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Coexistence between Digital TV Broadcasting and Cellular Systems in UHF: Policy Implications

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Abstract

The World Radiocommunication Conference (WRC-15) decided to conduct a review of the spectrum usage in the 470–694 MHz frequency band at WRC-23 to study possible introduction of primary mobile service allocation in this frequency band that is currently utilized by Digital terrestrial TV broadcasting systems.

Introducing new primary allocation for a service in a frequency band would require an examination of the coexistence between the new service and other incumbents. The frequency band 470-694 MHz is currently allocated to the broadcasting service on a primary basis in all three ITU regions and is used predominantly for the delivery of television broadcasting. In this case, it is required to assess the coexistence possibility between the incumbent broadcasting service (represented by DVB-T as digital TV system) and the new mobile service (represented by LTE as cellular system) in UHF below 694 MHz.

The objective of this paper is to recommend a minimum frequency separation (guard band) between DVB-T and LTE based on a coexistence approach that promotes global spectrum harmonization in the 470–694 MHz frequency band, and to highlight the possible implications of this approach on the work of WRC-23 towards having a new co-primary mobile service allocation below 694 MHz in UHF.

Keywords: Cellular-Broadcasting coexistence, Spectrum harmonization, UHF spectrum policy, Digital Dividend 3, WRC-23

1 Introduction

The emerging trend of Information and Communication Technologies (ICTs) at the global level focuses on satisfying the growing demands for further development of social and economic aspects, while recognizing the vital role of mobile broadband (MBB) in the transformations of societies in the last few decades. Also, the recent rapid adoption of smartphones and especially video streaming has resulted in a significant increase in the volume of wireless broadband traffic. Approximately 70% of this traffic is offloaded to fixed networks over Wi-Fi, and the remainder is carried over MBB networks. The amount of MBB traffic in Q1 2016 was over tenfold compared to Q1 2011 and 60% more than in Q1 2015 [1]. The increases in the amount of traffic are projected to continue. The availability of ubiquitous, affordable, reliable, and robust broadband connectivity in communities in developing countries, emerging economies, and less developed regions would support several sustainable development goals and targets as highlighted in the United Nations' 2030 Agenda for Sustainable Development [2].

In this regard, ITU has recognized “broadband” as a critical infrastructure requirement for economic growth, and “ICTs” as one of the main growth drivers of developed economies in the last few decades, as per many ITU references, such as [3] and [4]. The convergence of different services and technologies is becoming a reality. Where MBB systems are being developed, they can efficiently act as a delivery platform for other services such as broadcasting.

Spectrum is the lifeblood of the mobile broadband, especially UHF spectrum below 1 GHz where the propagation characteristics are suitable for building extended mobile broadband connections in rural and remote areas. In addition, as frequencies get lower, they suffer less attenuation while penetrating buildings, resulting in better indoor coverage. This coverage aspect is key for the developing countries, as the deployment of mobile broadband systems infrastructure can be time consuming and expensive. Higher deployment costs can make the situation more difficult for those developing countries looking to accelerate the closing of the digital gap [5]. Because of that, enabling global spectrum harmonization below 1 GHz for the mobile industry is becoming an essential pillar for providing nationwide indoor MBB coverage, and for achieving economies of scale in a timely manner, as well as to facilitate and expedite the development of mobile systems.

1 UHF Spectrum Utilization

1.1 Spectrum Plan for Digital TV

The spectrum between 470 and 862 MHz (UHF bands IV and V) had been used historically for the deployment of legacy analogue TV broadcasting systems. Back in 2006, and due to broadcasting technology advancements, ITU organized the Regional Radiocommunication Conference (RRC-06) to adopt the Geneva 2006 frequency plan (GE06) that introduced digital terrestrial TV broadcasting in UHF TV bands through an extensive interference planning process.

The Geneva 2006 frequency plan (GE06) was originally developed to provide T-DAB and DVB-T digital services in the VHF (Band III) and UHF (Bands IV and V) broadcasting bands in 118 countries [6], as highlighted in Figure 1.

