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SPECTRUM USAGE IN MOBILE BROADBAND COMMUNICATION SYSTEMS

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The increased demand of mobile broadband consumers on services in the mobile environment with high data rate and technologically developed mobile broadband communication systems will require more spectrum to be available in the future. The new technologies as well as the existing services require frequencies for their development. The authors investigate the available and potential future mobile terrestrial frequency bands – worldwide and in Europe. An insight into the spectrum management is provided, with radio access technologies, methods for more efficient use of mobile frequency bands and frequency cross-border coordination also addressed. It is stressed that the radio frequency spectrum is a limited national resource that will become increasingly precious in the future.

Key words: *frequency band, frequency cross border coordination, International Telecommunication Union (ITU), International Mobile Telecommunications (IMT), ITU Radio Regulations (ITU RR), mobile broadband communications systems, National Frequency Allocation Table (NFAT), radio frequency, spectrum, spectrum planning.*

1. INTRODUCTION

Mobile broadband traffic is ever increasing, driven by improved performance and quality of mobile networks, new technologies, new devices (smartphones, laptops, notebooks, tablets, etc.), new applications that introduce advanced ways of using mobile devices and services, better service offering and overall consumer demand for mobile data.

The difference between the user experience in mobile environment and the fixed (wireline) environment is becoming less significant as mobile networks can offer relatively high user data-rates. Mobile broadband users seek the similar quality of service to what they have been habituated using the fixed networks.

With the mobile data traffic increasing more spectrum resources will be necessary for the future mobile broadband communication systems. The ITU-R M.2078 report [1] was developed on spectrum estimates for IMT before the ITU World Radio-Communication Conference of 2007 (WRC-07). The predicted total spectrum requirement for both low and high user demand scenarios was calculated to be 1280 MHz and 1720 MHz (including the spectrum already in use, or planned

to be used) at least by the year 2020. In the calculations also improvements in spectral efficiency were taken into account that may come from the technologies under development for the radio access. Some initial studies [2] indicate that the previous forecasts made prior to WRC-07 greatly underestimated the growth of mobile data traffic. In the framework of the ITU World Radio-Communication Conference of 2015 (WRC-15) agenda (item 1.1) studies are ongoing on future spectrum requirement estimates for IMT systems, and possible additional spectrum allocations to the mobile service are considered in order to facilitate the development of terrestrial mobile broadband applications.

2. SPECTRUM PLANNING AND REGULATION

Spectrum management involves administrative, regulatory and technical procedures, e.g. spectrum licensing, spectrum planning, spectrum monitoring, electromagnetic compatibility calculations, etc. [3].

Radio frequency spectrum resources are managed in order to promote efficient use of this limited national resource and to gain a social benefit. Effective spectrum management requires regulation at the national, regional and global level.

The spectrum planning is done at international, regional and national level.

Spectrum planning at international level

Spectrum planning at the international level is done by ITU – an intergovernmental (member states) organization for development of telecommunications in which the private sector (sector members, associates and academia) entities also participate. ITU is the leading United Nations agency for information and communication technologies and spans three core sectors: ITU-R – the radiocommunication sector; ITU-D – the development sector; and ITU-T – the standardization sector. ITU works through Plenipotentiary conferences, Council, World conferences on International Telecommunications, and General Secretariat, which consider the impact of growing demand for various radio services and technological innovations on existing and planned changes in allocations [4].

The ITU-R coordinates the use of spectrum on an international level, seeking to globally harmonize radio frequency spectrum bands and to reduce harmful interference between stations of different countries to improve the use of radio frequency services [4].

Spectrum planning at regional level

Spectrum management at a regional level is done by several regional organizations – e.g. the Asia-Pacific Telecommunity (APT), Arab Spectrum Management Group (ASMG), African Telecommunications Union (ATU), European Conference of Postal and Telecommunications administrations (CEPT), Inter-American Telecommunication Commission (CITEL), Regional Commonwealth in the field of Communications (RCC).

