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**The challenges and opportunities for
spectrum management resulting from
the transition to digital terrestrial
television in the UHF bands**

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Foreword

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REPORT ITU-R SM.2353-0*

The challenges and opportunities for spectrum management resulting from the transition to digital terrestrial television in the UHF bands

(2015)

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* This Report should be brought to the attention of the ITU-D Study Group 1.

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1 Introduction

This Report contains information on the transition to digital terrestrial television in UHF bands and appearance of the digital dividend*, including amongst others expectations, definition of digital dividend, technical, regulatory, economic and societal aspects in the area of spectrum management. Also, national and regional experiences and practices in the spectrum management area with regard to these items are presented in the Annexes and Attachments of the Report. WRC-15 activities, in particular, those related to agenda items 1.1 and 1.2, are excluded. This Report is the continuation of the studies of ITU Report “Digital Dividend. Insights for spectrum decisions”, 2012¹). Some material (sections 4.3 and 4.4) has been taken from that Report with some necessary amendments. The major benefits foreseen in switching from analogue to digital technologies were much more efficient use of spectrum while being able to avoid loss of quality throughout the chain of transmission.

The objective of improving the technical quality and availability of television programmes through the Digital Terrestrial Television (DTT) platform was the initial idea of what the “dividend” from the transition from analogue to digitally modulated television broadcasting would be, at least among the broadcasting community.

The major driver for achieving the transition to DTT around the world was the example of the GE06 Agreement and associated frequency plans for digital broadcasting and analogue TV broadcasting during the transition period. The GE06 Plan was established at the RRC-06² as part of the general transition to digital television broadcasting in ITU Region 1 countries (except Mongolia) and the Islamic Republic of Iran.

As the outcome of RRC-06, broadcasting spectrum usage in the UHF bands was optimized as far as possible (the GE06 digital plan to a large extent contains single frequency networks). Together with the introduction of video compression algorithms, this process provides better opportunities for further development of terrestrial television, including an increase in the number of programmes, additional services and introduction of HDTV. However, even during the years when the preparations for RRC-06 were taking place, a more general concept of the “digital dividend” had developed among national spectrum regulatory authorities which foresaw the possibility of introducing more flexibility in the use of spectrum allocated to the broadcasting service in the UHF bands. Then this could be exploited for uses other than broadcasting, such as high data rate networks operating in the mobile service capable of providing mobile broadband connections.

In this way the “digital dividend” came to be accepted as a shorthand description for re-allocating UHF spectrum from the broadcasting service to mobile broadband networks. This narrow definition has become so pervasive that it is now common to refer to the “first digital dividend” and the “second digital dividend” to describe the successive reallocation in Region 1 of the “800 MHz band” (790-862 MHz) and the “700 MHz band” (~694-790 MHz) from the broadcasting service to mobile service.

* The term digital dividend in this Report is merely to indicate the use of spectrum released in UHF band after the transition from analogue to digital in terrestrial TV broadcasting.

¹ <http://www.itu.int/en/ITU-D/Technology/Documents/Broadcasting/DigitalDividend.pdf>.

² Regional Radiocommunication Conference for planning of the digital terrestrial broadcasting service in parts of Regions 1 and 3, in the frequency bands 174-230 MHz and 470-862 MHz (2nd session) (Geneva, 2006).

More recently, the term “digital dividend” has also come to be associated with the objective of bridging the “digital divide” by re-allocating broadcasting spectrum for the specific purpose of providing mobile broadband connectivity to sparsely populated areas, remote from the main centres of the population.

Alternatively, broadband/internet services may also be delivered efficiently and directly to the end user by satellite networks and systems. A direct delivery by satellite to end users does not require additional infrastructure on the ground. On the other hand additional infrastructure, satellite or terrestrial service links, would have to be introduced when using localized mobile service systems as the final step in delivering broadband/internet services in remote, rural or sparsely populated areas.

This Report tries to distinguish between the several nuances of meaning for the term “digital dividend” and to avoid confusion with the concept of the “digital divide”. Also, the Report describes possible ways and aspects of the exploitation of digital dividend as a result of increasing of the spectrum efficiency resulting from the transition to digital terrestrial television in the UHF bands.

2 Increase of the spectrum efficiency resulting from the transition to digital terrestrial television in UHF bands

2.1 Definition of the digital dividend

Currently, different objectives and practices around the world lead to several approaches to the definition of the digital dividend.

2.1.1 Cases of definition of the digital dividend in ITU Region 1

Europe

In Europe, where there was previously no allocation in the whole of Region 1 to the mobile service Band IV/V, some fairly specific understandings of the terms digital dividend, “first digital dividend”, and “second digital dividend” have become widely used.

The “first digital dividend” is recognized as the spectrum in the band 790-862 MHz which was allocated to the mobile service and identified for IMT in Region 1 pursuant to the outcome of the World Radiocommunication Conference in 2007 (WRC-07).

The concept of the “second digital dividend” appeared at WRC-12 and normally refers to the band 694-790 MHz.

For Member States of the European Union, the definition of the digital dividend used by the Radio Spectrum Policy Group (RSPG) and the European Commission had wider objectives and has proved to be the most relevant in setting technical and policy objectives. The RSPG adopted Opinions on the digital dividend in 2007 and 2009 and went on to include activities on this matter in its work programme of 2010. The digital dividend was also subject of the EC [Decision 2010/267/EU](#) on “*harmonised technical conditions of use in the 790-862 MHz frequency band for terrestrial systems capable of providing electronic communication services in the EU*”.

According to the RSPG, the digital dividend is understood as “*the spectrum made available over and above that required to accommodate the existing analogue television services in a digital form in VHF (Band III: 174-230 MHz) and UHF (Bands IV and V: 470-862 MHz)*”.

However, all of these specific meanings do not take account of other objectives or socio-economic factors such as encouraging competition in using available spectrum resources to the optimum

effect. Moreover, these terms do not necessarily have the same understanding or implications around the world, so administrations of different countries can have different views.

2.1.2 Cases of definition of the digital dividend in ITU Region 2

USA

In the United States of America, the (first) digital dividend is understood to mean the Digital Television Transition and Public Safety Act of 2005. This includes, among other things, the recovery of analogue spectrum, and the auction of said spectrum, and the digital-to-analog conversion box programme. As concerns frequencies the first digital dividend in the United States of America is the releasing of spectrum in the 700 MHz band, the second digital dividend is understood to mean the Middle Class Tax Relief and Job Creation Act of 2012. It is the basis for the 600 MHz band broadcast spectrum to be auctioned off to new services. The US experience may be found in the Attachment 3 to Annex 1 of the Report.

Brazil

In Brazil, with the establishment of the public policies for the 700 MHz band and the digital switchover, Anatel developed studies for re-farming television channels in order to release the television channels from 52 to 69 from the broadcasting service to the mobile communications i.e. the digital dividend in Brazil is understood as releasing spectrum in the 700 MHz band (see Attachment 4 to Annex 1 of the Report).

2.1.3 Cases of definition of the digital dividend in ITU Region 3

Viet Nam

In Viet Nam, digital dividend is understood as “the amount of spectrum made available by the transition from analogue to digital television broadcasting”. The roadmap for TV digitalization in Viet Nam covers the time period 2015 to 2020 and it will release the terrestrial TV broadcasting band 694-806 MHz for IMT.

Japan

In Japan, the digital dividend is generally understood as the spectrum re-allocation or re-allocated spectrum in the switchover from analogue television broadcasting to other applications. The corresponding frequency bands are from 90 to 108 MHz, 170 to 222 MHz, and 710 to 770 MHz. The Japan experience can be found in Report ITU-R BT.2140.

2.1.4 General approach to the definition of the digital dividend

Considering that in some countries the digital dividend has a different meaning, a general description that explicitly incorporates the diversity of use is therefore considered to be more appropriate. This Report will therefore use the description: “*Digital dividend is the spectrum that becomes available over and above that required to accommodate the existing analogue television services in a digital form in the UHF bands*”.

This definition reflects the importance of competition and innovation in the development of new telecommunication services, irrespective of whether competition is between service providers offering a similar set of services based on the same technology or based on different technologies. Thus it is important, when deciding how to make available the spectrum of the digital dividend in the optimum way, to consider all relevant services, i.e. terrestrial (broadcasting, fixed and mobile) and satellite, as elements of the total communication infrastructure intended to deliver content to end users. These factors must be considered in every activity involving reallocation of spectrum and services. In short, this description clarifies the essence of the digital dividend in the best possible way, i.e. to establish the availability of additional frequency resource regardless of its further usage.

Defining the nature of the digital dividend as the spectrum that becomes available over and above that required to accommodate the existing analogue television services in a digital form, it is necessary to consider that the amount of digital dividend depends on many factors and may vary in different countries.

2.2 Size of the digital dividend

The size of the digital dividend should be considered as its amount of frequency resource equivalent. The equivalent can be measured in MHz (overall bandwidth released from the analogue television) and in frequency channels (number of frequency channels released from analogue television). The size of it is measured in frequency channels because historically the VHF and UHF broadcast bands (the exact frequency bands are different in different Regions) were operated by the broadcasting service, particularly, by the analogue television systems. The digital switchover in Region 1 and the Islamic Republic of Iran is effected through the GE06 Agreement and associated frequency plans for digital broadcasting and analogue TV broadcasting during the transition period established at the RRC-06³ as part of the general transition to digital television broadcasting in ITU Region 1 countries (except Mongolia) and the Islamic Republic of Iran. Under the Agreement, all the signatory countries are divided into frequency allotment areas in the frequency bands 174-230 MHz and 470-862 MHz.

The GE06 Agreement and Plan are based on digital terrestrial broadcasting systems (DVB-T). According to the Agreement, the protection of analogue broadcasting will stop not later than 2015. In practice, many countries have decided to switch over earlier.

The amount of spectrum released for the digital dividend depends on how the replacement to DTT services are planned and implemented. The main issues that had to be taken into account in the establishment of the GE06 Agreement and Plan at RRC-06 are explained in Annex 2, which draws on several reports published by the EBU.

For the purpose of estimating the size of the digital dividend the frequency allotment areas used in the GE06 Plan may serve as the reference base. Each frequency allotment area contains a set of frequency channels that may be used by television. The average number of such channels for each allotment area varies from 6 to 8 due to ensuring the interference-free reception of digital terrestrial television.

The calculation technique for the size of the digital dividend is based on the following essential steps:

- 1 Quality determination for digital TV transmission, being the full substitute for TV programmes transmitted in the television system (NTSC, PAL, SECAM) keeping in mind the following:
 - 1.1 Evolutions of viewers' requirements;
 - 1.2 Applicable initial formats of TV programme production;
 - 1.3 Technical characteristics and special aspects of TV programme playback by modern TV receivers;
 - 1.4 Applicable standards for video signal compression.

³ Regional Radiocommunication Conference for planning of the digital terrestrial broadcasting service in parts of Regions 1 and 3, in the frequency bands 174-230 MHz and 470-862 MHz (2nd session) (Geneva, 2006).

- 2 Determination of the number of TV programmes in standard or high definition to be transmitted for adequate substitution of the analogue TV broadcasting with the quality preserved and adequate development of modern technologies.
- 3 Calculation of the total digital bit rate required to transmit all digital TV programmes.
- 4 Determination of the target type of reception: fixed, mobile or portable.
- 5 Determination of the digital transmission specification for the applied broadcasting system that provides the coverage as good as the analogue broadcasting stations with the same transmit antenna height and spectral power density in the band of radio frequency channel (6, 7 or 8 MHz).
- 6 Calculation of the digital bit rate per radio frequency channel corresponding to the technical characteristics of transmission determined in step 1.4.
- 7 Determination of the number of digital multiplexes required to achieve the total digital bit rate determined in step 1.2 with 10% margin for programme distribution losses between the multiplexes and for service transmissions.
- 8 Determination of the number of radio frequency channels pursuant to the existing frequency plans required to arrange one digital broadcasting multiplex with the coverage equal to the analogue TV stations operated in the relevant area.
- 9 With the outcomes of step 4 for the different areas and territories considered, to determine the overall bandwidth (in MHz) required for operation of the number of multiplexes determined under step 7 for 75%, 95% and 99% territory of the country.
- 10 Obtain the size of the digital dividend in MHz for the corresponding % of territories.

These calculations may be done for different assumptions that will reflect different strategies of the administrations in respect of DTT service development

2.3 Problems that could be solved by proper implementation of the digital dividend

Releasing a substantial amount of spectrum and its optimal use can facilitate in solving some telecommunication issues being experienced by the global society. One important problem is the digital divide between the urban and the rural population. This problem may be solved by a proper implementation of the digital dividend. The term “digital divide” refers to the disparity in access to modern information services. This concept could refer to the difference in access possibilities between developed and developing countries. This term could also refer to the digital divide between the urban and rural areas (suburbs, villages, and townships) and the digital divide between different regions within separate countries.

The issue of the digital divide between different regions of a country is typical for large countries. The issue has some reasons, such as:

- non-uniform size of regions;
- heterogeneously distributed population in regions;
- heterogeneously developed markets of communication services, both from a penetration point of view and the number and quality of such services;
- irregular penetration of different services and types of communication.

The issue of digital divide between urban and rural areas refers to the fact that the urban population is usually provided with broadband wire connections and, additionally, several alternative information service delivery links, such as cable broadcasting or broadband mobile communication. On the other side, rural areas and small towns often do not have even one channel to deliver information services.

The above issues can be solved by the use of the digital dividend. However, there is no general solution, instead a detailed analysis is required for each given region to determine the spectrum requirements for different technologies. Otherwise, the use of the digital dividend can only increase the above heterogeneities resulting in an increased digital divide.

2.3.1 Issue of bridging the digital divide between urban and rural areas

Radio communication technologies will have the utmost social value in those circumstances where the choice is restricted, or no acceptable alternatives are available to provide access to global and local data transmission networks. This is relevant for small towns, suburban and rural areas. Bridging the quality gap between urban and suburban/rural areas by penetration of communication services will be of great importance to improve the quality of life of the increased number of economically active members of the population who are permanently or temporally living outside the cities. Bridging the digital divide is considered to be the most important goal for the next decades in some countries. Bridging the digital divide between the urban and rural population is an important task for many countries. Development of communication networks in rural areas is typically much slower than in urban ones. The issue of complexity to provide an up-to-date level of information services to rural and remote areas primarily arises because of the impossibility for operators to get enough profit to cover expenses for building and operating broadband communication networks due to the low population density and low paying capability of the population. Attempts to apply the same approach to rural areas as to urban ones are too expensive and hence typically not successful. Thus, to successfully solve the issue of bridging the digital divide, it is necessary to use the approach of enabling the combination of wide bandwidth and low expenditures for network building and operation.

A substantial volume of the investments of world industry is in technologies to produce HD screens; large, extra-large and 3D screens; video survey and video communication systems; and numerous future developments in this field represent trends of mass technology development. Today the main limitation for the proper use of this future end user equipment is the lack of available channel bandwidth. It is justified to say that the demand for transmission of video images with high and higher quality via broadcasting and communication links will form the ground for further growth in the communications market for the next 20-30 years.

This is a real challenge for all types of systems using radio frequency spectrum and for regulators as well because the radio frequency spectrum is limited. In such conditions, it is crucial to define carefully the balance between spectrum assignments to different radiocommunication systems:

- broadcast data delivery to many users simultaneously (one-way radiocommunication);
- on-demand data delivery to a particular user (two-way radiocommunication).