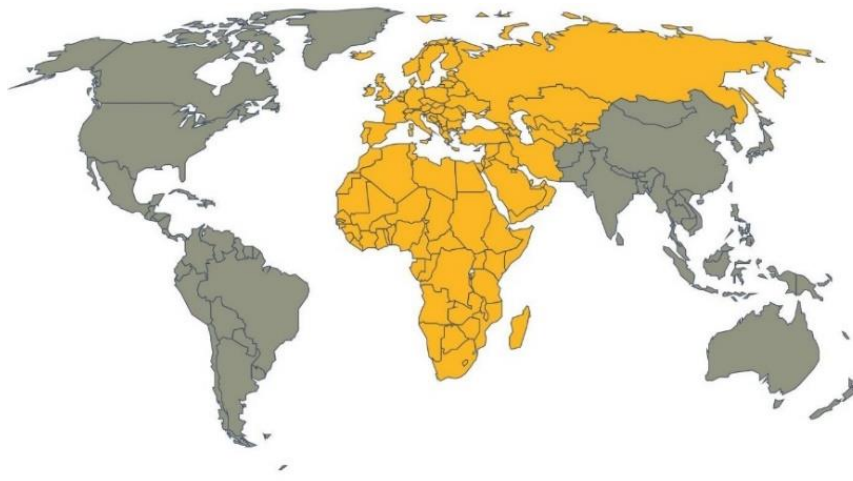


Figure 1 - GE06 (RRC-06) Planning Area

The frequency band 174-230 MHz (Band III) was subdivided into 7 or 8 DVB-T RF channels depending on whether the country proposed to use 8 or 7 MHz bandwidth and subdivided into 32 T-DAB blocks with 1.75 MHz bandwidth. The 470-862 MHz (Bands IV and V) was subdivided into 49 RF channels with 8 MHz bandwidth. The overall number of planned digital TV channels is shown in Figure 2.



Figure 2 - RRC-06 spectrum plan for DTT in UHF

1.2 Utilization of Digital Dividends

UHF spectrum below 862 MHz represents significant importance for digital terrestrial television broadcasting because it allows wide-area coverage from high-power transmitters, making possible an economic deployment of a network of transmitters serving extremely large audiences simultaneously viewing linear television broadcasting, thus it's particularly suitable for broadcasters, including public-service broadcasters, who have a requirement for ubiquitous coverage.

The transition from analog terrestrial TV to more spectrally efficient digital terrestrial TV (DTT) broadcasting allowed possible new scenarios for spectrum sharing with systems other than broadcasting. The available spectrum resulting from this efficiency gain after the Analogue switch-off (ASO) is known as Digital Dividend (DD) [7]. Digital Dividend is extremely important since the spectrum located between 200 MHz up to 1 GHz is very valuable because it is optimum in terms of the need of coverage and capacity [8]. After ASO finalization in several administrations, and the development of national plans for digital switch-over (DSO) in others, it became obvious that the reserved amount of spectrum for Digital TV was very much hyped and the actual needed spectrum is less than what was originally planned for in RRC-06. Because of that, several administrations agreed to conduct further iterations to modify the plan to reflect their actual national spectrum requirements for DTT and to better utilize the UHF spectrum and allow other uses for the released spectrum regionally [9]. This activity was then reflected on international spectrum management level, when World Radiocommunication Conferences began revision of UHF spectrum bands being exclusively allocated to broadcasting service in the Radio Regulations, in order to allow for the introduction of mobile services below 862 MHz. This revision was carried out in two consecutive WRCs resulting in mobile service allocations down to 694 MHz.

Introduction of mobile service allocation in spectrum allocated exclusively to broadcasting service was initiated by the World Radiocommunication Conference 2007 (WRC-07) that allocated the 790-862 MHz frequency band to the mobile service on co-primary basis [7]. This allocation was a result of worldwide agreement to utilize what is known as first Digital Dividend (DD1) which is the cleared spectrum from DTT transmissions after regrouping them into 470-790 MHz frequency band and the completion of the broadcasting DSO process in concerned administrations, thus opening the possibility for other uses in that part of the spectrum.

Furthermore, studies on how to exploit the unused spectrum gaps in actual deployments of digital TV networks through non-protected non-interfering secondary spectrum access led to the introduction of TV White Spaces (TVWS) approach [10]. The concept mainly relies on the fact that DTT broadcasting topology uses high power high tower transmitters, which leaves opportunities to reuse the spectrum with lesser power systems. TVWS concept was a manifestation of the need to maximize the utilization of the valuable UHF spectrum that could be underutilized if used exclusively by digital TV broadcasting technologies.