Spectrum planning at the regional level in Europe is done by the CEPT Electronic Communications Committee (ECC). The committee brings together 48 countries to develop common policies and regulations in electronic communi-

cations and related applications for Europe as well as to provide the focal point for the information on spectrum use. One of its primary objectives is to harmonize the efficient use of radio spectrum resources across Europe. It plays an active role at the international level, preparing common European proposals to represent European interests in the ITU and other international organizations. The work in ECC is based on consensus between the member countries. The European Commission (EC) and European Telecommunications Standards Institute (ETSI) are some of the ECC external partners [5].

Spectrum management at the European Union (EU) level is done by the EU institutions – European Commission radio frequency management working groups, e.g. Radio Spectrum Committee (RSC) and Radio Spectrum Policy Group (RSPG). Decisions taken at the EU level are compulsory for its member states. In turn, the EU is a sector member of ITU [6]. One of the EU spectrum management objectives is to improve spectrum allocations for mobile broadband communications systems in Europe through the creation of a coordinated and strategic spectrum policy directed at the EU level, which would increase the efficiency of spectrum management and, in turn, maximize the benefits for consumers and industry. The objective could be achieved through spectrum harmonization and harmonized spectrum utilization of mobile broadband in EU member states [7]. According to Radio Spectrum Decision [8], the EC has a right to issue mandates to CEPT to carry out technical studies on the radio spectrum matters.

Spectrum planning at national level

Spectrum management and planning at a national level is done by an appointed governmental authority (also known as Administration). Each country has its own National Regulatory Authority (NRA), which is responsible for spectrum planning at the national level.

National Frequency Allocation Table

Each NRA develops and maintains its own National Frequency Allocation Table (NFAT) for the frequency range from 9 kHz up to 3000 GHz (or the highest planned frequency) for allocations to radio-communication services defined by the ITU. The NFAT is reviewed by NRA periodically to be in line with the latest ITU Radio Regulations (RR), regional regulations – e.g. EU, regional agreements, etc.

The ITU RR is an international treaty signed by the ITU member states and revised at the WRCs, which are held every three or four years. The ITU RR provides a top level view of how the radio frequency spectrum is to be shared amongst the many global, regional and national radio-communication services.

Regional organizations (e.g. CEPT) and NRAs work in accordance with the ITU RR table of frequency allocations to meet their own specific priorities and needs. As long as there are no potential international interference situations, regional and national frequency allocation tables can differ from that of frequency allocations contained in the ITU RR (Article 5).

For the allocation of frequencies the world has been divided into three regions as shown in Fig. 1. For Europe the ITU RR requirements are applied to Region 1 [9].

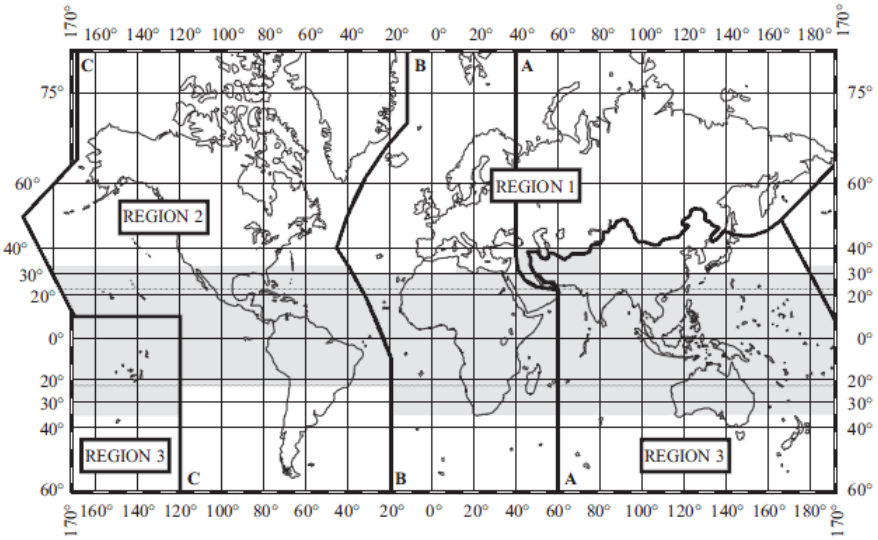

Fig. 1. ITU map identifying Region 1, Region 2 and Region 3.