Every modern radiocommunication system has been developed to address one of the two above-mentioned tasks primarily. In addition to that, it is often possible to also fulfill another task with the same system, but in a less optimal way. For example, on-demand data can also be transmitted to individual subscribers via digital TV broadcasting transmitters. Alternatively, the mobile network base stations can be used for digital multicasting.

This has been studied by various organizations, including:

- CITEL Technical Notebook “Cooperation and convergence between broadcasting and mobile services using LTE networks”⁴;

⁴ https://www.citel.oas.org/en/SiteAssets/About-Citel/Publications/Technical_Notebook/P2!R-3339p1_i.pdf.

- EBU Technical Report TR 027 “Delivery of broadcast content over LTE networks”, July 2014⁵;
- EBU Technical Report TR 026 “Assessment of Available Options for the Distribution of Broadcast Services”, June 2014⁶;
- Report ITU-R M.[IMT.AV] “Audio-visual capabilities and applications provided over terrestrial IMT systems”.

The different characteristics of various radio technologies combined with different topologies for coverage objective show that it may be difficult to construct a delivery system based on one technology only.

Preferably, households and users will have several alternative channels of communication. This approach provides the advantages of the use of various technologies, which increases the efficiency and reliability of radio communication in general. Intelligent user terminals and home media centers can send and receive data across different networks, to record broadcasts and work with content from different sources, providing a convergence at the application level of the OSI model (Open system interconnection model⁷). This approach will take advantage of all already developed media and data transmission technologies for easy and efficient implementation.

2.4 Aspects of the availability of a digital dividend

2.4.1 Problems that occur by implementing the digital dividend

For some implementations of the digital dividend, existing spectrum usage arrangements may be a limiting factor or a problem, that limits the availability of a digital dividend if a satisfactory solution is not found.

As mentioned above, currently, for ITU Region 1 countries (except Mongolia) and the Islamic Republic of Iran, the international use of spectrum for the digital television is regulated by the GE06 Agreement and associated frequency Plans. Any use of the digital dividend that does not comply with the Plan would require a number of measures to modify this frequency plan and to adopt additional bilateral or multilateral agreements.

The rights of the administrations under GE 06 to use spectrum were effected via allotments or assignments. Irrespectively of one or another form, each of them is related to the concept of “coverage” or “layer”. The layer represents a set of the frequency channels allocated throughout the planning area in such a manner that each point of the area, where the reception is planned, is covered by one multiplex.

According to the statistical analysis, with the spectrum availability for broadcasting reduced, for example, by more than 40 MHz, a significant part of the frequency plan assigned to the broadcasting service (GE06 Plan) would require to be modified due to significant losses in number of multiplexes in certain geographical areas.

As a result, when using a smaller frequency range for the same number of planned channels, a performance degradation of the broadcasting reception is to be expected (such as quality of reception, size of service area) due to a higher level of mutual interference. This applies to territories with moderate compatibility conditions. However, for some regions with more complex conditions to ensure compatibility, it would be a challenge to distribute an appropriate number of

⁵ <https://tech.ebu.ch/docs/techreports/tr027.pdf>.

⁶ <https://tech.ebu.ch/docs/techreports/tr026.pdf>.

⁷ <http://www.itu.int/rec/T-REC-X.200-199407-I>.

frequency channels for each administration when the frequency range is reduced, compromising the success for the new rearrangement.

Therefore, this rearrangement can be implemented on a multilateral basis only.

2.4.2 Conditions and time constraints of the availability of the digital dividend

The existing usage of the spectrum by incumbent services may be a limiting factor and impose time constraints on the appearance of the digital dividend.

Many countries cannot implement the digital dividend prior to the analogue to digital switchover and the switch-off of the analogue TV stations. In those countries, most of the spectrum potentially available for the digital dividend is still occupied by analogue TV broadcasting.

A number of countries have already completed the analogue to digital switchover and switched off all analogue TV stations. Other countries have only just begun or are planning to commence the analogue stations switch-off in the future. The approved concept to implement DTT in a number of countries assumes that the analogue switch-off would be possible only after the period of simulcasting by analogue and digital broadcasting, assuming that the entire service area has been covered by digital transmissions. A certain term of simultaneous broadcasting (e.g. 9 months) is usually established and is necessary for the population to purchase new TV sets or set-top boxes. Moreover, for a country with a rather large territory, the analogue switch-off in different regions can be fulfilled in different timeframes. Therefore, the analogue switch-off is a long-term process of which the rate depends on many factors.

In relation to this, the Digital Switch Over (DSO) database has been set up by ITU, at the request of Kenya (Council 2014). The database shows ongoing, completed, not started and known activities for each country, and provides a useful snapshot of global progress towards the digital switchover⁸.

As already mentioned, historically, the VHF and UHF broadcast bands were used by the broadcasting service, particularly, by analogue TV systems. In all countries around the world, these bands were used or are still used for national terrestrial TV broadcasting networks. And thus for the digital dividend to appear, total substitution of the current set of analogue TV programmes in digital format is required to switch off the analogue TV broadcasting and to optimize the use of the spectrum by TV broadcasting. Moreover, successful optimization of radio spectrum use by terrestrial digital TV broadcasting will require the review or modifications of terrestrial TV broadcasting frequency plans and appropriate modernization of transmitting networks of digital terrestrial television broadcasting. The completion of this work would be the key condition for the digital dividend. After exclusion of the frequency bands 694-790 and 790-862 MHz the reduction in number of assignments and allotments available in the countries of the GE06 Agreement may be different from country to country. This is explained by the fact that when developing the GE 06 plan, the entire frequency bands were not planned with the assumption that particular frequency bands would be excluded for use by other services. According to the GE06 Agreement, a principle of equal spectrum access is valid for border regions of member countries. That is why in coordination areas administrations have in average an equal number of coverage areas in the band 470-862 MHz (TV channels 21-69 TV). However, the channels in one area of the frequency plan could not be equally distributed throughout the frequency sub-bands in the UHF. If one administrations has more channels in the frequency plan in one part of the frequency band than another administration, it would mean that it has a smaller number of channels in the other part of the frequency band. If frequency bands of the digital dividend will be used for mobile communication or other applications (except TV broadcasting), such an administration would lose

⁸ <http://www.itu.int/en/ITU-D/Spectrum-Broadcasting/Pages/DSO/Default.aspx>.

more spectrum for TV broadcasting than the adjacent administration. Such issues shall be solved by administrations within the plan modification procedures on a bilateral or multilateral basis.

In respect to time constraints, for ITU Region 1 the deadline for international legal protection of the frequency plan for stations of analogue TV broadcasting was set by the GE 06 Agreement as 17 June 2015 (the deadline is set for all countries in ITU Region 1 (except for Mongolia) and the Islamic Republic of Iran). However, the operation of analogue TV stations will be possible even after the deadline based on appropriate agreements with concerned countries. The actual timeframe for switch-off for the analogue stations is defined by the administrations, considering several factors, such as: coverage of digital TV broadcasting, information awareness of the population and access to and availability of digital TV receivers to the population.

In addition to the above mentioned global conditions, there is another condition to prepare the digital dividend.

This condition is understood as carrying out work on reallocation of the released radio frequency resource in the bands considered, i.e. ensure compatibility, radio monitoring and partial withdrawal of government radio use from the frequency bands considered. The latter is a characteristic of the ex-Soviet countries, where aeronautical radio navigation service is allocated within the bands indicated.

2.4.3 Compatibility issues of the digital dividend

However, it is also necessary to recognize the inclination of digital systems to suffer a rapid degradation in quality (the “cliff edge” effect) in circumstances where the analogue systems could still provide some recognizable output. Digital systems, therefore, incorporate coding schemes with varying degrees of error detection and correction depending on the service requirements. Where very high integrity is required digital systems may also incorporate the techniques previously developed for analogue data links of retransmitting on error (Automatic Request Repeat – ARQ) or routinely transmitting each set of data packets twice (Forward Error Correction – FEC).

In some cases, the design and planning of digital networks and systems have to take account of error mechanisms that have no parallel in analogue systems. The reduction in spectrum use is often achieved through complex data coding and compression schemes, especially in the audio-visual sector, which can suffer extended delays in data reconstitution if errors occur at a critical time in the synchronization cycle.

While repeat data packet transmission can be used where the data file is not intended for real-time access, such as files downloaded for storage and later access, there is of course no possibility to repeat compromised data in the real-time unidirectional transmissions used for broadcasting. Special care is therefore needed in planning digital broadcasting networks in order to ensure a very high degree of reliability. A stable and predictable radio frequency environment is essential for digitally modulated broadcasting systems in order to guard against interference from other radiocommunication services and wired telecommunication systems.

As for now, there are still practically unsolved and economically unfeasible issues of compatibility provision for new services, for instance, the mobile service, with existing services, e.g. TV broadcasting, operating in neighbouring or overlapping frequency bands (in different countries/regions).

3 Application of the digital dividend

When reviewing the future use of frequency bands for the digital dividend and evaluating future spectrum needs for broadcasting and mobile services, it is reasonable to focus on the creation of an efficient transmission environment that is accessible to the whole population and specifically those in rural areas. Specifying the radio spectrum needs of broadcasting and mobile services, one should keep in mind that certain types of content in rural areas are effective to be transmitted by broadcast delivery and the other – via mobile communications. Radio spectrum for broadcasting services should further develop, in order to deliver content by using different radio technologies.

3.1 Further development of digital terrestrial broadcasting

The main trend in the current TV broadcasting is the increased quality of transmitted image made possible by a quick evolution of such TV receivers and screen characteristics such as: the size of display area, definition of displayed image, 3D transmitted image, quality and multiple number of audio channels and so on.

Even now, the quality of transmitted images for most of the air, satellite, and cable TV channels is much behind the possibilities of image display offered by popular modern TV receivers. Technological constraints (many broadcasting networks operate digital transmission technologies) do not cause the delay, but the shortage of channel capacity. Even HD programmes operated by most of the operators experience excessive compression during transmission and decrease the digital bit rate resulting in obvious image distortions. Digital multiplexes in air broadcasting are still transmitting standard definition programmes. The shortage of channel capacity is directly connected to the insufficient amount of frequency spectrum, available to transmit programmes in digital format. However, there is a demand for enhanced quality. In the absence of other factors, HDTV using the DVB-T2 system could be introduced over terrestrial broadcasting networks, without placing too much pressure on the available spectrum. EBU studies indicate that two HDTV programmes can be accommodated in a DVB-T multiplex in place of four standard definition programmes. However, HDTV is not compatible with standard definition TV reception, and therefore HDTV needs to be transmitted in parallel to DVB-T multiplexes (at least transitionally until all viewers have HD-capable equipment).

Digital terrestrial broadcasting has significant advantages compared to other means of terrestrial delivery of video content, such as conventional fixed or mobile radio communication networks. With broadcast delivery, the quality of the service and cost of the networks are not dependent on the density of the users in the covered area. There is no need to establish a particular link to every particular active user, or to deliver individual data to every user separately. Therefore, one-to-many broadcast services consume much less of the spectrum to deliver hi-quality and traffic-consuming content to users (same to all), and this efficiency is maximized when it is a widely demanded content (required by many users simultaneously). This is very useful when you have to establish delivery of such content using a limited amount of spectrum (such as typically available in terrestrial channels) and when limitations are imposed on the cost of the network due to economic and social aspects.

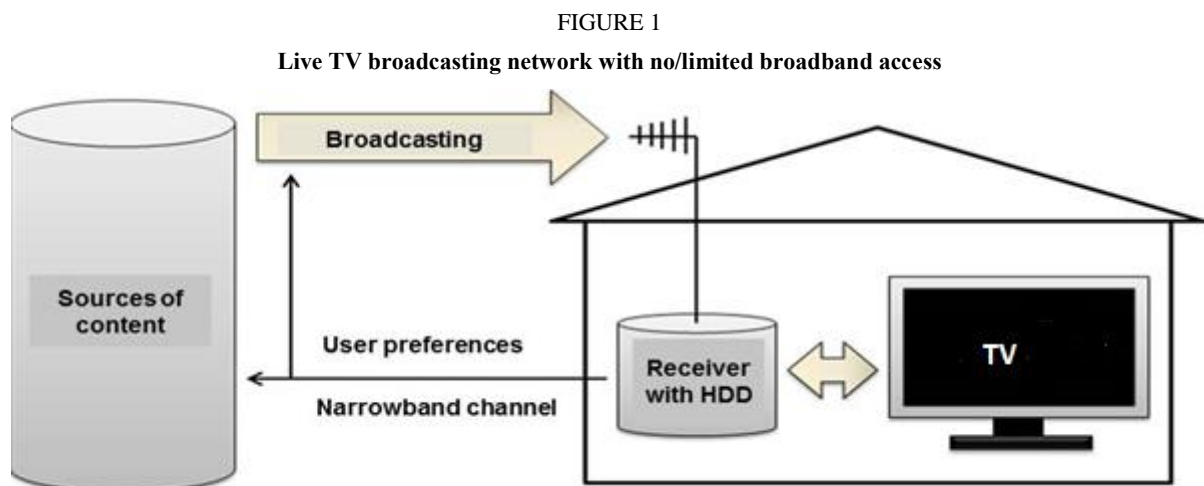
It is anticipated that the DVB-T2 standard allows networks to be configured to deliver program service content to mobile and handheld devices. This feature of DVB-T2 networks could complement mobile broadband networks and be used to offload a significant amount of traffic reducing costs (both for the consumer and mobile broadband network operators) and offering improved quality of service.

Other innovative ways of using the DVB-T2 technology are being investigated, (such as the Tower Overlay approach) which may enable cooperative use of broadcasting systems such as DVB-T2 and LTE technologies.

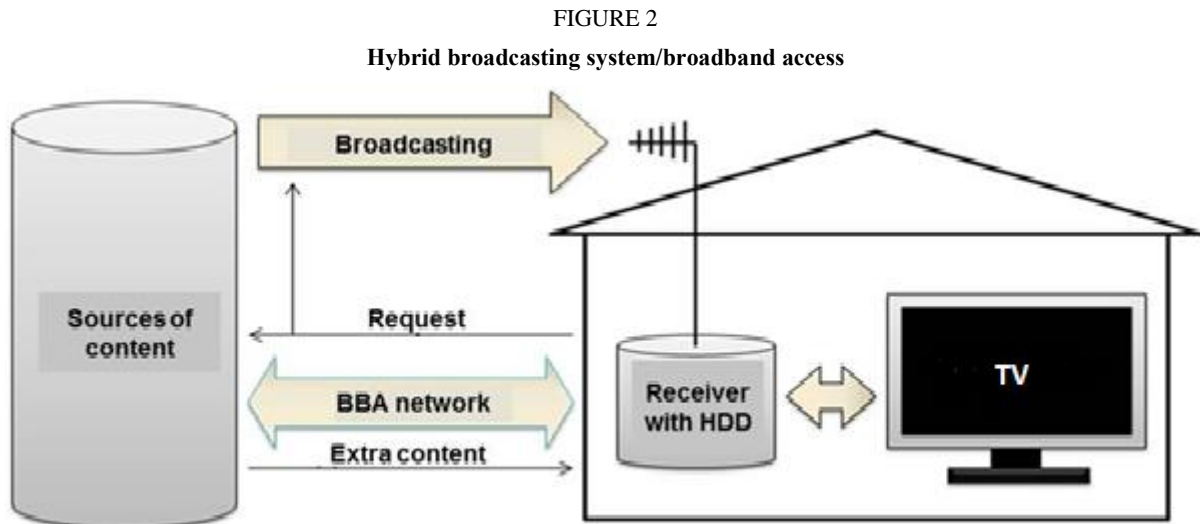
The future delivery environment for digital content will require different radio technologies to achieve the most effective delivery of “heavy” broadband content through radio communications. Therefore from the point of view of service accessibility for end users a hybrid system is the most effective, combining the advantages of broadcasting and individual data transmission channels.