2012 was the year when African countries challenged the procedures of WRC-12 to have the 700 MHz allocated co-primarily with broadcasting service without being on the agenda of the conference considering the severe objections of the European countries in addition to Iran [11]. WRC-12 agreed to extend the allocation of the mobile service on co-primary basis to the 694-790 MHz frequency band [12] as a result of the expected regrouping of DTT transmissions below 790 MHz in Region 1 with a common deadline for clearing that second Digital Dividend in the 700 MHz band by 2020 in Europe. Spectrum allocations to mobile service after WRC-12 are shown in Figure 3.

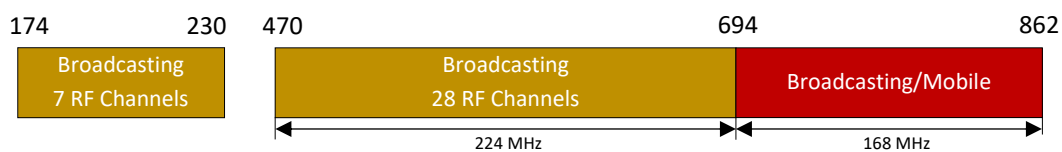


Figure 3 - Status of the UHF spectrum allocated to mobile service after WRC-12

In 2015 during the WRC-15, a group of developed & developing countries from different ITU regions (Arab, African and American) made a common proposal for a harmonized co-primary mobile service allocation within the 470-694 MHz frequency band, thus affording flexibility to administration in choosing whether to use the 470-694 MHz frequency band entirely for digital TV broadcasting systems or utilize parts of it for mobile systems, or a combination of both. This time the call for having spectrum below 694 MHz allocated to mobile service is neither backed up by technical studies to justify service sharing in the band, nor by a clear definition for a third Digital Dividend in large number of administrations. The decision was made that the allocation will not be changed, and Digital TV broadcasting status in this frequency band will be safeguarded until 2023 and the WRC-23 is to conduct a review of the spectrum usage in the 470-694 MHz band to study possible introduction of co-primary mobile service allocation in this band, The main driver for the opposition came from the European

Union which had already formulated a policy against primary mobile service allocation below 694 MHz packed by broadcasting community to keep that part of the spectrum exclusively allocated to broadcasting service until 2030 [13]. Figure 4 illustrates the time line summarizing WRC decisions regarding the 470-960 MHz frequency band.

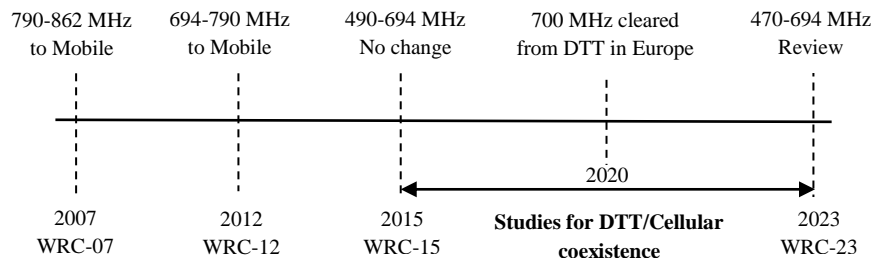


Figure 4 - Timeline of WRC decisions for the use of UHF spectrum

2 UHF Mobile Service Allocation at WRC-23

This section shall investigate the possible effect of a third Digital Dividend towards having a new candidate band for mobile service allocation below 694 MHz and the associated lower edge for this candidate band along with required conditions for coexistence between broadcasting and mobile systems in the candidate band.