3. PRESENT AND FUTURE POSSIBLE MOBILE FREQUENCY BANDS

The frequency bands in the first column of Table 1 have so far been identified for IMT systems in the ITU RR for all three ITU Regions [9]. For comparison, we have added to Table 1 a column showing mobile frequency bands (IMT bands) where spectrum usage rights (licenses) are issued to the mobile operators in CEPT countries [10]. Most of these frequency bands also correspond to the CEPT and EU harmonized frequency bands.

Table 1

Mobile frequency bands

IMT frequency bands identified for IMT systems in the ITU RR for three ITU regions, MHz	Licensed mobile bands[1] in CEPT countries, MHz	Frequency arrangement
450–470	450–470	FDD[2]
790–960	790–862	FDD
	880–915/925–960	FDD
1710–2025	1710–1785/1805–1880	FDD
	1900–1920	TDD[3]
	1920–1980/2110–2170	FDD
	2010–2025	TDD
2110–2200	1920–1980/2110–2170	FDD
2300–2400	2300–2400	TDD
2500–2690	2500–2690	FDD/TDD
	3400–3600	FDD/TDD
	3600–3800	TDD

[1] Frequency band or its part is licensed in several CEPT countries.
[2] Frequency Division Duplex (FDD).
[3] Time Division Duplex (TDD).

Due to increase in the mobile broadband spectrum demand, the future estimates and studies on finding additional spectrum allocations are ongoing at all spectrum planning levels. The expected capacity demand of mobile broadband traffic could be accommodated by agreeing on additional spectrum for the mobile broadband use.

As relates to the identified IMT spectrum, some countries have already made 800 MHz and 2.6 GHz bands available for the use of mobile broadband communication systems in Europe, with other countries willing to follow. Additionally, the 3.4-3.8 GHz band could be made available to mobile operators.

ITU and CEPT activities

At the WRC-12, a new allocation was decided on mobile service in Region 1 in the frequency band 694–790 MHz to be effective immediately after WRC-15, and approved Resolution 232 (WRC-12) on the "Use of the frequency band 694–790 MHz by the mobile, except aeronautical mobile, service in Region 1 and the related studies", and, in response to this resolution, the ITU has started the appropriate studies [11].

WRC-15 agenda item 1.1 Resolution 233 (WRC-12) invites ITU-R to consider additional spectrum allocations to the mobile service on a primary basis and identification of additional frequency bands for IMT systems and related regulatory provisions, to facilitate the development of terrestrial mobile broadband applications.

Examples of some often mentioned frequency bands which are considered as potential candidate bands for the additional spectrum allocations to the mobile service (according to the initial studies done at ITU [4] and CEPT [5]) are collected in Table 2, where other frequency bands suitable for IMT systems in the range between 400 MHz and 6 GHz are also tabulated.

Table 2

Possible future mobile frequency bands

Some of possible candidate frequency bands to be identify for IMT systems in the ITU RR for all three ITU Regions, MHz
470–694/698
1375–1400/1427–1452
1452–1492
2700–2900
3400–3600
3600–3800
3800–4200

Harmonization of mobile frequency bands and technical implementation activities in EU

Currently, a need exists to make available the already identified spectrum for terrestrial IMT at the European level in a harmonized manner.

The EU released its *Digital Agenda for Europe* in May 2010, setting out the following objectives: Europe needs download rates of 30 Mbps for all of its citizens and at least 50% of European households subscribing to internet con-

nections above 100 Mbps by 2020 [12]. The agenda aims to turn this ambition into reality by stimulating investments and proposing a comprehensive radio spectrum plan.

In March 2012, European Parliament and Council has approved multiannual Radio Spectrum Policy Programme (RSPP) which addresses monitoring of capacity requirements of mobile broadband and the assessment of the need for action to harmonize additional spectrum bands [13].