It will become possible due to a home multimedia server, to have a system element serving home and personal fixed and portable user terminals (TV displays, computers, tablets etc.), and i.e. allowing the most effective selection of services of the top (application) level of the ISO model.

For that kind of model, interactive TV receiver with recording capabilities, providing real-time viewing of a TV programme due to availability of a fast subscriber communication channel is placed directly indoor at the subscriber's premises, and the need for fast bi-directional communication channel is fulfilled. Network diagrams for such networks with broadband access channel unavailable/available are given in Figs. 1 and 2 respectively. With broadband channels unavailable, the diagram at Fig. 1 allows implementation of interactive broadcasting services at low cost and no need for extra infrastructure or degradation of the quality with an increased number of users.



When selecting programmes to be stored from broadcasting streams, a home multimedia server with view list statistics, can consider the preferences of its users. It will ensure maximum “hits” even with the limited volume (i.e. low cost) of the data storage device. Users will not have to download multimedia programmes and other data via a data transmission network, if these programmes would be already available in a storage device of a home multimedia centre. When shaping programme broadcasting streams (Fig. 2), information on user preferences can be considered to achieve maximum efficiency of hybrid system use.



Such a combined delivery system has significant advantages in suburban and rural areas, thus enabling the significant reduction of total costs of the solution and subscriber's expenses not exceeding the level acceptable for mass use.

Advantages of a hybrid approach are:

- ensured interactivity with a reduced load of radio channel or Broad Band Access;
- reduced total costs, being crucial for subscribers in rural and less economically developed areas;
- reduced dependence on a single operator and from the occupancy level of his communication network;
- possibility to ensure simultaneous delivery of certain programs to all subscribers, *inter alia*, in emergencies;
- service integration at user application level – requiring no modifications to existing standards or standardization of new radio communication/broadcasting systems.

Broadcasting or broadcast delivery of multimedia content, as a technology whereby the quality of radio channel operation does not depend on the number of receiving devices (“subscribers”), will maintain its position, where networking technical or economic constraints exist, or with objective limitations of aggregate radio channel capacity available.

The example of limited radio channel capacity is frequency spectrum in the UHF band. Due to limited bandwidth, the capacity is insufficient to serve the substantial number of broadband subscribers in densely populated areas, but under the same condition it provides broadcast delivery of high-quality programmes and high-speed multimedia content to all subscribers simultaneously. Meanwhile, delivery of “global” and nationwide content may be efficiently implemented by use of satellite broadcasting (for subscribers with satellite receivers).

ITU-R collected data on current and prospective use of frequency band 694-790 MHz for terrestrial TV broadcasting in ITU Region 1. For this purpose, the administrations have received a questionnaire requesting to indicate their position on this issue. Report ITU-R BT.2302 addresses the feedback from the administrations.

The analysis of the feedback has shown that in 54% of responding countries more than 50% of population is being provided with TV through the air broadcasting, however, in the future the number of multiplexes in the band 470-862 MHz in most countries may vary from 4 to 8, and the required amount of UHF spectrum for TV broadcasting in 27 countries exceeds 224 MHz.

3.2 Increase of available radio spectrum for other primary service

3.2.1 Mobile service (IMT systems)

There are several efforts currently underway aiming at further enhancing the performance of mobile technologies in delivering higher capacity, data rates, and user experience and in delivering mobile multimedia services efficiently.

WRC-07 allocated the band 790-862 MHz also to the mobile, except aeronautical mobile service in Region 1. WRC-12 adopted Resolution **232 (WRC-12)** relating to the allocation of the frequency band 694-790 MHz in Region 1 also to the mobile service, except aeronautical mobile service (see also footnote RR No. **5.312A**).

The identification of the frequency band 694-790 MHz for IMT use may require sharing and compatibility studies⁹ throughout Region 1 in order to allow the introduction of mobile services in this band, while protecting the existing rights as contained in GE06.

In Regions 2 and 3 large parts of the mentioned bands were already co-allocated to mobile at an earlier date.

3.2.2 Other mobile communication systems

With the emphasis on devoting the frequency resources that may become available through the digital dividend to providing broadband connectivity in remote or rural areas, it is necessary to ensure that the spectrum newly available for the mobile service makes efficient use of spectrum and also provides affordable service to the public. This accords with the definition of the digital dividend used in this Report, which expects the realization of a digital dividend to be on a technology and service neutral basis, with the aim of promoting competition and innovation.

There is a number of applications capable of providing broadband connectivity in large areas with low population density available. The various alternatives, therefore, need to be evaluated in order to ascertain if devoting the digital dividend primarily to IMT/LTE use in the UHF Band does indeed make the best use of the spectrum resources in all circumstances.

To cover the needs of rural areas for broadband connectivity has often been highlighted as an important task for ITU-R but for rural areas it is also critical to keep a diversity of technology available for the users, bearing in mind to consider accessibility for the entire population. Reliance on only one technology for providing electronic communication services supporting broadband (i.e. IMT/LTE) will actually limit flexibility in the provision of service offerings and the availability of bandwidth capacity because every technology has essential limitations.

For rural areas then, it is very important that the re-allocated spectrum is used to support a diversity of services, as this will provide the best conditions for competition in the broadband market, and hence the conditions for its further development. Each technology has its strengths and weaknesses, and it is not reasonable to expect that selecting *a priori* a single winning technology.

3.3 Different ways to exploit the digital dividend

Modern digital delivery radio systems may be in competition when providing all or some particular services. At the same time, they can be effectively combined at the higher (application) level for the effective use of all the advantages of each delivery means. Convergence of services and communications technologies in the future will lead to the formation of a single multi technological information environment, which will include both existing technologies and new ones. Wireless

⁹ Report ITU-R M.2241 – Compatibility studies in relation to Resolution 224 in the bands 698-806 MHz and 790-862 MHz.

broadband access via mobile communication networks is currently growing quickly, as there is a demand for data transmission services. The advantage of mobile communication networks is to transmit data packets, including on-demand delivery of broadcast TV content. Plus, mobile service provides users with a more extensive list of services through access to the Internet (which, among other things, provides access to public governmental services), data exchange and voice communication.

However, due to the specifics of mobile communication, when a network is highly loaded, quality of service (transfer of data to the user upon request at the desired speed) may decrease. Therefore, mobile networks and wireless broadband networks, apparently, cannot be regarded as a complete replacement for broadcast TV networks to ensure the transmission of high-quality programmes to a large number of users simultaneously. The exception is the use of the infrastructure of mobile networks for broadcast transmissions (e.g. mode eMBMS). In this case, it is possible for the mobile networks to establish broadcast transmissions. Currently used mobile communication broadband access technologies (UMTS, LTE) assume the use of existing mobile network infrastructures, created primarily for voice communication (such as GSM). Unlike voice communication, broadband access results in an increase in the traffic usually happening when new data-consuming applications became popular. This problem can be solved in three ways: increasing the amount of spectrum used, improving the efficiency of spectrum use (new technologies, offload traffic solutions), and the expansion of networks infrastructure (for example, reducing the size of the BS service areas). Due to the cost of modern mobile networks, in many countries a large part of the area is still not covered. However, coverage of the population in many other countries has already exceeded 90%. Therefore, when considering the development of mobile communications in rural areas, there is a need to look for the most effective solutions for reducing the cost of networks, such as the use of the lowest frequency bands.

Broadcasting or broadcast (one-to-many) delivery of multimedia content on the downlink as a technology in which the quality of the radio channel does not depend on the number of receivers ("subscribers"), can play an important role, together with the on-demand data delivery, as there are technical or economic restrictions on building networks and there are objective limits the total radio channels bandwidth. The frequency spectrum in the UHF band has a limited capacity. Due to the limited bandwidth, resource is insufficient to provide on-demand delivery to a large number of subscribers in a densely populated area, but it makes possible to provide broadcast (one-to-many) delivery of high-quality programmes and multimedia content to subscribers in rural areas, or to provide the broadcast delivery of high-quality programmes and multimedia content simultaneously to all subscribers within the city, where, in addition to broadcasting, there are many alternative methods for on-demand TV content delivery (cable TV, IPTV, etc.).

Terrestrial mobile service channels (especially when intending to keep large Base Station service areas and capacity), and the fixed satellite services for bidirectional data transmission, in terms of on-demand delivery of multimedia content to the masses, should be considered as a relatively narrow band channels. Their limited resource should be used as efficiently as possible, primarily for the transmission of specific content to individual users, or a by-request transmission of the content what is not part of mass broadcast streams. Other delivery means, such as broadcasting, can play an important role as the efficient offloading solution with respect to certain types of traffic. For example, the broadcast service is most suitable for the transmission of bandwidth-demanding content wanted by a large number of users – news, sports events, weather forecasts, current and previous issues of entertainment programs such as movies and TV series, etc. Could such a content be transferred via broadcast delivery channels, especially in combination with maintaining for some time in the memory of receiver for on-demand display later (if necessary), it will significantly offload broadband access channels for on-demand transmission of other, also important data, by the request of individual users.

4 Spectrum management aspects relevant to the digital dividend

Spectrum management has the objective of creating the possibilities for efficient and effective use of spectrum. It promotes the provision of services with minimal cost for the consumer. As far as the realization of the digital dividend makes the choice of different technologies and services possible, spectrum management activities should take into account the existing conditions in a particular frequency band. Depending on the use of the digital dividend, spectrum management actions should be undertaken e.g. rearranging of existing services. By looking at the nature of the spectrum which is considered as a digital dividend, the following factors should be taken into account:

Current exploitation of frequency bands in a certain territory and contiguous regions;

- spectrum demands of different radio services, calculated for conditions of certain territory and frequency band;
- opportunity to change the spectrum exploitation for a certain territory and contiguous regions to a certain technology. Regulatory and technical measures and time constraints for that change and possible implementation of new radio services;
- problems of compatibility and problems of collateral utilization of frequency bands between current and new radio services;
- social importance and cost of different telecommunication services; Bearing in mind the accessibility implications, balance social and economic benefits, of new services with the cost of spectrum management measures towards the change of frequency band use;
- benefits from to broadcasters and mobile operators by the exploitation of the digital dividend;
- different radio services will complement each other in relation to digital content delivery.

It may be reasonable to combine different delivery mechanisms to users to achieve the maximum efficiency of use of the limited spectrum resource. It is also necessary to take account of the infrastructure implications in reaching the final delivery point.

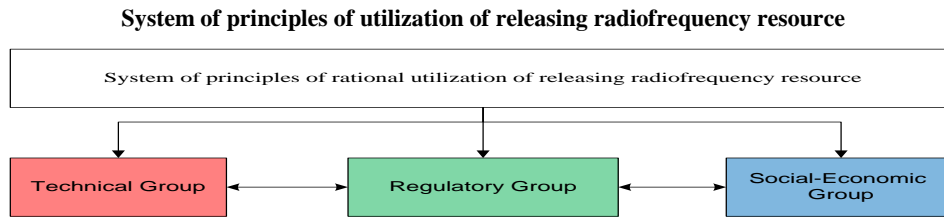
4.1 Issue 1: Spectrum planning principles

A variety of possible ways to use the released radiofrequency resource exist. Based on high spectrum demands of broadcasting¹⁰ and mobile¹¹ radio services there is the necessity to consider spectrum planning principles within the framework of digital dividend utilization. These principles are the basis for making a decision of rational realization of Digital Dividend. They can be presented as a system of interrelated groups (Fig. 3). On Fig. 4 the matter of principles and their connections has been expanded (belonging to the group of principles is marked by the same colour as on Fig. 3).

¹⁰ Report ITU-R BT.2302 – Spectrum requirements for terrestrial television broadcasting in the UHF frequency band in Region 1 and the Islamic Republic of Iran. <http://www.itu.int/pub/R-REP-BT.2302-2014>

¹¹ Report ITU-R BT.2302 – Spectrum requirements for terrestrial television broadcasting in the UHF frequency band in Region 1 and the Islamic Republic of Iran. <http://www.itu.int/pub/R-REP-BT.2302-2014>

FIGURE 3



The technical principles group can be regarded as the group of restrictions i.e. these principles are required for planning of the use of released spectrum to ensure a non-interference environment.

The social-economic principles group can be regarded as the group of choices i.e. these principles should be the basis of choosing the way of allocation and utilization, releasing radiofrequency resource such as digital dividend to ensure maximum social and economic benefit.

The regulatory principles group can be regarded as the group of additions i.e. these principles connect the technical and the social-economic group.

Table 1 represents descriptions of principles and some examples of their interconnection.