2.1 Towards Digital Dividend 3

Examination of the penetration of terrestrial TV broadcasting shows that it differs significantly between different GE-06 planning areas in Region 1. While it plays a significant role in most of European countries as a major platform for television content delivery, the situation is completely different for the rest of Region 1 areas where terrestrial TV networks play less significant role in delivering television content compared with other platforms like satellite and/or cable TV. A study developed on terrestrial broadcasting and spectrum use in the Arab states concluded that the digitization of terrestrial broadcasting in the Arab states can be accommodated by the available spectrum below 694 MHz and down to 582 MHz [1], the study demonstrated that there are significant amounts of spectrum that can be cleared across the Arab region through the efficient utilization of the terrestrial broadcasting spectrum, even in the case of all existing TV channels continue to be broadcast over digital terrestrial platforms. The study also highlighted the tradeoff between continuing to use significant amounts of spectrum to serve a small number of TV consumers, versus an efficient allocation of the scarce resource.

This situation reveals that in ASMG GE-06 region can gain up to 112 MHz of spectrum below 694 MHz as a third Digital Dividend, that amount of spectrum is the headroom limit for further investigation to a possible candidate band for the new allocation.

2.2 Candidate Band Lower Edge

Examination of 470-694 MHz frequency band allocation to the different services in Article 5 of the 2016 Radio Regulations as well as the relevant footnotes indicate that sub-band 614-698 MHz is allocated to the mobile service on primary basis in 10 countries in Region 2 but it is subject to the agreement of other neighboring countries, while the sub-band 610-890 MHz is allocated to mobile service on primary basis in Region 3 [14].

Table 1 below summarizes the sub-frequency bands allocated to the mobile service on a primary basis in the entire 470-694 MHz frequency band.

TABLE 1

Sub frequency bands allocated to the mobile service on a primary basis

Frequency band (MHz)	Allocation to mobile service on a primary basis
470-694	Entire Region 3
512-608	11 countries in Region 2, No. 5.297
<u>614-698</u>	<u>10 countries in Region 2, No. 5.293</u>

According to No. **5.293**, the band 614-694 MHz is already allocated to the mobile service on primary basis in 10 countries in Region 2, subject to obtaining the agreement of other neighboring countries for such use according to the footnote. The current mobile allocation in this band for several countries in Region 2 as well as the allocation of the entire 470-694 MHz to Region 3 qualifies the 614 MHz to become the candidate lower edge for mobile service allocation at WRC-23 in order to facilitate global harmonization of mobile service allocation across the 3 Regions. The following section would investigate further the required technical conditions for successful coexistence between broadcasting and mobile systems based on the 614 MHz as lower edge.

2.3 Required Coexistence Conditions

To study possible coexistence that supports introducing new mobile service allocation in the 614-694 MHz frequency band, protection of the incumbent broadcasting service systems would be required. Therefore, the suggested coexistence scenario is worst case interference that involve single DVB-T system transmitter operating at channel 38 (DVB-T channel bandwidth 8 MHz). The operational environment is chosen to match the use case scenario for LTE in rural or suburban MBB. The LTE system is operating with channel bandwidth of 10 MHz that is separated from the DVB-T channel 38 by a guard band having lower edge of 614 MHz based on the previous discussion, and its lower edge is to be determined according to the simulation results. LTE handsets (UEs) are located at the coverage edge of the DVB-T transmitter and operate as multiple interferer uplinks randomly distributed around the victim DVB-T receiver, all technical parameters used based on 3GPP standards [15], [16] and ITU-R publications [17]–[20] as well as relevant compatibility assessment criterion [21]. The methodologies used previously in ITU-R studies for the adjacent bands 694-790 MHz and 790-862 MHz can be applied to the candidate band 614-694 MHz [22]–[24].

Figure 5 below shows a layout of the frequency assignments used by the two systems in the scenario.

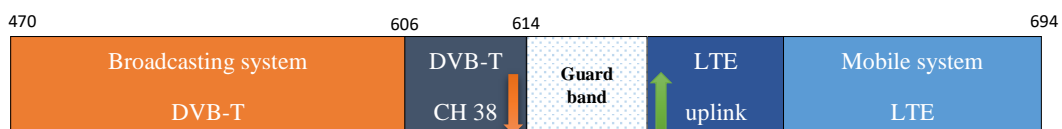


Figure 5 - DVB-T & LTE frequency assignments for the simulation scenario

Interference probability assessment was evaluated through Monte-Carlo analysis [25], [26]. Monte Carlo is applicable as it gives flexibility by the manner of the characterization of input parameters inside the system and simulate mainly all possible radiocommunication-based scenarios. The input type of each variable parameter (such as horizontal and vertical antenna pattern, EIRP, propagation environment etc.) is modeled like statistical distribution function, enabling a realistic estimate of the potential interference [27]. The analysis was conducted using SEAMCAT (Spectrum Engineering Advanced Monte-Carlo Analysis Tool) [28] to determine the minimum guard band required for the protection of the DVB-T receiver. SEAMCAT modeling results based on standardized inputs are considered accurate to a large