At the EU level, work is going on the following frequency bands and related issues:

- mandate to CEPT for developing the technical conditions in the bands 1900–1920 MHz and 2110–2125 MHz for the introduction of uses other than terrestrial mobile electronic communications services (ECS);
- draft mandate to CEPT on developing the technical conditions for the introduction of wireless broadband in the 694–790 MHz band;
- harmonized technical conditions for the frequency band 3400–3800 MHz in order to adapt them to the latest developments in technology;
- implementation of the spectrum inventory [14].

Sufficient spectrum resources would also facilitate the development of innovative services and applications and stimulate competition in mobile broadband landscape to the benefit of consumers.

4. RADIO ACCESS TECHNOLOGIES FOR MOBILE BROADBAND COMMUNICATION SYSTEMS

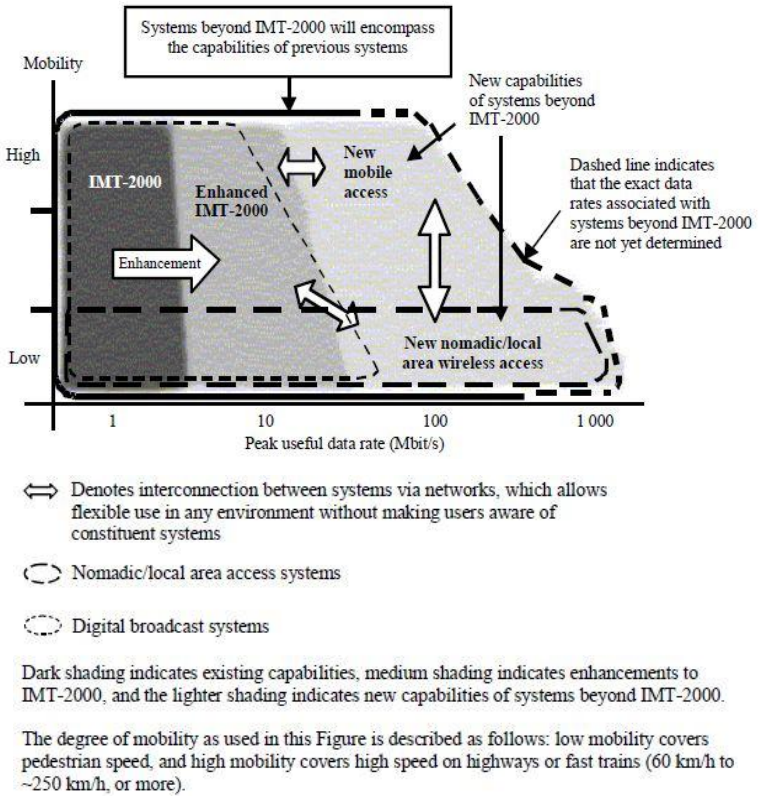

Fig. 2. An illustration of capabilities of IMT-2000 and systems beyond IMT-2000.

This section provides an insight into the radio access technologies for mobile broadband communications systems.

IMT as the root name encompasses both IMT-2000 and IMT-Advanced. Capabilities of IMT-2000 and systems beyond IMT-2000 are given in Recommendation ITU-R M.1645 [15]. An illustration of the capabilities of IMT-2000 and systems beyond IMT-2000 is given above in Fig. 2.

Evolution of mobile technologies

Technologies deployed by mobile operators in Europe for the time being are mostly 2G, e.g. GSM, GPRS, EDGE, and 3G, e.g. UMTS (WCDMA), HSDPA/HSUPA, HSPA+, LTE, CDMA2000 (CDMA2000 1x, 1xEV-DO Rel.0, 1xEV-DO Rev.A, Multi Carrier EV-DO, EV-DO Rev.B) [16], WiMAX. Under development are 4G technologies: LTE-Advanced (LTE Release 10 & beyond) and Mobile WiMAX 2.0 (802.16m).