FIGURE 4
System of principles of rational utilization of Digital Dividend

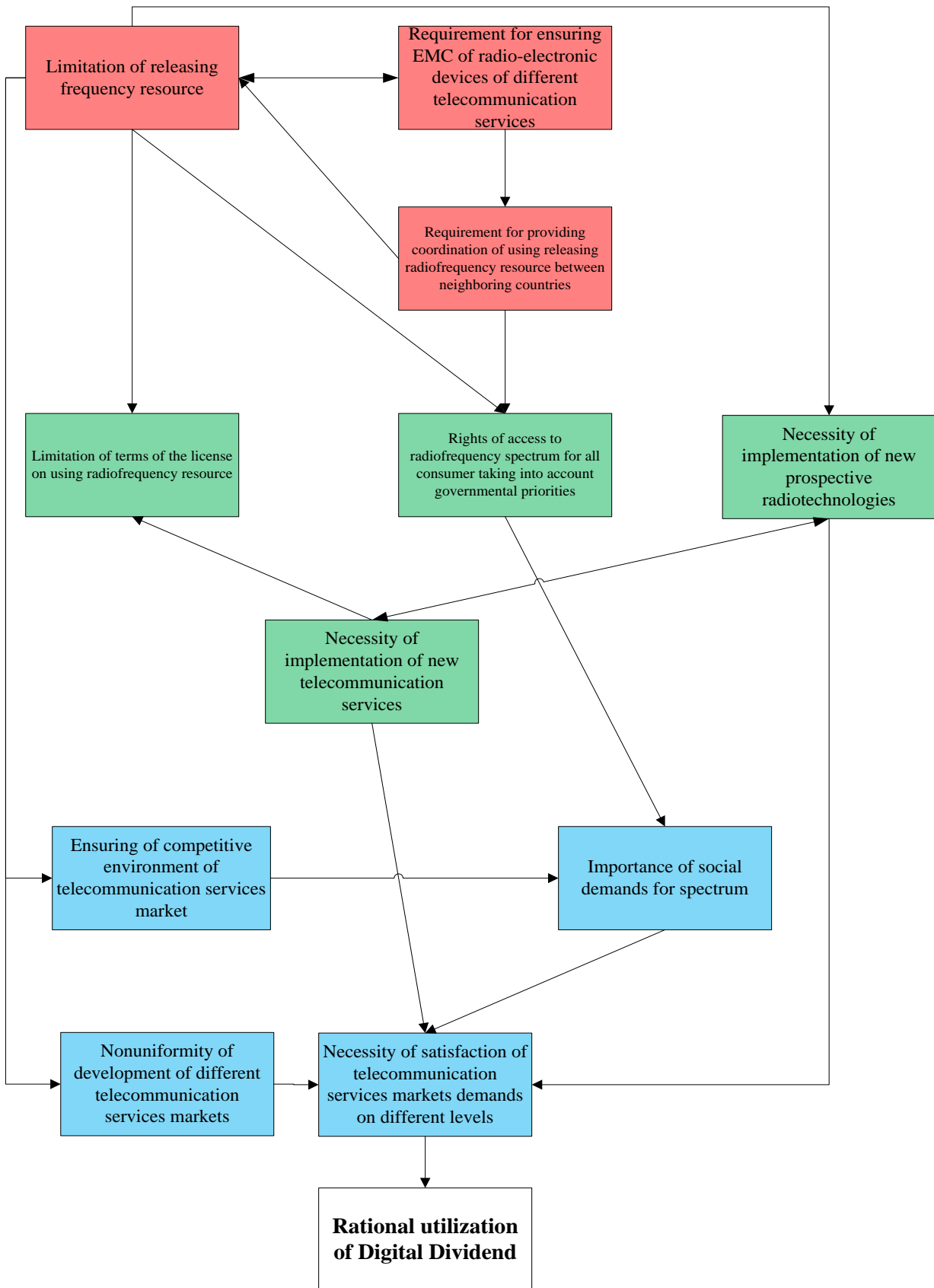


TABLE 1

Principles of rational utilization of Digital Dividend

Principle	Groups	Description
Limitation of released frequency resource.	Technical	The radio frequency resource is a limited natural resource with a set of features. It means that in some cases (such as digital dividend) it is impossible to satisfy all of the spectrum demands of the telecommunication services market. It leads to the necessity of sharing the resource between telecommunication services or choosing a more important one for allocation of the released radiofrequency resource.
Requirement for ensuring EMC between radio-electronic devices of different telecommunication services.	Technical	Allocation of the spectrum to the different radio services leads to the necessity of ensuring EMC between radio-frequency devices of different telecommunication services. Disregarding EMC principles can cause the lowering of the quality of services up to the full failure of rendering them.
Requirement of providing coordination of using released radiofrequency resources between neighbouring countries.	Technical	Radiofrequency resource of the same frequency range can be utilized for different telecommunication services in countries. Particularly digital dividend can be used for DTV and IMT. That fact leads to the necessity of providing coordination of planning of utilization of the digital dividend in bordering territories of neighbouring countries. Disregarding that principles can cause the same problems as disregarding the EMC-principle.
Limitation of terms of the licence for using radiofrequency resource.	Regulatory	This principle is a result of the limitation of frequency resource. This principle should be considered during the allocation of the digital dividend decision-making process because this limitation stimulates the competitive environment of the telecommunication market and also the development and implementation of new telecommunication technologies.
Rights of access to radiofrequency spectrum for all consumers taking into account governmental priorities.	Regulatory	Respecting this principle is necessary for providing a governmental function such as national defence, law-order, and disaster management. Moreover, that principle provides for ensuring the social rights for equal access to telecommunication services.
Necessity of implementation of new innovative radio technologies.	Regulatory	Providing governmental policy for implementation of new radio technologies that use the radiofrequency resource more effectively is the key factor for a new releasing of resources such as the digital dividend. Also, new technologies can be a bridge for fundamentally new services that cannot be provided by current technologies.

TABLE 1 (*end*)

Principle	Groups	Description
Necessity of implementation of new telecommunication services.	Regulatory	This principle is the consequence of the previous one. The telecommunication services market is a fast-growing area that should be filled by new innovative services that stimulate market competition also provide an increase of efficiency of radiofrequency spectrum use.
Ensuring a competitive environment for the telecommunication services market.	Social-economic	Market competition for the rights of using limited radiofrequency resource regarding governmental priorities and limitation of terms of the licence for using radiofrequency resource ensure the adherence to the principle of necessity of implementation of new telecommunication services and upgrading the current ones.
Importance of social demands for spectrum.	Social-economic	This principle is the consequence of the principle of governmental priorities and is necessary for providing different telecommunication services in conditions of non-uniformity access and demand for them i.e. non-uniformity of development of different telecommunication services market
Non-uniformity of the development of different telecommunication services markets.	Social-economic	Non-uniformity access to telecommunication services (digital divide) can appear on different levels: cross-country level (countries with better access to services-countries with worse access), inland level (territories inside a country with better access to services- territories inside a country with worse access) city-rural level. Considering that it is possible to state that principle of priority of social demand leads to the necessity of satisfaction of telecommunication services markets demands on different levels such as regions or administrative areas.
Necessity of satisfaction of telecommunication services markets demands on different levels.	Social-economic	This principle is the resulting principle on a base of that Digital Dividend allocation decision should be done to maximize the social-economic effect of utilization releasing frequency resource.

Adherence to these principles allows to utilize the released frequency resource rationally, to ensure the achievement of the main goal of spectrum management – ensuring the maximum social-economic benefit of using the radiofrequency spectrum without interference. Moreover, it can help to bridge the digital divide (see § 2.3).

4.2 Issue 2: International and regional harmonization

Regional harmonization has a key role to play for the allocation of the digital dividend in order to obtain the benefits resulting from economies of scale on the provision of services and avoiding insurmountable interference problems in border areas.

4.2.1 Europe

In Europe, spectrum issues are discussed through the following process:

- The Radio spectrum Policy Group (RSPG), develops Opinions on various spectrum related policy issues to the European Commission (EC);
- On this basis, the EC could decide to develop spectrum harmonization measures in cooperation with the Radio Spectrum Committee (RSC). In order to have the technical conditions for the use of the spectrum developed, the EC issues mandates to the CEPT (the European conference of Posts and Telecommunications administrations, formed by 48 administrations).
- These conditions are integrated in EC implementing decisions, which are adopted in cooperation with the RSC (binding on EU Member States).

Within Europe, discussions on the digital dividend started in 2006 with the adoption of a first RSPG Opinion and a first Mandate from EC to CEPT in early 2007. In response, CEPT identified the upper part of the UHF band as the preferred band for the purpose of a mobile allocation as part of the digital dividend.

After WRC-07, in April 2008, the EC issued a second Mandate to CEPT on the technical considerations regarding “harmonization options for the digital dividend in the European Union”. On the basis of the CEPT response, the EC adopted the following:

- [European Commission Recommendation 2009/848/EC](#) on “Facilitating the release of the digital dividend in the European Union”, in October 2009”
- [Commission Decision 2010/267/EU](#) on “harmonised technical conditions of use in the 790-862 MHz frequency bands for terrestrial systems capable of providing electronic communications services in the European Union”, in May 2010.

This decision is binding on EU Member States, but a common implementation date has not been established and implementation has been or is dependent on the political decision to make the band available to the mobile service. When the band is made available the technical conditions of the EC Decision have to be applied on the political decision.

Concerning the frequency range 694-790 MHz, a further mandate to CEPT was issued by the EC in 2013. In response, CEPT delivered CEPT Report 53 on the harmonised technical conditions for the 694-790 MHz in the EU for the provision of wireless broadband and other uses in support of EU spectrum policy objectives.

The technical considerations regarding harmonization options for the digital dividend in the European Union are described in CEPT reports. Five CEPT Reports have been adopted, see Table 2. Further ECC Report 224 was finalized November 2014 on the Long Term Vision for the UHF broadcasting band.

TABLE 2
CEPT/ECC reports related to digital dividend

CEPT Report	Title
CEPT Report 29, 26 June 2009	Guideline on cross border coordination issues between mobile services in one country and broadcasting services in another country
CEPT Report 30, 30 October 2009	The identification of common and minimal (least restrictive) technical conditions for 790-862 MHz for the digital dividend in the European Union
CEPT Report 31, 30 October 2009	Frequency (channelling) arrangements for the 790-862 MHz band
CEPT Report 32, 30 October 2009	Recommendation on the best approach to ensure the continuation of existing Program Making and Special Events (PMSE) services operating in the UHF (470-862 MHz), including the assessment of the advantage of an EU-level approach
CEPT Report 53, 28 November 2014	Harmonised technical conditions for the 694-790 MHz in the EU for the provision of wireless broadband and other uses in support of EU spectrum policy objectives
ECC Report 224, 28 November 2014	Long Term Vision for the UHF broadcasting band

CEPT Report 29 gives guidance on cross-border coordination issues which are of particular relevance during the coexistence phase, i.e. when some countries may have implemented the technical conditions optimized for fixed and/or mobile communications networks, while others still have high-power broadcasting transmitters in operation in the band 790 to 862 MHz. The GE06 Agreement provides the applicable regulatory procedures for cross-border coordination.

CEPT Report 30 identifies restrictive technical conditions through the concept of Block-Edge Masks (BEMs), which specify the permitted emission levels over frequencies inside and outside the licensed block of spectrum, respectively. The report specifies three levels of protection of broadcasting channels:

- A) digital television channels where broadcasting is protected;
- B) digital television channels where broadcasting is subject to an intermediate level of protection;
- C) digital television channels where broadcasting is not protected.

For the protection of terrestrial broadcasting channels in use at the time of deployment of Mobile/Fixed Communications Networks, baseline requirement mentioned in situation "A" is to be applied. For digital terrestrial television channels which are not in use when implementing an electronic communications network base station, an administration may choose between the baseline requirements mentioned in situations "A", "B" or "C". The intermediate level of protection in situation "B" can be justified in some circumstances (e.g. agreement between broadcasting authority and mobile operators).

However, it is recognized that even the BEM for category A does not provide sufficient protection in all cases and further measures are necessary, such as improved digital television receivers and/or additional measures to be taken by mobile operators to protect previously established broadcasting transmissions.

The additional measures include:

- Reducing the radiated power of the mobile base stations and adjusting their antenna characteristics to reduce interference problems, taking into account local conditions, especially for the base stations using the first frequency block above 790 MHz;

- Using a base station antenna polarization that is opposite to that of the digital terrestrial television transmitter, especially for base stations using the first frequency block above 790 MHz;
- Use of additional RF filtering at mobile base stations, especially for base stations using the first frequency block above 790 MHz;
- Use of on-channel low-power digital television repeaters at the mobile base stations to restore the degradation of signal to noise ratio at affected digital television receivers. Such remedies should be coordinated with the impacted broadcast multiplex operator, since it may not be easily applicable, such as in the case of digital television transmitters operating in a Single Frequency Network (SFN).

CEPT Report 31 concludes that the preferred frequency arrangement for the frequency range 790 to 862 MHz should be based on the FDD mode in order to facilitate cross-border coordination with broadcasting services, noting that such an arrangement would not discriminate in favor of or against any currently envisaged technology. The frequency arrangement is shown below. It has been included in the European Commission Decision mentioned above and is therefore of mandatory application in EU countries wishing to use the mobile service in this band:

FIGURE 5
Preferred harmonized channeling arrangement for the band 790-862 MHz in EU
(Source CEPT)

790-791	791-796	796-801	801-806	806-811	811-816	816-821	821 – 832	832-837	837-842	842-847	847-852	852-857	857-862
Guard band	Downlink						Duplex gap	Uplink					
1MHz	30 MHz (6 blocks of 5 MHz)						11 MHz	30 MHz (6 blocks of 5 MHz)					

CEPT Report 32 recognizes the interest in the continued operation of applications for PMSE and identifies a number of potential frequency bands and innovative technical developments as a solution to the current use of the band 790 to 862 MHz by these applications. More studies are considered necessary.

In other regions of the world, similar efforts have been undertaken to ensure regional harmonization of the parts of the UHF spectrum identified by WRC-07 for IMT. In the Asia-Pacific region, the APT (Asia-Pacific Telecommunity) has also adopted technical conditions for the use of the band 698-806 MHz band.

In CEPT Report 53, CEPT confirmed the lower edge at 694 MHz as the only option to be studied in the WRC-15 preparation and discussed possible channelling arrangements on that basis. CEPT identified one channelling arrangement for mobile/fixed communications networks (MFCN).

Within the band 694-790 MHz the MFCN channelling arrangement set out in CEPT Report 53 is as follows:

- The block sizes shall be in multiples of 5 MHz, which does not preclude smaller channel bandwidths within a block;
- Paired frequency arrangement (FDD):
 - terminal station transmitter: 703-733 MHz,
 - base station transmitter: 758-788 MHz;
- Unpaired frequency arrangement,

- Supplemental downlink¹² using ‘zero up to four’ of the following frequency blocks: 738-743 MHz, 743-748 MHz, 748-753 MHz and 753-758 MHz. This decision on the number of contiguous blocks would be taken at national level. This national approach ensures flexibility for combination with other alternative options described hereafter.

Maximum inter-regional harmonization is achieved by basing the paired channelling arrangement on the lower duplexer of the APT 700 MHz band plan allowing for economies of scale. As this would only provide for 63% utilization of the band by MFCN, placing up to four blocks of 5 MHz MFCN SDL in the duplex gap would result in a utilization of 83% by MFCN.

FIGURE 6
Channeling arrangement for MFCN in the 700 MHz band: FDD 2 × 30 MHz and Supplemental Downlink (SDL) option in the duplex gap

694-703	703-708	708-713	713-718	718-723	723-728	728-733	733-738	738-743	743-748	748-753	753-758	758-763	763-768	768-773	773-778	778-783	783-788	788-791
Guard band	Uplink						Gap	SDL (A)				Downlink				Guard band		
9 MHz	30 MHz (6 blocks of 5 MHz)						5 MHz	20 MHz (zero up to four blocks of 5 MHz)				30 MHz (6 blocks of 5 MHz)				3 MHz		

For the SDL option: There are alternative options such as for PMSE, PPDR, M2M and other services on a national basis being considered in CEPT. “The zero up to four blocks of 5 MHz approach” provides flexibility for combining different options.

ECC Report 224 addresses the trends in the evolution of services and consumer behaviour, as well as the networks and technologies that offer the potential to deliver these services in the band. It includes consideration of the way in which audio visual content consumption habits may be changing. The most important developments in relation to the evolution of delivery of broadcast services in fixed and mobile environments are also identified.

The studies are based on anticipated developments for the various current platforms and technologies under consideration and linked to the demand and supply of the envisaged services. Thus, it was necessary to develop relevant indicators in order to monitor the assumptions that align with anticipated developments used for the construction of the future scenarios.