extent in comparison with the results measured from practical scenarios having the same inputs [29]. Furthermore, the modeling is conducted for extreme worst-case parameters for both LTE and DVB-T systems. For example, out of band (OOB) emission mask for LTE UE is modeled without considering the actual reduction of OOB limits in the case of partial resource blocks assignment to UE. And a worst case ACS DVB-T receiver mask is representing the extreme protection ratios as provided by DTT community to cover all types of implemented DTT receiver (including obsolete ones).

Figure 6 below summarizes the results of Interference Probability (IP) evaluated against multiple values for the guard band in rural and suburban environments.

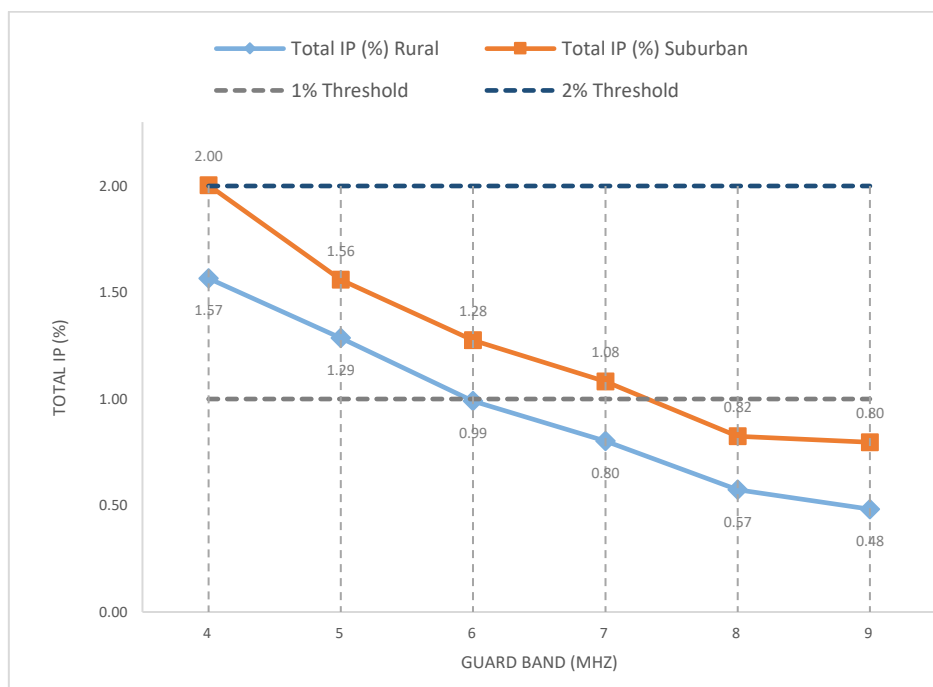


Figure 6 - Total Interference Probability (IP) for different guard bands

Most of the modeling studies to date have considered that the worst-case scenario of DVB-T receiver is located at the edge of a TV coverage area/cell, with no TV coverage in the opposite direction to the TV transmitter (where reception of the TV service is noise-limited). However, the actual deployed scenario would be an overlapping coverage from several TV transmitters as shown in Figure 7.

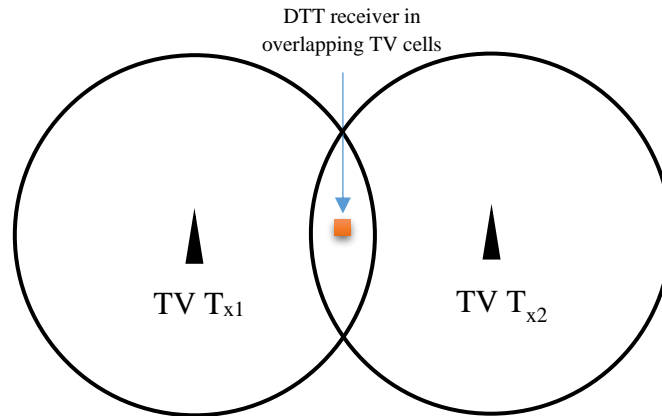


Figure 7 - Overlapping TV cells

An average increase in received TV signal level of 3.7 dB is suggested as a result of the typical situation of overlapping coverage from several TV transmitters [30], thus the Interference Probability results will be significantly lower in more practical scenarios.