Coverage for the mobile broadband penetration

Refarming of frequency bands enables operators to deploy, e.g., 3G technologies in the 900 MHz band, which offers larger cell radius and better coverage than the 2100 MHz band, or to deploy new technologies such as LTE etc. in the 2100 MHz band instead of only UMTS. Licensing of the 800 MHz spectrum with good coverage characteristics and of 2.6 GHz spectrum will bring additional resources for mobile broadband roll-out.

The overall trend is that the cell size in mobile networks is decreasing. Smaller size cells (such as *picocells*) are likely to be used to increase capacity at the demand hotspots. *Femtocells* can also provide some capacity increase in specific situations – e.g. domestic environments where they can improve the indoor coverage [17].

NRAs issuing licenses for mobile operators often define coverage obligations. When defining the specifics of coverage obligations, in EU member states this is often done in different ways: by reference to covering a proportion of area; by reference to covering a proportion of population; by reference to covering the key national infrastructure such as roads and ports; by reference to covering specific locations which have been identified as not having access to quality broadband services or no service at all; any combination of the above mentioned solutions is possible [11].

Spectrum efficient technologies

The opening of existing 2G spectra in 900 MHz and 1800 MHz bands to more spectrally efficient technologies like 3G will allow more capacity to be delivered over existing IMT spectrum.

Development of new technologies such as 3G and 4G networks, introduction of Multiple Input Multiple Output (MIMO) antennas, and application of advanced modulation schemes increases the spectral efficiency. However, new modulation schemes and new technologies are reaching the theoretically possible limits of spectral efficiency [17].

5. METHODS FOR IMPROVEMENT OF EFFICIENCY AT THE USE OF MOBILE FREQUENCY BANDS

Most of the frequency bands in use for mobile broadband communications systems are provided on a licensed basis. The *licensed* or *individually authorized* band means that the spectrum usage rights are granted in time, frequency and geography. These rights are usually exclusive, e.g. a license might last for 15 years and apply to a frequency block on the national basis (this approach applies e.g. to 900 MHz, 1800 MHz and 2100 MHz bands).

A first step towards better utilization of mobile frequency bands in Europe could be a need to make available the already identified spectrum by WRCs for terrestrial IMT in an efficient and harmonized manner.

The following step could be starting the utilization of unused mobile frequency bands; particularly, this applies to unused TDD frequency bands. However – e.g. for unpaired 1900–1920 MHz and 2010–2025 MHz bands – we can see a lack of mobile network end user terminals supporting these bands. In practice, even a licensed spectrum of FDD mobile bands often is not utilized fully or its occupancy is low – e.g. in different parts of a country.

Introduction of novel spectrum sharing methods, e.g. dynamic spectrum access (DSA), licensed sharing access (LSA), spectrum trading, continuing harmonization of mobile bands in Europe could also improve the efficiency of spectrum use.

Diversified technical solutions and technological development of mobile networks could also work in the same direction. For example, closer cooperation of mobile networks with broadband wireless access hotspots like heterogeneous networks (HetNets), carrier aggregation in mobile bands (e.g. for IMT-Advanced), introduction of cognitive radio, utilization of "white spaces" in TV broadcasting bands by white spaces devices (WSD) could help to better utilize the available frequency resources.

6. TECHNICAL CONDITIONS OF FREQUENCY USE IN BORDER AREAS

The spectrum management incorporates several challenges to deal with increasing future demands of additional spectrum allocations like interference management, spectrum sharing, technology neutrality, harmonization of the mobile frequency bands, and frequency cross-border coordination.

As concerns the technology neutrality approach, it applies for ever growing number of mobile frequency bands in Europe, since due to different technologies implemented and different nature of radio signal propagation there are different technical conditions of frequency use for each separate band in the border areas.

7. CONCLUSIONS

Factors like technological development of mobile networks, availability of new devices with improved performance, and increasing consumer demand for mobile data will significantly impact the development of the mobile broadband which will require more spectrum in the future.

Studies on additional spectrum allocations to the mobile service and identification of additional frequency bands for IMT systems are ongoing at the ITU, regional and national levels.