4.2.2 Asia Pacific

In the Asia-Pacific Telecommunity (APT,) consensus was reached in regard to the basic structure of a harmonized frequency arrangement for the band 698-806 MHz¹³. Recognizing the need to provide sufficient protection for the services in adjacent bands, it was concluded that a combination of mitigation measures would be necessary, including sufficient guard-band allocations within the 698-806 MHz band. It was agreed that spectrum should be allocated as follows:

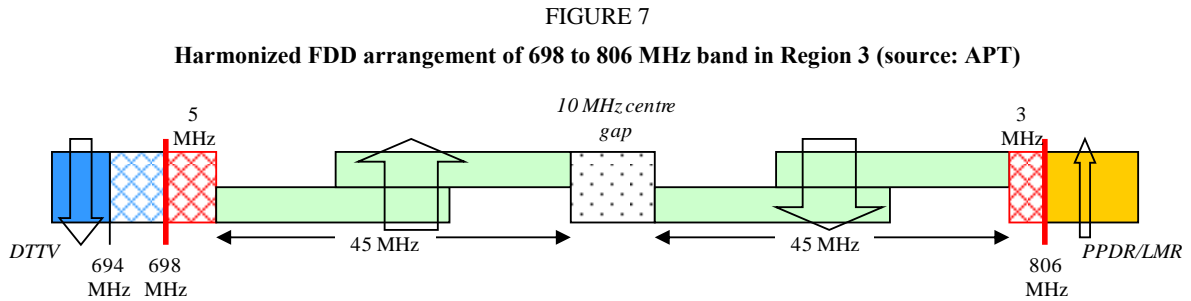
- a guard-band of 5 MHz at the lower end, between 698-703 MHz; and
- a guard-band of 3 MHz at the higher end, between 803-806 MHz.

¹² MFCN SDL could aggregate the usual downlink channel of a MFCN paired (FDD) band with a supplemental downlink channel(s) in the unpaired spectrum to increase the downlink capacity.

¹³ APT Report on harmonized frequency arrangements for the band 698-806 MHz, No. APT/AWF/REP-14; September 2010.

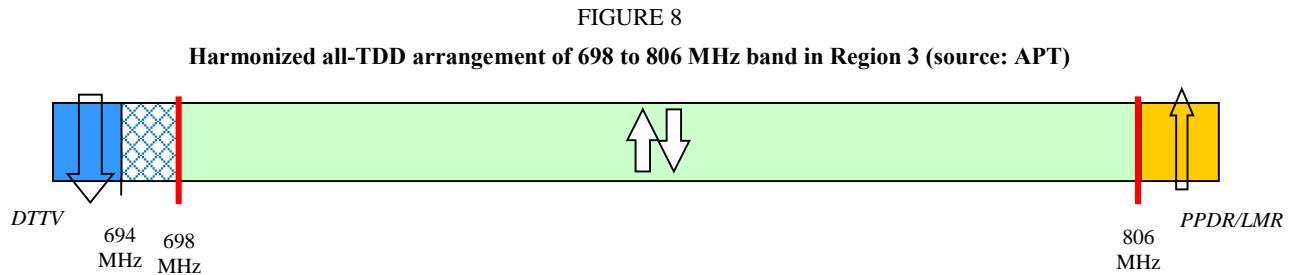
For FDD arrangement, there are two duplex frequency arrangements of 2×30 MHz (703-733 MHz/758-788 MHz and 718-748 MHz/773-803 MHz), providing a total of 2×45 MHz of usable paired spectrum.

The overall structure of the harmonized FDD arrangement for the band 698-806, MHz is illustrated in Fig. 7:



For TDD arrangement, the band 698-806 MHz is for all-TDD use. Taking into account the external 4 MHz guard band (694-698 MHz), a minimum internal guard-band of 5 MHz at the lower edge (698 MHz) and 3 MHz at the upper edge (806 MHz) needs to be considered.

The harmonized all-TDD arrangement for the band 698-806 MHz is illustrated in Fig. 8.

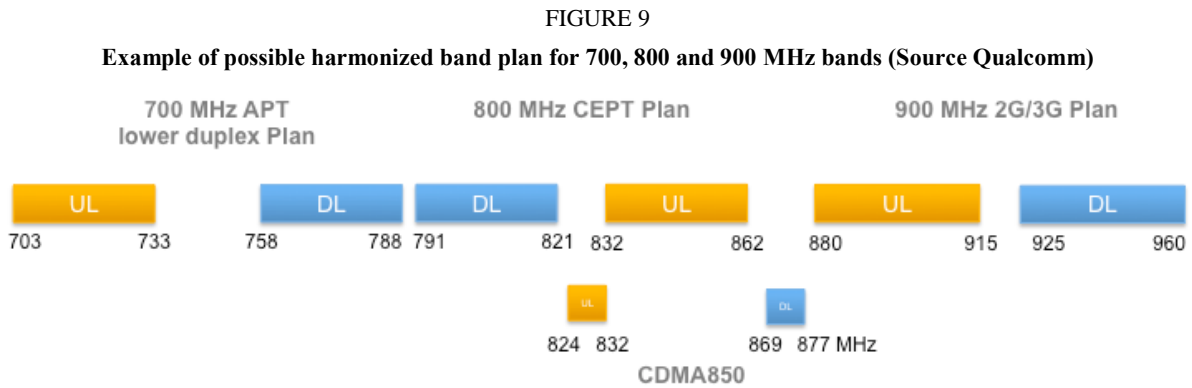


4.2.3 Worldwide Harmonization

The decision of WRC-12 to allocate the band 694-790 MHz to the mobile, except aeronautical mobile, service in Region 1 opens the way for the worldwide harmonization of both the 700, 800 MHz and 900 MHz bands for IMT.

This harmonization would resolve the long-standing differences in UHF mobile spectrum allocations between Regions, which result from the incompatible deployment of CDMA and GSM networks in the 850/900 MHz bands from the years 1990.

Significant activity is currently taking place for the adoption of such a plan. An example of the solution proposed to reconcile the CEPT and APT plans while continuing to accommodate residual CDMA 850 networks is shown in Fig. 9. This would provide a total of 2×60 MHz in the 700 and 800 MHz bands while relying on the existing band plans of CEPT and APT.



Although it should be recognized that the current use of the 700 MHz by broadcasting may prevent its availability to the mobile service in many countries in the years to come, this band will however become available soon for the latter service in many countries, which have lesser requirements for broadcasting and will therefore benefit from worldwide harmonization of the frequency band plans for IMT.

4.3 Issue 3: Cross-border coordination

WRC-07 and WRC-12 established an international framework that allowed each country to decide, whether to continue its use of the upper UHF band by television broadcasting or military applications or to use for mobile services. The only international condition to implement this national decision is that neighbouring countries agree, which requires bilateral or multilateral negotiations.

International and domestic pressures to make spectrum available to the mobile service as permitted by WRC-07 and WRC-12 can be expected to grow in coming years, if anything as a result of the remarkable growth of mobile data services and its positive impact on economic and social development, in particular in developing countries. This evolution can be expected to facilitate the above negotiations, especially where it is also formalized at the regional level.

In cases where bilateral negotiations meet difficulties, the ITU assistance may be requested to facilitate a successful outcome.

The GE06 Agreement established the international framework applicable to 119 countries for the use of the UHF band by television broadcasting. Although this agreement is not applicable to all countries, many elements of the discussions currently in progress between countries contracting to this agreement may be of use for other countries.

The GE06 Agreement contains a procedure to modify the GE06 Plan. For a modification to be recorded in the Plan, this procedure, which is routinely applied, requires the agreement of all affected countries. This agreement may be obtained by bilateral and multilateral discussions. Renegotiating the GE06 Plan, therefore, does not require renegotiating the GE06 Agreement.

4.3.1 European coordination

In Europe, the corresponding negotiations started in 2008, with multilateral discussions held within two groups: eight countries around Belgium (WEDDIP group, for Western European Digital Dividend Implementation Platform), created in May 2009, and nine countries around Germany (NEDDIF group, for North-Eastern Digital Dividend Implementation Forum), created in October 2010. At the end of this process, the GE06 Plan will be modified using the above procedure, hence the *target frequency plan* will be the GE06 Plan, as updated by this process.

The objective of these negotiations was to restore equitable access among broadcasting transmissions (typically 7 channels per geographical area) in a band limited to 470-790 MHz and to distribute any additional capacities among countries equitably.

Obviously, this process will require a more intensive use of the spectrum used by broadcasting. Such a change requires acceptance of more technical constraints to either accept more interference in certain areas and to limit the interference produced in those areas. Technical solutions involve reducing transmit power, shaping and tilting transmit antennas to reduce power in certain directions, increasing the use of SFNs to consume less spectrum¹⁴ and creating new transmitting sites to offset interference. In most cases, implementation of these solutions will result in additional cost compared to the original situation in the GE06 Plan.

From a formal point of view, the above objective may be achieved by the following:

- The current entries in GE06 Plan below channel 61 (i.e. below 790 MHz) have to be kept stable.
- Potential extensions may be considered by the addition of assignments/allotments, on the basis of the main broadcasting sites. These extensions may be recorded in the GE06 Plan as modifications of the Plan, following the formal procedure of the GE06 Agreement.
- In order to ensure compatibility between potential extensions and existing entries in the Plan, some restrictions may have to be applied to some of the latter, e.g. reduction in the equivalent radiated power, antenna pattern restrictions in some sectors, selection of one type of polarization (V or H). These restrictions may be accepted without modifying the current entries (no loss of right).
- Restrictions on existing networks should be avoided.

The key factor in identifying additional opportunities in the GE06 Plan (as well as in the case of a Plan to be established between any group of countries) is to determine the areas that may be able to share the same channels and agree on the measures that could be acceptable on each side to ensure that this sharing is possible. This may require carrying out on-site measurements in the areas where interference is predicted by the calculations, in addition to using terrain model interference predictions.

Once these areas of mutual compatibility have been identified, it is possible to develop a compatibility matrix between all the allotment/assignments that currently exist in the GE06 Plan, and those that may be considered as the replacement frequencies.

Once this compatibility matrix has been agreed, it may be used on a channel per channel basis to determine which channel may be used in a given area/site: if this channel is incompatible with one or more existing allotments/assignments in the plan, it cannot be used in the given area/site. Otherwise, it may be used at potential areas/sites, provided that another area/site which is incompatible with it, does not request the same channel, in which case two or more scenarios may have to be considered, depending on which of the competing sites/areas is selected for this channel.

Various scenarios may then be combined, and the most promising combinations of them are assessed, in an iterative process, against the requirements of each country involved until general satisfaction is obtained.

The following CEPT ECC Recommendations provide the guidance on inter-alia field strength levels to CEPT administration on cross-border coordination issues for mobile / fixed communications networks in the frequency ranges between 694 MHz and 862 MHz:

¹⁴ The use of SFN to increase the size of allotment areas may be difficult for smaller countries.

- ECC Recommendation (15)01 on “Cross-border coordination for mobile / fixed communications networks (MFCN) in the frequency bands: 694-790 MHz, 1 452-1 492 MHz, 3 400-3 600 MHz and 3 600-3 800 MHz”;
- ECC Recommendation (11)04 on “Frequency planning and frequency coordination for terrestrial systems for Mobile Fixed Communications Networks (MFCN) in the frequency band 790-862 MHz”.

4.3.2 African coordination

Within the African Telecommunication Union (ATU), following a ministerial summit on the issue, two frequency coordination meetings have studied possible rearrangements of frequency assignments in order to make space for a harmonized frequency band for mobile services (694-862 MHz) while ensuring a minimum capacity of four nationwide broadcasting coverages for each African country and concluded on their feasibility¹⁵.

4.3.3 Asian coordination

Mitigation of cross-border interference between Indonesia, Singapore and Malaysia

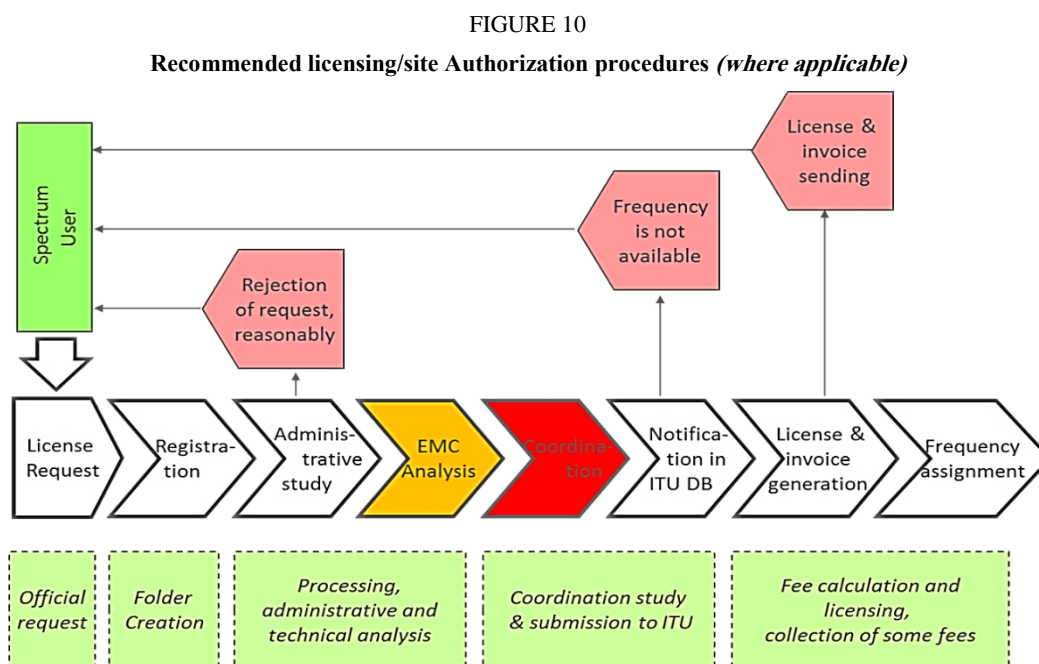
The cross border interference issue is a long standing issue between the operators of the three countries: Indonesia, Singapore and Malaysia.

Operational Recommendations

These represent the steps that MCIT should take (while following the current organization structure) in order to improve current processes and procedure for efficiently managing spectrum on day to day basis.

Licensing and/or telecom site Authorization processes

MCIT through its General Directorate of SDPPI has a very elaborate structure of dealing with issues related to Spectrum Management. However review of the operational procedures of licensing or providing authorization for spectrum usage (where applicable) may be required. The recommended procedural flow is as below:



¹⁵ <http://www.itu.int/en/ITU-D/Technology/Documents/Broadcasting/DigitalDividend.pdf>.

The function highlighted in red is especially important to control unwanted interference within country and across borders. In order to undertake the coordination study before approval, MCIT should provide the applicant with detailed technical, operational and administrative coordination requirements and may ask from applicant RF survey report before the site authorization is provided especially in cases where the location of the transceiver/transmitter is at the border areas. Although these reports are preferred in the form of drive test survey reports however simulation studies from well-known network planning tools may also be effective provided that MCIT reconfirms them using latest digital maps with detailed geographic and city structure data. The reports would also help in getting required agreement from affected stakeholder/countries.

Function highlighted in yellow is especially important for populated areas especially for sites with high radio infrastructure sharing. It should be responsibility of the regulator to undertake such general surveys regularly. A comparative study of two successive surveys would help in identifying the areas that need attention.

5 National spectrum management aspects

There are some activities on national and regional level on the digital dividend questions, with support provided by ITU. These activities aim at collecting country experiences on digital dividend issues. In 29-31 January 2014, a Regional Seminar on Transition to Digital Terrestrial Television Broadcasting and Digital Dividend for Europe was held in Budapest, Hungary¹⁶. This Seminar was the final event of the European Regional Initiative on Digital Broadcasting for Europe for the exchange of best practices encountered on the path of digital migration, and worked towards the way to maximize the economic and social benefits of the digital dividend. It considered also how to develop further a unified approach in order to enhance the advantages that it will bring to the region of Central-Eastern Europe.

