial TV (DTT) band:
  - This is an opportunistic scheme
  - Systems using “White Space” are only secondary users of the spectrum.
- LSA: Licensed Shared Access
  - This is Spectrum on Demand
  - With Dynamic LSA: some kind of compromise has to take place between co-primary services.

In both cases, there is no 100 % guaranty of immediate availability of spectrum.

With the NB-BB coexistence scheme proposed in the present paper:

- Both Narrowband PPDR and Broadband PPDR are primary users. They have their “own” resources.
- Narrowband Service is not impacted by Broadband deployment.
- Broadband adapts his spectrum usage (Resource Blocks shut-down) on a planned and guaranteed basis.

VI. CONTRIBUTION MADE TO THE ETSI TECHNICAL REPORT (ETSI TR 103 217) IN ETSI RRS WG4 STANDARDIZATION WORKING GROUP

The ETSI TR 103 217 is a technical report, which is managed by ETSI RRS WG4 working Group. The title of the TR 103 217 is “Feasibility study on inter-domains synergies; Synergies between civil security, military and commercial domains”. AIRBUS Defence and Space as ETSI member and representing the EMPhAtiC project has made a contribution to this ETSI Technical Report on the spectrum sharing approach between civil security, military and commercial domains PMR systems. The contribution focuses specifically on the introduction of PMR broadband systems in the 400 MHz band.

The ETSI TR 103 217 report is currently in draft mode [3]. It can be consulted on the ETSI website.

VII. CONCLUSION

EMPhAtiC project has put a lot of efforts in order to follow and to contribute to the standardization and regulation bodies whose activities are in relation with the project.

It is obvious that the subject studied by EMPhAtiC project is meaning a lot of changes in existing systems. This has been a big difficulty for having a direct impact of the project on future systems' standardization.

Since current 3GPP activities are focused on LTE and its evolutions based on a classical OFDM and SC-FDMA approach, it was not possible to envisage introducing a new technology such as FB-MC in the frame of current 3GPP LTE standardization process.

The introduction of new technologies changing the bases of the communication systems, including its lower layers, could be done only in the frame of future 5G.

The standardization landscape for 5G was not in place during the frame of the EMPhAtiC project, so it was decided, with the encouragement of the reviewers of the project to focus contributions to the ETSI RRS Technical Committee (Reconfigurable radio Systems) who is covering Software Defined and Cognitive Radio. The EMPhAtiC project has particularly contributed to the WG4 Working group dealing with Civil Security.

The project has provided a contribution to ETSI Technical Report ETSI TR 103 217 "Feasibility study on inter-domains synergies; Synergies between civil security, military and commercial domains" and a presentation of the approach for the introduction of Broadband PMR systems was made during RRS Workshop that took place in Sophia Antipolis on December 3rd and 4th, 2014.

The contribution to ETSI Technical Report and the presentation made at RRS workshop are demonstrating that Broadband PMR can be deployed in the 400 MHz and in the 700 MHz band, and that, in the 400 MHz band it can be deployed progressively with the opportunity to add mission-critical broadband capability and capacity in a band already occupied by mission-critical narrowband PMR systems by using properly intelligent frequency refarming and Filter Bank technology.

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[5] ECC REPORT 199, "USER REQUIREMENTS AND SPECTRUM NEEDS FOR FUTURE EUROPEAN BROADBAND PPDR SYSTEMS (WIDE AREA NETWORKS)", APPROVED BY CEPT/ECC AND PUBLISHED.

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ABBREVIATIONS

3GPP	3rd Generation Partnership project
BB	BroadBand
CEPT	Conférence Européenne des Postes et Télécommunications
CP	Cyclic Prefix
CR	Cognitive Radio
CRS-I	Cognitive Radio Standardization Initiative
DG Infso	Directorate General for Information society and Media, the former name of DG Connect
DMR	Digital Mobile Radio, an ETSI PMR standard
DSA	Dynamic Spectrum Access
DTT	Digital terrestrial TV
EC	European Commission
ECC	Electronic Communications committee, a committee of CEPT
EMC	Electro-Magnetic Compatibility
EN	European Norm
ERM	Electromagnetic and Radio Matters, an ETSI technical committee
FB-MC	Filter Bank – Multi Carrier
FDD	Frequency Division Duplex
FM	Frequency Management, a working group of CEPT/ECC
FP7	7th Frame Program, research program of the European Commission
ICT	Information and Communication Technologies
ITU	International Telecommunication Union
JTFER	Joint Task force ERM RRS
LEWP	Law Enforcement Working Party
LSA	Licensed Shared Access
LTE	Long Term Evolution, the broadband 3GPP Mobile Radio Standard)
NB	NarrowBand
OFDM	Orthogonal Frequency Division Multiplex
PMR	Professional Mobile Radio
PPDR	Public Protection and Disaster Relief
PS-SIG	Public Safety – Special Interest Group
PSCE	Public Safety Communication Europe
RAN	Radio Access network, a 3GPP Group
RB	Resource Block
RRS	Reconfigurable Radio Systems, an ETSI Technical Committee
SA	Service and system Aspects, a 3GPP Group
SC-FDMA	Single Carrier – Frequency Division Multiple Access
SCA	Software Communications Architecture
SCF	SCF Associates LTD, a European Commission consultant company
SDR	Software Defined Radio
TC	Technical Committee
TCS	Thales Communications and Security
TCCE	TETRA and Critical Communications Equipment, an ETSI technical committee
TDD	Time Division Duplex
TEDS	TETRA Enhanced Data Service
TG	Technical Group
TGDMR	Technical Group on Digital Mobile Radio, a technical group of ERM
TR	Technical Report
TS	Technical Specification
TSI	Transceiver System interface
UE	User Equipment terminal equipment in LTE system)
UTRAN	Universal Terrestrial Access Network
WG	Working Group
WInnF	Wireless Innovation Forum
WRC	World Radio Conference