Typical value for maximum allowed IP is 1% in most of coexistence studies as a rule of thumb, where actual broadcasting network deployment effects are generally not considered. Another practical approach would be having a more relaxed threshold of 2% Interference Probability as an acceptable level.

Based on above discussions, a stringent threshold of less than 1% Interference Probability and a guard band of 8 MHz would be recommended. For a more relaxed threshold of less than 2% Interference Probability, a guard band of 5 MHz would be required.

3 Policy Implications

To address the coexistence issue, a guard band inside 614-694 MHz to protect the broadcasting service is proposed, in this regard there were two approaches: a stringent approach of 8 MHz guard band, and a more relaxed one of 5 MHz guard band.

The stringent approach would follow the usual coexistence studies threshold thus yielding 8 MHz of guard band, this would leave the mobile service 72 MHz of spectrum in the new allocation ready for developing frequency arrangements for mobile systems. This stringent guard band has the potential to address the stringent requirements of broadcasting community

to over protect their systems, thus can be used as a last resort in discussing the new mobile allocation in the 614-694 MHz band at WRC-23.

The other relaxed approach of 5 MHz as guard band is a more realistic one and would leave the mobile service with 75 MHz of spectrum in the 614-694 MHz frequency band while sufficiently protecting the broadcasting systems, thus it is considered more efficient in utilizing the spectrum resources.

In either approach, the broadcasting service within the frequency band 470-694 MHz shall be granted exclusive allocation up to 614 MHz (DVB-T channel 38) only, which means that DTT transmissions would have to be regrouped up to channel 38 in order to be protected. Namely, countries that support this new allocation should have digital switch-over policy that mandates utilizing DTT transmissions up to channel 38 only. This could seem difficult specially for European countries that have plans to use the entire 470-694 MHz for DTT, but the fact that the need for a new allocation arises from geographically sub regions far from European countries like Arab, African and North American regions solve the situation to a large extent provided that the members of these sub-regions unite their policy towards the maximum amount of spectrum grants for DTT.

In that case, the candidate frequency band 614-694 MHz would have the support from both Regions 2 (mainly North America) and 3 countries (Already allocated) as it would harmonize the allocation among these two regions. With African and Arab counties from Region 1 supporting the band, there should be enough momentum to make WRC-23 have the decision to allocate and harmonize that band for mobile service across the 3 Regions. The rest of countries (especially Europe) that do not wish to have the new mobile allocation covering their territories, can have the usual practice to exclude themselves through a footnote.

Having a consensus towards the proposed guard band (either 8 or 5 MHz) for protecting broadcasting service would play major role in reaching the agreement for the new allocation. In the meantime, the agreed upon guard band would be the basis for developing the required frequency arrangements that will be implemented by mobile equipment manufacturers and used in future deployments of mobile systems in the 614-694 MHz.

4 Conclusions

As presented earlier in this paper, there was a clear need for having a new mobile service allocation below 694 MHz. This need was manifested by several administrations from the different 3 Regions inside ITU during WRC-15. This new allocation has been postponed till WRC-23 to give time to technical and regulatory studies to backup this new proposed allocation.

The paper proposed the sub-band, 614-694 MHz, as a candidate frequency band for the new mobile service allocation at WRC-23. Accompanied by coexistence conditions to protect broadcasting service, this sub-band has the potential of achieving global harmonization for the new mobile allocation across the 3 Regions in ITU, thus making deployment of mobile broadband in rural areas, especially in the least developed countries, more economic.

It is expected that the recommended outcomes from this study would facilitate harmonization of the new proposed allocation of the 614-694 MHz to mobile service in the future. In addition to that, they would help the industry and regulatory bodies define a global frequency arrangement for LTE within the 614-694 MHz frequency band.

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