In 5-7 May 2015 a Regional Workshop for Europe and CIS on Spectrum Management and Transition to Digital Terrestrial Television Broadcasting was held in Budapest, Hungary¹⁷. This Workshop was organized in the context of the European Regional Initiative approved by WTDC-14 on Spectrum Management and Transition to Digital Broadcasting that seeks to provide a basis for the exchange of best practices encountered on the path of digital terrestrial television broadcasting transition, and works towards the way to maximize the economic and social benefits of the digital dividend.

6 Other relevant aspects (socio-economic, societal and political) for decisions on the digital dividend utilization

Considering the decision on the optimal use of the digital dividend, it is not enough to consider only the economic benefits. As already mentioned above (see § 2.3.1), there is a range of social and economic issues to be settled by the use of the digital dividend. The digital divide, as mentioned in § 2.3, i.e. the inequality in access to advanced communications services, is the most important of them.

There are different methods/approaches to deciding how the digital dividend could be better used.

¹⁶ <http://www.itu.int/en/ITU-D/Regional-Presence/Europe/Pages/Regional-Seminar-on-Transition-to-digital.aspx>.

¹⁷ <http://www.itu.int/en/ITU-D/Regional-Presence/Europe/Pages/Events/2015/Spectrum-Management.aspx>.

6.1 An approach based on general considerations: technical, socio-economic, societal and other

This approach assumes consideration of key important factors like:

- Socio-economic aspects in the respective regional area
- Possible business models and corresponding social benefits
- Potential coverage of respective services
- Demands of local societies
- Benefits that may be driven by competition
- Technical constraints
- Level of investment required for introduction/continuation of respective services
- Spectrum availability and conditions of the use (including the requirement for reallocation of existing services, if necessary)

and others.

When considering these factors and the usage of the digital dividend, it is usually intended to maximize public benefits, as understood in a particular administration. This is a general description; local decisions may be taken on the basis of particular considerations of only some of the factors given above.

6.2 An approach based on the estimation of the consumer demand for one or another future service (or extension/prolongation of existing service) in the respective area (region, country, part of a country)

The optimal usage of the digital dividend is closely related to the heterogeneous development of relevant communication service markets. The consumer demand for different kinds of services is the most crucial factor reflecting the development of the communication service markets. The consumer demand reflects the value of the potential subscriber base for such services and potential amount of payments from those subscribers. At the same time, it is necessary to take into account the fact that the frequency resource that could be available as the digital dividend, typically is not large enough to provide the necessary bandwidth for the establishment of totally new services. Normally, the digital dividend is only able to improve some of the existing services (i.e. mobile service or broadcasting) to improve or expand their capabilities or decrease operation and infrastructure cost. The effect of that improvement will depend on the total spectrum demand of the respective service and the amount of other available spectrum when comparing the size of the digital dividend bands. Consumer demand will be dependent on the following factors:

- potential improvement provided in case of the digital dividend usage for respective service to user-important properties of that service;
- the cost and, correspondingly, potential future penetration of respective service (as social factor) when taking into account consumer's interest and willingness to pay;
- the population (consumers) density, infrastructure limitations and other social and technical factors, which will affect the costs and benefits of respective services.

This approach sets up a clear criterion based on estimation of the potential benefits of different digital dividend usages through the analysis of consumer demand for television and mobile services. It is necessary to use similar input data to estimate consumer demand for television services and consumer demand for mobile communication services. It is assumed that continuation of the usage of the digital dividend for broadcasting service beyond the basic functionality, what simple replacing former analogue services, is also a possible implementation of the digital dividend.

In details, this approach is described in Annex 3.

7 Summary

The transition from the analogue terrestrial television to the digital one created the phenomenon of the digital dividend. There is a different understanding of digital dividend in different ITU Regions and countries. Despite that there is an equal problem for the world telecommunication society – how to utilize the digital dividend in the optimal way. This Report contains the examples of the national experience of some countries with regard to that problem. Also this Report contains the information on problems which can be solved by the optimal utilization of the digital dividend (for example, bridging the digital divide) as well as the problems which can occur by the non-optimal utilization (for example, failing to satisfy the demands of the telecommunications service markets). Also, it is necessary to determine the conditions for the appearance of the digital dividend. The decision on the digital dividend realization should be based on the consideration of many factors: technical, regulatory and social-economic. These factors are described in the Report. However, most information about the technical side of the digital dividend utilization is about Europe and DVB-T/T2. There is the opportunity to revise this Report in future by adding some new examples of national experience as well as new information on technical and economic issues (ATSC, ISDB-T, DTMB; their compatibility with IMT; additional telecommunication services that can be implemented in the frequency ranges of digital dividend, etc.).

Annex 1

National experience on the implementation of the digital dividend in different countries

Attachment 1 (to Annex 1)

National experience on the implementation of the digital dividend in the Russian Federation

1 Introduction

Historically parts of the bands 174-230 and 470-862 MHz were mainly used by analogue TV. Active development of the digital technologies facilitated making the decision about the beginning of the implementation of digital broadcasting in Russia. Thus in 2005 implementation of digital TV in DVB-T standard in the bands 174-230 and 470-862 MHz was approved by the decision of the State Commission for radiofrequencies.

RRC-04/06 decisions have stimulated the development of provisions for transition of analogue TV broadcasting into digital format and adoption in 2009 in the Russian Federation of Federal programme “Development of TV and radio broadcasting in the Russian Federation for 2009-2015”.

2 National decisions concerning availability of the digital dividend

According to the Federal programme “Development of TV and radio broadcasting in the Russian Federation for 2009-2015” the first, second and the following additional digital terrestrial TV multiplexes have been planned, which could accommodate the current terrestrial analogue TV programmes into the digital format. However, even when analogue TV broadcasting will be fully duplicated by the digital format, it will take the time to reach the sufficient level of households’ penetration by digital receiving equipment. It is expected that digital switch-over in the Russian Federation will be possible around 2019.

As a result of actions on the frequency planning within the transition into digital TV broadcasting, the released part of the spectrum is the frequency band 790-862 MHz, which can be considered as digital dividend. For the aim of implementation innovative technologies on the territory of Russia, the band 790-862 MHz was given to LTE and its further modifications in 2011.

Moreover, later in July 2012 the contest for acquiring licenses to provide services by using LTE or its further modifications over the Russian territory in the band 791-862 MHz was held. The frequency band was divided into four parts. By the terms of contest, each operator-winner shall provide LTE-communication in settlements with more than 50 000 population till 2019, investing in the networks construction not less than 15 billion RUR per year in the period from 2013 to 2019. Moreover, the winners in cooperation with the Government and other spectrum users shall complete spectrum redeployment works in this band in accordance with agreed roadmap. Such works are in progress for the frequency band 790-862 MHz.

In 2012 for the purpose of the further development of digital TV broadcasting the decision was taken to use the DVB-T2 standard in the bands 174-230 MHz and 470-790 MHz. In 2014, the Governmental decision was taken on beginning of the transition of channels of the first and second TV multiplexes into HDTV standard.

Attachment 2 (to Annex 1)

An example of spectrum redeployment process based on the Benin experience

The redeployment of the spectrum is a complex task which can become harder when implemented in a developing country because of the immaturity of the national framework for spectrum management and especially the lack of a national strategy shared by all stakeholders (government, regulatory authority, operators ...).

However, these reasons should not be taken as an obstacle for developing countries as a redeployment may represent a real opportunity for effective and efficient use of the spectrum. Indeed, due to the lack of a national strategy for spectrum management, various technologies from various regions have often been deployed in inadequate frequency bands, so a spectrum redeployment usually put things in order and allow the introduction of appropriate technologies and services.

This Attachment is based on the Benin experience of spectrum redeployment of the 790-890 MHz frequency band, which may be useful for some of the developing countries.

1 Issues and objectives of the redeployment

The Benin telecommunications sector is driven by three main actors offering various services:

- a public operator offering fixed telephony (wired and wireless) and internet access services;
- five private operators offering mobile telephony and internet services;
- five internet access providers through wireless access networks.

The 790-890 MHz frequency band, identified for IMT, was previously occupied by the public operator for its CDMA 2000 network as fixed internet wireless access system. Due to the decision of the Government of the Republic of Benin to grant licenses for new generations networks, it has been necessary to carry out a redeployment of this band.

The main objective of this redeployment was to make the 790-862 MHz frequency band available for the promotion of mobile broadband, and by doing so, to enable the efficient use of the band.

2 Methodology

The regulatory authority of Benin is the structure responsible for the management and control of the radio spectrum. As such, it could lead the redeployment process, from design to implementation, but in order to be impartial and due to the short time given, it was decided to hire a consulting company to carry out the redeployment.

The selection of the company was made according to criteria such as expertise in radio engineering, planning and deployment of CDMA and UMTS networks and knowledge of associated costs.

A committee was appointed to monitor the redeployment process, with members from the regulatory authority, the Ministry of ICT, and operators involved. The study mission lasted five months and required regular meetings with all the operators involved. At the end of the mission, the following deliverables were developed:

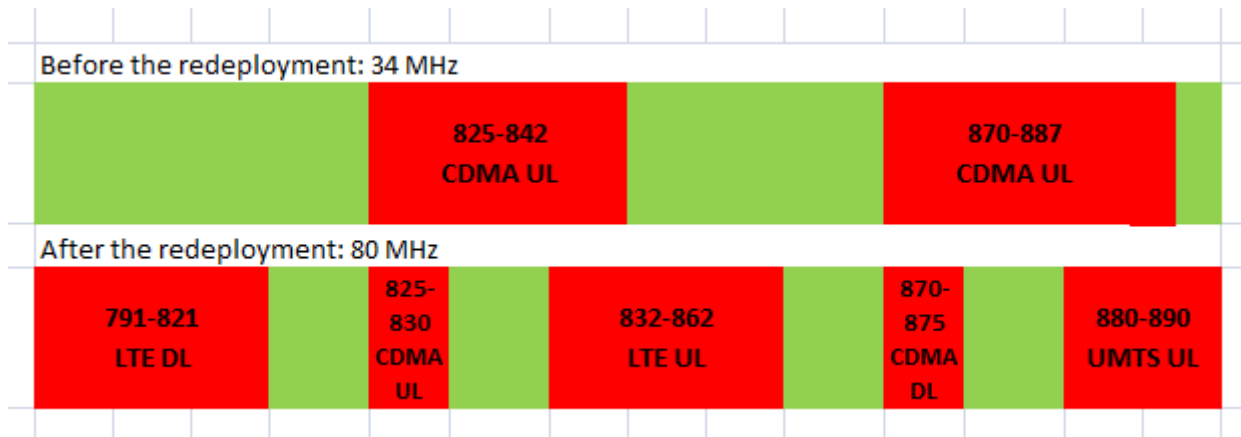
- a document detailing three options for the outgoing operator with the frequency plan, the benefits and the technical constraints of each option;
- the schedule of implementation of each option;
- the cost of the redeployment regarding each option with the detailed elements associated costs;
- a detailed communication plan to address the subscribers of the outgoing operator.

3 Results of the redeployment

First digital dividend made available and improvement of the spectral efficiency

This redeployment has achieved the main goal consisting on making available the 790-862 MHz frequency band for the promotion of mobile broadband in Benin.

The following picture shows the evolution of the occupation of the spectrum before and after the redeployment:



Economic and social benefits

The redeployment of the 790-890 MHz frequency band offer both economic and social advantages. Indeed, the CDMA network operated by the public operator has 93 012 voice subscribers and 48 890 data subscribers (population of Benin: 9 500 000 inhabitants in 2012) with limited coverage and services.

It is therefore obvious that the introduction of mobile broadband in the band will lead to important economic benefits (new licenses, operators' contribution, payment of fees, etc.), as well as social benefits (universal service, job creation, access to mobile broadband for everyone, etc.).

4 Conclusion

This redeployment was a very good thing for Benin because it has helped achieving an important aim, which is making available the first digital dividend for the deployment of third generation networks, in line with international trends. This has led to better use of spectrum resources.

Moreover, this redeployment allowed to experience the main difficulties of a redeployment and find appropriate solutions. Special attention should be given to the following points during an operation of redeployment in a developing country.

The involvement of all stakeholders in the redeployment

This is an elementary precaution that will guarantee success. Indeed, it is essential all stakeholders be actively involved in the redeployment to ensure that their needs and constraints are taken into account.

Service continuity

Redeployment should not in any case lead to services disruption for subscribers; service continuity must then be ensured. To do so, it should be necessary to make a clear and detailed communication plan to subscribers, as well as a detailed schedule of changing customer equipment when necessary.

Financial assessments

Validation of financial assessments was one of the most difficult tasks of the study because of the lack of documentation to determine the depreciation of the equipment and the residual value of the equipment. The outgoing operator was not able to provide purchase invoices, so the evaluations were based on estimations collected from suppliers.

Redeployment funding

As there is usually no redeployment funding in developing countries, it is crucial to determine early source of funds to finance the implementation of the redeployment and to ensure that these funds will be available when required, so that the effective implementation of the redevelopment will not be delayed.

Attachment 3 (to Annex 1)

Information on the implementation of the digital dividend in the United States of America

The law in the 700 MHz band was enacted by the US Congress, whose members are affiliated with various political groups. This law impacted full power television broadcasting but did not address low power television broadcasting. It addresses other conditions and time constraints on the appearance of the digital dividend. It also specifies the size of the digital dividend and other aspects. <http://www.gpo.gov/fdsys/pkg/PLAW-109publ171/pdf/PLAW-109publ171.pdf>. The United States of America has changed the time constraints once during the transition: http://fjallfoss.fcc.gov/edocs_public/attachmatch/FCC-09-19A1.pdf.

The United States of America has its Departments and agencies implement the legislation through regulations and Rules. The National Telecommunications and Information administration created regulations regarding coupons so that the public would be able to purchase the digital-to-analogue converter boxes to view digital television on analogue receivers that did not contain digital tuners. <http://www.ntia.doc.gov/legacy/dtvcoupon/rules.html>. The Federal Communications Commission created regulations toward TV tuner requirements. <http://www.gpo.gov/fdsys/pkg/CFR-2003-title47-vol1/pdf/CFR-2003-title47-vol1-sec15-117.pdf>. The United States of America maintained the website, as one aspect of its outreach with regard to the transition from Analogue Television to Digital Television: <http://www.dtv.gov/>.

The full power analogue TV broadcast spectrum in the 700 MHz band in the United States was auctioned and licences may be used for flexible fixed, mobile, and broadcast uses, including fixed and mobile wireless commercial services. Public Safety services were also included for the licences offered: http://wireless.fcc.gov/auctions/default.htm?job=auction_factsheet&id=73.

The rules for the flexible use, except public safety are at: <http://www.gpo.gov/fdsys/pkg/CFR-2012-title47-vol2/pdf/CFR-2012-title47-vol2-part27.pdf>, while the rules for the public safety are at: <http://www.gpo.gov/fdsys/pkg/CFR-2012-title47-vol5/pdf/CFR-2012-title47-vol5-part90-subpartR.pdf>

The licences may be viewed through a database query at: <http://wireless2.fcc.gov/UlsApp/UlsSearch/searchAdvanced.jsp>

The current market aspect of digital dividend is contained in an annual report of commercial wireless services. Excerpt Appendix A section D, page 265 of this report refers to the 700 MHz service: http://transition.fcc.gov/Daily_Releases/Daily_Business/2013/db0321/FCC-13-34A1.pdf.

The United States of America has reached agreements with Canada and Mexico regarding the 700 MHz band: http://transition.fcc.gov/bureaus/ib/sand/agree/files/can-nb/700_MHz.pdf and <http://transition.fcc.gov/bureaus/ib/sand/agree/files/mex-nb/110728.pdf>.