Development of mobile technologies, mobile spectrum harmonization, spectrum trading, appropriate technical solutions and spectrum sharing will enhance the spectrum usage efficiency.

Frequency cross-border coordination is one of the relevant challenges incorporated into the spectrum management.

REFERENCES

1. Report ITU-R M.2078 "Estimated spectrum bandwidth requirements for the future development of IMT-2000 and IMT-Advanced", http://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2078-2006-PDF-E.pdf, 2006.
2. ECC PT1(11)162_Annex23, CEPT ECC PT1 Internal Report on Mobile broadband landscape, p. 2, September 2011.
3. Ancans, G. (2012). Necessity of actualisation and process of making amendments in the Latvian National Radio Frequency Allocation Plan. *Qualification Paper in Law*, p.3. Riga: Turība University.
4. http://www.itu.int.
5. http://www.cept.org/.
6. Ancans, G. (2012). Necessity of actualisation and process of making amendments in the Latvian National Radio Frequency Allocation Plan. *Qualification Paper in Law,* pp. 14-17. Riga: Turība University.
7. http://ec.europa.eu/information_society/policy/ecomm/radio_spectrum/eu_policy/rsc/index_en.htm.
8. Decision No 676/2002/EC of the European Parliament and of the Council of 7 March 2002 on a regulatory framework for radio spectrum policy in the European Community (Radio Spectrum Decision).
9. Radio Regulations, International Telecommunications Union (ITU). Vol. 1 (articles edited in 2012).
10. ECO Report 03 "The licensing of 'Mobile Bands' in CEPT", 22 Oct., 2012.
11. Draft RSPG Report on proposed spectrum coordination approach for broadcasting in the case of a reallocation of the 700 MHz band. *Radio Spectrum Policy Group*, RSPG12-433, Brussels, 25 Oct., 2012.
12. European Commission. Digital Agenda for Europe. Fast and ultra-fast Internet access. Available at http://ec.europa.eu/digital-agenda/en/our-targets/pillar-iv-fast-and-ultra-fast-internet-access.
13. Decision No 243/2012/EU of the European Parliament and of the Council of 14 March 2012 establishing a multiannual radio spectrum policy programme.
14. European Parliament: Commission activities related to radio spectrum policy (25 Oct. 2012). *Radio Spectrum Policy Group*, RSPG12-437, Brussels.
15. Recommendation ITU-R M.1645 (06.2003). Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000, p. 7.
16. http://www.cdg.org/worldwide/index.asp.
17. ECC PT1(11)162_Annex23, CEPT ECC PT1 (Sept. 2011). Internal report on mobile broadband landscape, p. 33.

RADIOFREKVENČU IZMANTOŠANA MOBILO PLATJOSLAS SAKARU SISTĒMĀS

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K o p s a v i l k u m s

Mobilo sakaru pakalpojumu lietotāju pieaugošais pieprasījums pēc lielākiem datu pārraides ātrumiem un mobilo platjoslas sakaru sistēmu attīstība nākotnē prasīs papildu radiofrekvenču spektra resursus. Esošo sistēmu, kā arī jauno tehnoloģiju attīstībai būs nepieciešamas papildu frekvences.

Šī raksta galvenais mērķis ir izpētīt frekvenču joslas, kas iedalītas starptautisko mobilo telesakaru (IMT) sistēmām, kā arī sniegt ieskatu par iespējamām nākotnes IMT frekvenču joslām sauszemes mobilo sakaru sistēmām Eiropā un pasaulē.

Rakstā dots neliels ieskats par radiofrekvenču spektra pārvaldes jautājumiem, mobilo sakaru radiopiekļuves tehnoloģijām, iespējamām piemērojamām metodēm mobilo radiofrekvenču spektra joslu efektīvākai izmantošanai, kā arī par radiofrekvenču koordinācijas jautājumiem.

Radiofrekvenču spektrs ir ierobežots resurss, nacionālā bagātība, kas nākotnē kļūs arvien vērtīgāks.

18.02.2013.