Currently, the United States of America is ready for its second digital dividend at 600 MHz as part of its 2010 national broadband plan and its Middle Class Tax Relief and Job Creation Act of 2012: <http://wireless.fcc.gov/incentiveauctions/learn-program/index.html>.

Attachment 4 (to Annex 1)

National experience on the implementation of the digital dividend in Brazil

In 2013, the Ministry of Communications of Brazil established the guidelines for the 700 MHz auction, the first digital dividend in the country: (i) improve access of the population to Digital Broadcast Television; (ii) provide spectrum to improve the mobile broadband with high speeds; (iii) expand the optical fiber networks in the whole country; and (iv) improve the national technology development and national industry.

These were the main goals for the whole process carried out resulting in the 700 MHz Auction, and which were considered in several decisions regarding the construction of the auction process.

Alongside with the 700 MHz Auction process, the transition from analogue to digital television is being carried out by broadcasters in Brazil following the public policies established by the government. However, with the discussions of the 700 MHz Auction, the government changed the logic by which the analogue switch-off would happen. First, it was planned a single switch-off for the whole country (“one-shot”) that would happen in 2016. With the implementation of the first digital dividend, the switch-off will now happen from 2015 until 2018 on a phased fashion.

The main objective of this change was to anticipate the switch-off in some regions, in order to allow the implementation of the digital dividend. This is one of the aspects which were impacted by the 700 MHz Auction. In the following sections the process carried out with the above-mentioned auction to implement the first digital dividend in Brazil is briefly detailed.

1 The 700 MHz Auction and the process of reforming the first digital dividend band

In order to allow the usage of the 700 MHz band, Brazil developed studies to reorganize the allocation of television channels in the allotment plans so that all the television channels residing in the 700 MHz band would be released. After a lot of debate between broadcasters, the Ministry of Communications¹⁸, and Anatel¹⁹, new channels in lower UHF Band were allocated for the broadcasters that operate in the 700 MHz band.

The planning was an important part of the process and allowed Anatel to assess the number of channels that would need to be reallocated after the 700 MHz auction, a total number of 1 050 channels in 1 096 municipalities (Brazil has 5 565 municipalities in total), which accounts for around 43% of the total population (Brazil has around 203 million people).

¹⁸ In Brazil, the Ministry of Communications is the entity responsible for licensing broadcasting services, all other telecommunication services are licensed by Anatel.

¹⁹ In Brazil, ANATEL is the Agency responsible for spectrum planning and allocation.

In order to guarantee the execution of all the changes necessary to allow for the usage of the first digital dividend, the 700 MHz auction proceedings established that all costs involved in the migration of those 1 050 television stations to other frequency channels would be paid by the winners of the 700 MHz band auction. Alongside all those costs, the auction proceedings also established that the costs involved in interference mitigation and the communication of the analogue switch-off to the population would also be covered.

To accomplish this task, the auction proceedings established that the winners would have to constitute a third party entity, named EAD – *Managing Entity of the Process of Redistribution and Digitalization of Television and Retransmission of Television Channels*²⁰. This company would then manage all the process, which involves planning, acquisition of the necessary equipment and implementation of the entire infrastructure to enable the television broadcasters to operate in the new channels. Furthermore, the company would be responsible to undertake actions for interference mitigation between the incomers and the TV broadcasting, and also develop strategies to properly communicate the analogue switch-off to the population, as said before.

This third party entity (EAD) is a facilitator of the whole process with the specific responsibility of fulfilling the task of making the spectrum available, which, in some cases and specific municipalities, can involve switching off analogue transmissions to allow the reallocation of channels. For example, at cities like Brasília, São Paulo and Rio de Janeiro, which are surrounded by a multitude of other smaller cities forming dense metropolitan areas, the spectrum is today very crowded in the UHF band with several analogue and digital channels. Those metropolitan areas will need to switch-off analogue transmissions prior to the reallocation of channels to free up the 700 MHz band.

Bearing that in mind, it was established that the reallocation of those television stations residing on the 700 MHz band would start after the analogue switch-off schedule²¹ for each region. Moreover, the incomers can only start operating new services in the band one year after the TV switch-off of each region. Among other reasons, this obligation will allow the alignment of both tasks and will incentivize coordinated work to facilitate the transition to digital broadcasting. It is important to note that the EAD can conduct studies to anticipate the entrance of mobile services in 700 MHz Band in identified areas where switching-off television channels is not a requirement to reallocate TV Channels or where the band is already freed up. In this scenario, coexistence between new services and TV broadcasting must be guaranteed.

The main objective of following similar schedules for the reallocation of channels and the analogue switch-off is having the EAD support during the whole process. The EAD will ultimately perform important tasks to a successful analogue switch-off: (i) communicate the population of the analogue switch-off date for any specific region, (ii) clarify doubts such as which equipment is necessary for receiving digital television transmissions by means of a Call Center, (iii) acquire and install equipment for the reallocation of several television stations, and (iv) acquire and distribute to the low income population digital television receivers, antennas and other equipment necessary for the reception of digital television transmissions, among other involved tasks.

The budget of this third party entity (EAD) comes from a discount on the public price to be paid for the spectrum by the auction winners. As stated above, this budget should also finance digital

²⁰ Translation from the Portuguese Term: “Entidade Administradora do Processo de Redistribuição e Digitalização de Canais de TV e RTV – EAD”.

²¹ Analogue Switch-off schedule was established by Decree no. 5820/2006 and further detailed by Ordinance No. 477/2014, available at <http://pesquisa.in.gov.br/imprensa/jsp/visualiza/index.jsp?jornal=1&pagina=42&data=23/06/2014>.

television reception for families with low income and mitigate interference between the television transmissions and mobile transmissions in the 700 MHz band, as further detailed in the next section.

The activities of this third party entity (EAD) will be supervised by a group chaired by Anatel, with participation of the Ministry of Communications, the winners of the 700 MHz auction and the television broadcasters, namely the Digitalization and Redistribution of TV and Retransmission TV Channels Implementation Group (GIRED)²².

Among other duties, GIRED will be responsible for the approval of: (i) communication plans to inform the population regarding the analogue switch-off, (ii) specification of digital receivers, antennas and other equipment to be handled to low income families, (iii) specification of equipment necessary for the mitigation of interferences between television transmissions and 4G services, (iv) guidelines for the transmission equipment to be used in the reallocation of television channels residing in the 700 MHz band, (v) technical feasibility assessment to advance the deadline for commencement of the 4G transmissions using the 700 MHz band, (vi) validation of the achievement of the condition for the termination of analogue TV transmissions (93% of households that receive free to air television ready for receiving digital signals), etc.

2 The refarming of the digital dividend band

With the establishment of the abovementioned public policies for the 700 MHz band and the digital switchover, Anatel developed studies for refarming television channels in order to release the television channels from 52 to 69.

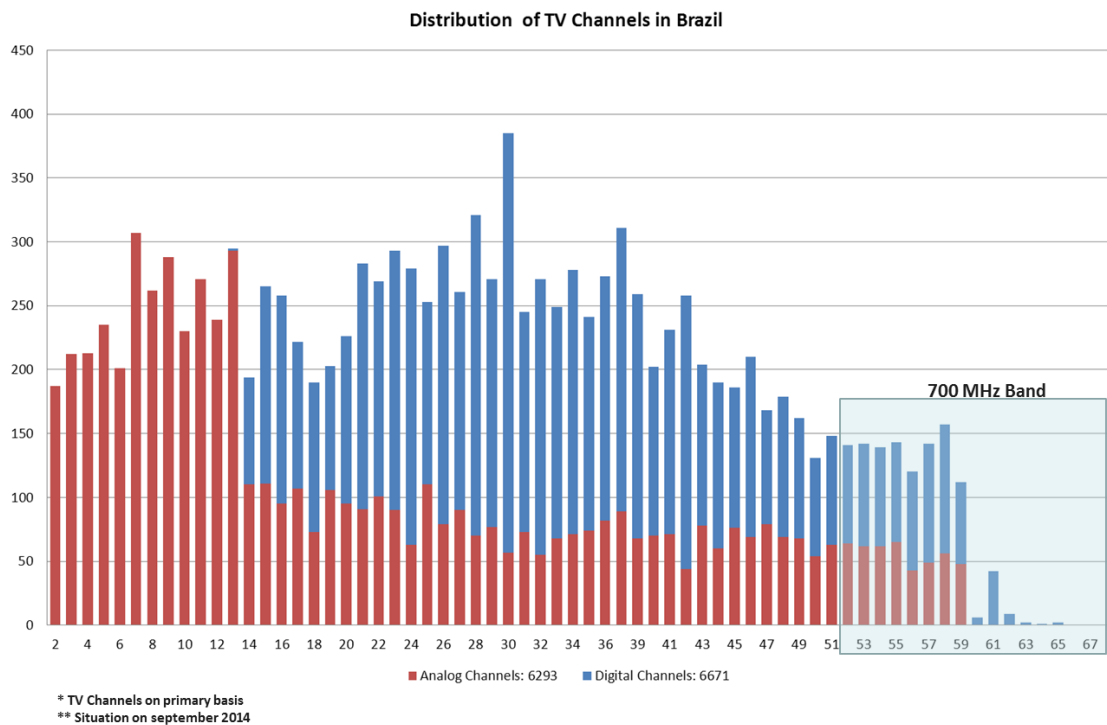
In regions where the UHF spectrum is more densely occupied, it was necessary to consider the situation of the analogue switch-off to succeed in releasing the band. That is the case for 1 096 of the 5 565 Brazilian municipalities, which represent about 43% of the country's population. In the remaining municipalities, it was possible to reallocate all analogue and digital channels (restacking all the channels), and ensure the release of 700 MHz.

In summary, it will be necessary to change the frequency of about 1 050 television stations' channels. Furthermore, during the process, were included 4 300 additional digital channels in the Digital Television Channel Assignment Plan, so as to ensure that the current analogue coverage would be preserved in the digital television transmissions.

This process is being carried out during the switchover phase, and the 700 MHz band will be released gradually. Figure 11 details the amount of channels that were considered in the refarming process.

²² Translation from the Portuguese Term: "Grupo de Implantação do Processo de Redistribuição e Digitalização de Canais de TV e RTV – GIRED".

FIGURE 11



2.1 The strategy to implement the refarming of the 700 MHz band

So to ensure that the 700 MHz band would be timely released, it was decided that the costs of migrating TV channels in that band down to TV channels 7 to 51 would be defrayed by the Auction²³ winners. It was also established that 36% of the amount collected by the auction would be used to reimburse all broadcasters that are now operating in 700 MHz band. In other words, it was established that the entities that would use the spectrum for mobile services would need to bear the costs of migrating the television channels that are currently using it.

It is relevant to emphasize that this is currently the policy used for other frequency auctions in Brazil. The difference in the case of the 700 MHz band is that, for the specific case of Brazil, some municipalities will need to have their analogue transmissions completely switched-off to allow the migration of the television channels residing on the 700 MHz band to lower channels in the UHF band. The reason for that is the usage of the spectrum in larger cities in Brazil, which is densely occupied and not enough channels are available to relocate all broadcasters using the 700 MHz band.

In addition, since the auction winners will need to defray the costs of the analogue switch-off of several cities, other costs were also allocated to the auction winners, for example, the costs to mitigate interference between digital television transmissions and mobile services using 700 MHz, and to publicize the analogue switch-off of several municipalities (densely occupied metropolitan areas) where the redistribution of television channels can only be performed if analogue transmissions are ceased.

²³ Notice for the Auction of the 700 MHz band in Brazil (EDITAL DE LICITAÇÃO Nº 2/2014-SOR/SPR/CD-ANATEL – RADIOFREQUÊNCIAS NA FAIXA DE 700 MHZ). Available at <http://www.anatel.gov.br/Portal/verificaDocumentos/documento.asp?numeroPublicacao=315784&assuntoPublicacao=null&caminhoRel=In%EDcio-Biblioteca-Apresenta%E7%E3o&filtro=1&documentoPath=315784.pdf>.

The 700 MHz band auction in Brazil happened September 30th, 2014.

2.2 Avoiding conflicts of interest between Telecom Service Providers and Broadcasters

After the decision that the auction winners would defray the costs for the migration and the transition to digital television in several markets, Anatel discussed internally methodologies that could be used to accelerate the process and to avoid conflicts of interest between the parties.

Following that discussion, it was decided that a specific third party entity (the EAD as mentioned in the previous section), to be established by the auction winners, would be responsible to manage the amount raised by the auction for restacking digital TV services. The entity would also carry actions to ensure the completion of the switchover to digital TV and apply methodologies to avoid interference between the mobile services and broadcasting services in UHF band.

The reasoning for this decision is to avoid money transfers between the parties involved and to standardize the receiving and transmission equipment that will be used in the migration of television channels and transition to digital broadcasting, reducing costs and allowing for coordinated implementation. A centralized entity responsible for the acquisition of equipment, the logistics and the implementation of the infrastructure can make the process easier and accelerate the implementation of the digital dividend.

Annex 2

Planning considerations embodied in the GE06 Agreement and Plans

This Annex provides a summary of the planning considerations and objectives used in the establishment of the GE06 Agreement and Plans drawn from several reports²⁴ published by the EBU.

The planning process for effecting the digital switchover through the GE06 Agreement and Plans came to rely on the “layer” concept. This term was often used, though not formally defined in the GE06 Agreement or during the RRC-06 planning conference, as a way of describing national input requirements – a “layer” being a convenient way to describe a set of RF channels²⁵ which could be used to provide full or partial nationwide coverage. The number of requirements (allotments/assignments) submitted by national administrations was conditioned by their geographical situation, the coordinated level of accepted interference, transmission and reception characteristics and the way an administration composes its layers out of the available Plan entries all added to the spectral requirements/overhead that is required to be achieved for cross border frequency coordination.

Although the deployment of analogue television services in many countries within the GE06 planning area was simple enough that they could plan their TV distribution networks on the basis of around four analogue TV programme streams from each main transmitter site, allowing them to be accommodated into one DVB-T multiplex, for which one DVB-T layer is needed, the general

²⁴ See the following EBU publications:

[A Road Map for Broadcast Technology](#), [GE06 – Overview of the Second Session \(RRC-06\) and the Main Features for Broadcasters](#), and [Implementation of the Digital Dividend — Technical Constraints to be Taken into Account](#).

²⁵ To distinguish from “TV channels” meaning a distinct programme stream broadcast from a single transmitter site or a network of transmitters.

situation required many more factors to be taken into account. Once a country has to accommodate five or more analogue TV services or intends to use DVB-T with a robust modulation (with more bandwidth devoted to error correction), at least two DVB-T multiplexes are needed, and thus two layers for broadcasting their existing analogue television services in digital format.

In general, the estimation/determination of the spectrum requirements for planning digital television networks is a more complex process still involving a myriad of factors²⁶. However, there are three discrete steps in assessing requirements for the future of DTT services:

- 1) **Broadcast Service Requirements:** Ascertain the number and format of broadcast programme services required in a particular area. For example how many standard definition services, how many HDTV services, how many 3D services, how many UHD TV services, interactive data services etc.
- 2) **Multiplexing services:** By making use of variable bit-rate encoding and statistical multiplexing gain, the total bit-rate required for a set of broadcast programme services assembled into a single multiplex can be minimized, while maintaining picture quality. There may be advantages of assembling services targeting a particular geographical area into the same multiplex.
- 3) **Spectrum planning:** Frequency channels are assigned for each coverage layer across a wide area such that the desired quality of reception is achieved. Different transmission and reception modes will result in different frequency re-use factors, which will also depend on geography and local propagation conditions. The use of single frequency networks (SFNs) over wide areas can result in fewer frequency channels being required, but does limit regional granularity.

The number of RF channels required to give one complete layer depends on aspects such as:

- the size and shape of the intended service areas;
- the network structure applied;
- the target coverage;
- location and suitability of available transmission sites;
- propagation conditions in the surrounding area;
- the intended reception conditions;
- vco-existence with other primary services;
- the need to respect national borders.

National requirements for services ancillary to broadcasting and programme making (SAB/SAP) also had to be accommodated within the GE06 planned allotments, unlike the previous situation where the large gaps between analogue television channels could be used for SAB/SAP purposes without having an impact on neighbouring countries. In the very tightly packed arrangement of layers and allotments generated by the planning process for the digital television switchover, the need for such additional requirements had to be recognized at the outset, rather than relying on the former, more ad-hoc, arrangements to find spare spectrum for SAB/SAP purposes.

In general, it was found that 6-8 RF channels were required for a single layer across most planning areas for both SFN and MFN planning.

The initial T-DAB and DVB-T requirements submitted by administrations before RRC-06 would have exceeded the available band capacity several times over, for the most part by a factor of two or three, but in some cases up to ten times over. In defining input requirements, administrations had to

²⁶ See also Report ITU-R BT.2302.

take into account their long-term broadcasting needs and any rights to use other primary services operating in Bands III, IV/V (if any) and, in some cases, possible future use for other applications. This would indicate that early thinking on how to make use of the digital dividend by administrations had anticipated a greater expansion of broadcasting services than could be accommodated by the size of the digital dividend actually possible.

Administrations therefore had to accept a degree of rationing during RRC-06, having to reduce their requirements in accordance with the following guidance:

TABLE 3
Guidance for number of “layers”

Band III		Band IV/V
T-DAB	DVB-T	DVB-T
3	1	7-8

The guidance was largely effective, with most European countries being successful in achieving at least these numbers of layers, although this required detailed coordination to take place during RRC-06, with administrations often having to accept a greater than desirable level of incoming interference in order to adjust with practical realities.

Annex 3

Possible approach to decide on the optimal use of the digital dividend through an analysis of consumer demand of television and mobile communication services

1 Social-economic factors affecting the decision on the use the digital dividend

Considering the decision on the optimal use of the digital dividend, it is not enough to consider only the economic benefits. As already mentioned above (see § 2.3.1), there is a range of social and economic issues to be settled by the use of the digital dividend. The digital divide, as mentioned in § 2.3, i.e. the inequality in access to advanced communications services, is the most important of them. It is reasonable to consider the inequality in access to advanced mobile communication and digital TV services based on the possibilities of the digital dividend use described above in § 3.

The issue of the digital divide is closely related to the heterogeneous development of relevant communication service markets. The consumer demand for such services is the most crucial factor reflecting the development of the communication service markets. The consumer demand reflects the value of the potential subscriber base for such services and potential amount of payments from those subscribers.

For the implementation of the approach to estimate the optimal use of digital dividend through the analysis of consumer demand for television and mobile services, it is necessary to use similar input data to estimate consumer demand for television services and consumer demand for mobile communication services. Despite of the fact that DTT is mostly used for fixed antenna reception and the IMT-family applications are mostly used for mobile devices, it is necessary to estimate

consumer demand on: advanced TV services for fixed antenna reception, advanced TV services for portable and in-motion reception, advanced mobile communication services to connect fixed devices and advanced mobile communication services to connect mobile devices only. By this way, it should increase the accuracy of using that approach. The last factor for evaluation is a willingness to pay for services which should present the potential limit of payments from subscribers of advanced services which will affect how expectations of demand will translate into realities regarding the optimal use of the digital dividend.

2 Consumer demand for future TV services

The consumer demand for advanced TV services reflects both the demand for the increase of TV programmes available and demand for the increase of image quality of the existing programmes. Particularly, in some countries the use of the digital dividend for the broadcasting service is necessary because it is a major condition for the introduction of High Definition TV within the Digital Terrestrial Television platform (DTT). To assess the demand for future TV services and, consequently, the optimal use of the digital dividend for further development of DTT, the potential possible subscriber base should be assessed. Inversion from the value of the cumulative level of penetration of types of the similar service delivery which are alternative to the DTT, i.e. satellite and cable TV providing similar services (HDTV, UHDTV, 3D-TV, etc.) and the same programme content. For that purpose, it is reasonable to use the index (D_{DTT}) which generally calculated as:

$$D_{DTT} = 100\% \text{ of inhabitants/households of certain territory} - P_{DTT} \quad (1)$$

where P_{DTT} is the index which reflects value of the aggregate level of penetration of types of the similar service delivery which are alternative to the DTT, i.e. satellite and cable TV providing similar services (HDTV, UHDTV, 3D-TV, etc.) and the same programme content.

The aggregate level of penetration is measured in percentage of subscribers/households connected to the above alternative types of TV signal delivery with the possibility to use those services and programmes in similar or higher quality which can be provided by the digital terrestrial TV, provided the digital dividend is allocated to the broadcasting service. The reason to use this index is that the subscriber currently connected to the alternative TV types with the relevant amount of future TV services will not have the obvious need to be connected to the terrestrial digital TV for the same TV receiver.

Also it should be noted that the subscriber can be interested in the DTT connectivity even being connected to other types of delivery mechanisms, for example in case of mobile/portable reception or connection an additional fixed TV set. As it previously said for increasing accuracy of using proposed approach D_{DTT} will be segregated for two formulas.

The following formula is used to calculate the demand for future TV services for fixed antenna reception:

$$D_{DTT_F} = 1 - (P_{STV} + P_{CTV}) * (1 - k_a) - P_{DTT_{eq}} * (1 - k_p) \quad (2)$$

where:

- D_{DTT_F} : percent of TV service market that has demand on digital dividend to be used for the digital terrestrial TV in case of fixed antenna reception
- P_{STV}, P_{CTV} : the level of satellite and cable TV penetration respectively with similar services and programmes available in the same volume and quality, as well as a comparable price as the terrestrial digital TV would be able to be used by broadcasting applications. The level of satellite TV penetration shall include

only those subscribers who have receiving equipment and subscribed to relevant services not exceeding the price of the DTT (considering the scope/quality rate for the services provided versus the services that could be provided by DTT) and shall not include the subscribers connected to the cable TV

- k_a : percent of households with additional (second, third, etc.) TV receivers not connected to cable or satellite services
- P_{DTT_EQ} : the level of possible terrestrial TV broadcasting penetration with similar services and programmes available in the same volume and quality, and for the similar price as the terrestrial digital TV can provide by the allocation of digital dividend to the broadcasting service but without use of the digital dividend (it could be possible, for instance, in some regions)
- k_p : percent of households covered by the possible air TV broadcasting penetration with similar services and programs available in the same volume and quality and for the similar price without use of the digital dividend (P_{DTT_EQ}), also covered by cable or satellite TV with similar services and programs available in the same scope and quality and for the same price (P_{STV} or P_{CTV}).

Besides the fixed reception, the digital TV broadcasting provides automotive and portable reception. It is reasonable to determine the demand for the portable and in-motion reception as additional ones and to use for the population with no need for DTT reception on the fixed antennas.

The following formula is used to calculate the demand for future TV services for portable and in-motion reception:

$$D_{DTT_P} = k_p - (P_{Mobile_IPTV}) * (1 - k_{ap}) - P_{DTT_P_{eq}} * (1 - k_{op}) \quad (3)$$

where:

- D_{DTT_P} : percentage of TV service market which has demand on the digital dividend to be used for the terrestrial digital TV in case of portable and in-motion reception
- k_p : percentage of users interested in portable or in-motion reception
- P_{Mobile_IPTV} : penetration of video on demand (IPTV) in wireless and mobile networks
- k_{ap} : percentage of users interested in portable or in-motion reception of TV broadcasting programmes in addition to the IPTV programmes received by them in wireless and mobile networks (possible reasons – lack of coverage, scarce set of programs, low quality at high network load)
- $P_{DTT_P_EQ}$: level of possible air TV broadcasting penetration for portable and mobile reception with similar services and programmes available in the same volume and quality and for the same price as the terrestrial digital TV can be provided by the allocation of digital dividend to the broadcasting service but without use thereof
- k_{op} : share of users covered by possible DTT broadcasting penetration for portable and mobile reception with similar services and programmes available in the same volume and quality and for the same price without use of the digital dividend ($P_{DTTV_P_EQ}$), also covered by IPTV penetration in wireless and mobile networks with similar services and programmes available in the same scope and quality and for the same price (P_{Mobile_IPTV}).

3 Consumer demand for future mobile communication services

The demand for future mobile communication services reflects the demand on the additional capacity of mobile communications networks to increase the amount of existing or new services delivery based on the need to use the mobile broadband access.

For that purpose, it is reasonable to use the index (D_{MC}) which generally calculated in the similar way as D_{DTT} :

$$D_{MC} = 100\% \text{ of inhabitants of certain territory} - P_{MC} \quad (4)$$

where P_{MC} is the index that reflects the value of penetration level of the mobile broadband access including the satellite broadband access, with the similar capacity.

The level of this penetration is measured in percentage of mobile communication subscribers who use the mobile broadband access with a capacity that is at least equal to what the IMT-family mobile communication systems can offer with the digital dividend allocated to the mobile service. The reason to use that index is that the subscriber, who already uses mobile broadband access with the relevant capacity, will have no obvious need for the additional capacity of a mobile communications network. The same as for TV, the need for prospective mobile communication services is segregated into two segments: the demand for mobile broadband access to connect to fixed devices, e.g. the home PC, and the demand for mobile broadband access to connect mobile devices.

The following formula (5) is used to evaluate the demand for future mobile communication services to connect fixed devices:

$$D_{MC_F} = 1 - (P_{FBA} + P_{SBA}) * (1 - k_w) - P_{MBA_{eq}} * (1 - k_{aw}) \quad (5)$$

where:

- D_{MC_F} : percentage of the mobile service market that has demand on the digital dividend to be used for mobile communications when connecting fixed devices
- P_{FBA}, P_{SBA} : level of penetration of fixed wire and satellite broadband access respectively with the same capacity provided, availability of similar services in the same scope and quality, and for the same price as the mobile communication is able to provide should the digital dividend be allocated to the mobile service

The level of penetration of the satellite broadband access shall include only the subscribers with receiving equipment and subscribed to the relevant services, and shall not include the subscribers also connected to wire broadband access.

- k_w : percent of households with additional (second, third, etc.) fixed devices not connected to wire fixed and satellite broadband access networks
- P_{MBA_EQ} : level of possible penetration of the mobile broadband access provided with the same capacity, availability of similar services in the same volume and quality, and for the same price as the mobile communication is able to provide without use of the digital dividend
- k_{aw} : percentage of households covered by possible penetration of mobile broadband access with the same capacity, availability of similar services in the same scope and quality, and for the same price as the mobile communication can provide without use of the digital dividend; (P_{MBA_EQ}), also covered by wired broadband access with the provision of the same capacity, availability of similar services in the same volume and quality and for the same price (P_{FBA} or P_{SBA}).

Additional need for prospective mobile broadband services for connection of mobile devices only is calculated for the population in no need for prospective mobile communication services to connect fixed devices.

The following formula (6) is used to evaluate the demand for future mobile communication services to connect mobile devices only:

$$D_{MC_M} = 1 - P_{MBA_A} - P_{MBA_{eq}} * (1 - k_{am}) \quad (6)$$

where:

- D_{MC_M} : percent of the mobile service market that has demand on the digital dividend to be used for mobile communications, when connecting mobile devices
- P_{MBA_A} : level of penetration for mobile broadband access with the same capacity, availability of similar services in the same volume and quality, and for the same price as the mobile communication can be provided should the digital dividend be allocated to the land mobile service
- P_{MBA_EQ} : level of penetration for mobile broadband access with the same capacity, availability of similar services in the same volume and quality, and for the same price as the mobile communication is able to provide by the allocation of digital dividend to the mobile service but without use of thereof
- k_{am} : percentage of users, covered both by P_{MBA_A} and P_{MBA_EQ} .

4 Willingness to pay for future TV and mobile communication services

Willingness to pay is the index ($W_{service}$) which unites the consumer demands for certain services and potential payment from their users. This index is represented as additional average payments that can be received from subscribers of services that are provided by advanced technologies of television and mobile communication through the use of the digital dividend. As it is mentioned before, necessary condition for consumer demand is that the costs are not raised for subscribers for the existing services, but for the evaluation of potential amount of additional payments it would be well to estimate highest level of that index. The best way of evaluating this is to use the comparative estimation on a base of analysis of average revenue per user for certain telecommunication services in different countries (evaluation for country) or different parts of one country (evaluation for administrative area) regarding levels of consumer demands for certain telecommunication services and income of population of different countries (regions of country).

In the example of the Russian Federation factors of the consumer demand for the above-mentioned telecommunication services and average revenue per user for certain telecommunication services have been analysed at the level of regions of the Russian Federation and it has been detected that the regions of the Russian Federation are heterogeneous in the context of penetration level of TV and mobile communication technologies and, consequently, consumer demand on prospective communication services (see Fig. 12)^{27, 28}. The applied method of cluster analysis showed that there are large groups (clusters) of regions with substantially different demands in the context of the

²⁷ E. Volodina, A. Plossky. "Features of the Digital Dividend Implementation in Conditions of Great Population Density Discontinuity and Limitation of the Frequency Resource". Proceedings of the 10th International Symposium on EMC (EMC Europe 2011), York, UK, September 2011.

²⁸ E. Volodina, A. Plossky. *Influence of economic factors on clustering of regions for the digital dividend implementation in a number of specific conditions*. Proceedings of the 11th International Symposium on EMC (EMC Europe 2012), Rome, Italy, September 2012.

digital dividend use. There have been recognized three clusters: High Developed Cluster, TV Cluster and Mobile Communication. TV Cluster contains regions with low penetration of TV services (i.e. high consumer demand for using digital dividend for DTT); MC Cluster contains regions with the reverse situation. It is also mentioned that these two clusters have comparatively low average revenue per user for certain telecommunication services. However, for a high developed cluster with high penetration of advanced services of both TV and mobile communication characterizes by the significantly higher level of average revenue per user for that service. Thus the increase in the level of penetration, i.e. satisfaction of consumer demands on advanced TV and mobile communication services substantially impacts on the increase of potential revenue. Considering the relative level of average revenue per user of advanced TV and mobile communication services for the high developed cluster (see Fig. 12) as the highest level of $W_{service}$ of certain services, it is possible to calculate the indexes of willingness to pay (W_{DDTV} and W_{DDMC}).

Thus the following formula (7) is used to assess the optimal use of the digital dividend for terrestrial digital TV and mobile communication:

$$\begin{cases} R_{DD_{DTT}} = (D_{DTT_F} + D_{DTT_P}) * W_{DTT} \\ R_{DD_{MC}} = (D_{MC_F} + D_{MC_M}) * W_{MC} \end{cases} \quad (7)$$

FIGURE 12

