Analysis of the WRC-23 Agenda Item Concerning the Future Use of the 470-694 MHz Band in Europe

Hussein Taha, Péter Vári, and Szilvia Nagy

***Abstract*—The upcoming World Radiocommunication Conference 2023 (WRC-23), according to the preliminary agenda item 1.5, will decide the long-term use of the 470-694 MHz band in International Telecommunication Union Region 1 and consider regulatory actions for the rest of the decade. This article attempts to inform the debate on the future use of spectrum in the 470- 694 MHz band and the status of broadcasting services at the European level and in many individual member states. This article highlights the role WRCs played by allocation of the previous digital dividend bands for mobile services. It provides an overview of the most recent trends and developments of existing services in the sub-700 MHz band. The article also explores and analyzes options for future use of the 470-694 MHz band in Europe and discusses the benefits and implications of adopting each option. Based on this analysis, it is recommended to introduce a secondary allocation to mobile service in the downlink-only mode alongside traditional broadcasting services in the sub-700 MHz band at the upcoming WRC-23.**

***Index Terms*—WRC-23, Digital Dividends, 470-694 MHz, sub-700 MHz band, IMT, BBPPDR, DTT, Broadcasting, PMSE**

I. Introduction

The International Telecommunication Union (ITU) holds World Radiocommunication Conferences (WRCs) every three to four years with the main objective of reviewing and updating the Radio Regulations based on the preliminary agenda items set by the ITU Council [1]. Subsequent to the WRCs, Radio Regulations are issued to allow new radiocommunication systems and applications access to the radio spectrum while safeguarding the operation of existing radiocommunication services.

This section mainly reviews the historical approach of the ITU at WRCs to regulate the Ultra-High Frequency (UHF) spectrum in ITU Region 1. Figure 1 shows how the UHF spectrum was regulated between broadcasting and mobile services following WRCs.

Hussein Taha is with the Doctoral School of Multidisciplinary Engineering Sciences, Széchenyi István University, Győr, Hungary (e-mail: taha.hussein@sze.hu, hussein.taha91@gmail.com)

Péter Vári is with the Department of Telecommunications, Széchenyi István University, Győr, Hungary (e-mail: varip@sze.hu);
He is also with the National Media and Infocommunications Authority, Budapest, Hungary (e-mail: vari.peter@nmhh.hu).

Szilvia Nagy is with the Department of Telecommunications, Széchenyi István University, Győr, Hungary (e-mail: nagysz@sze.hu).

DOI: 10.36244/ICJ.2023.3.1

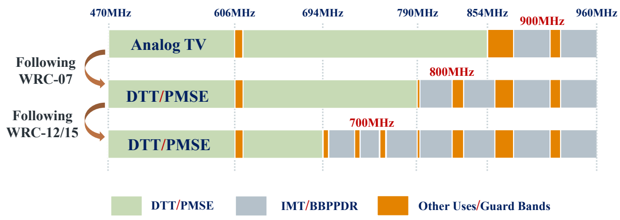

Fig. 1. Spectrum regulation among services operating in the UHF band in ITU Region 1.

In 2006, based on the Geneva agreement (GE-06), analog television broadcasting was switched off and transitioned to digital television broadcasting in Europe, the Middle East, and Africa [2]. The transition period started on 17 June 2006 and ended on 17 June 2015. This transition provided a significant improvement in the quality of TV broadcasting service and allowed some radio spectrum to be freed up for other purposes, known as the “digital dividends”.

The ITU allocated these digital dividends also to mobile services (except aeronautical mobile) on a co-primary basis with broadcasting in two phases. In 2007 following WRC-07, the first digital dividend known as the 800 MHz band, the spectrum from 790 MHz to 862 MHz, was allocated for mobile service [3]. During WRC-12/15, the decision was made to allocate the second digital dividend known as the 700 MHz band, the spectrum from 694 MHz to 790 MHz to mobile service from 2015 [4]-[6].

As decided by WRC-15 Resolution 235, the upcoming WRC-23 will review spectrum usage and study the spectrum requirements of existing services in the 470-960 MHz frequency band in ITU Region 1. This will specifically focus on the spectrum needs of broadcasting and mobile services (excluding aeronautical mobile services), with consideration given to relevant ITU Radiocommunication Sector (ITU-R) studies, recommendations, and reports [5], [6].

Based on the recommendations of the latest WRC-19, there is interest in allocating an additional spectrum for International Mobile Telecommunications (IMT) and Broadband Public Protection and Disaster Relief (BBPPDR) services in a band below 694 MHz [7]. Besides, agenda item 1.5 of the upcoming WRC-23 calls for an assessment of the spectrum needs for existing services in the sub-700 MHz band, which spans from 470 to 694 MHz, in ITU Region 1 and explores the possibility of granting a new IMT allocation in all or parts of the band [8].

Stakeholder viewpoints varied on potential future scenarios for the best use of frequency band 470-694 MHz in Europe. Historically, this band has been allocated and used primarily by Digital Terrestrial Television (DTT), with Program-Making and Special Events (PMSE) services on a secondary basis (plus a small allocation for use by radio astronomy in some countries). DTT and PMSE provide common values to all European citizens. DTT efficiently delivers linear TV services to huge audiences, even for free. It provides near-universal reach, is dependable in emergencies and crises, and enables broad, targeted information. PMSE offers an essential service that connects people through the digital economy.

On the other hand, WRC-23 is a chance to allocate a new digital dividend band for IMT (such as the 600 MHz band) that could aid in boosting the accessibility of 5G, guarantee future growth and innovation, address the digital divide, and can facilitate the introduction of 6G. The WRC is a frame regulation, as the European Conference of Postal and Telecommunications Administrations (CEPT) and/or the European Union (EU) consider technical harmonization measures essential for the introduction of a service other than broadcasting [9]. Additionally, as a result of the Lamy report, the UHF decision provided long-term investment predictability and stimulated innovation by safeguarding, under Article 4, the availability of the 470-694 MHz band for DTT and PMSE services until at least 2030 in all EU member states [10].

Consequently, the future strategy for the sub-700 MHz band should be flexible enough to respond to evolving both broadcasting and mobile market realities while considering technological and consumer behavior developments. In this regard, the article explores and analyzes potential use options for the future 470-694 MHz spectrum in Europe. The benefits and challenges of each alternative are discussed concerning the relevant studies conducted by stakeholders. Based on this analysis, the article outlines the rationale for adopting each option at the upcoming WRC-23.

The rest of this article is structured as follows. Section II highlights the benefits of using digital dividend bands for IMT and BBPPDR. Section III reviews the current situation and future development of DTT, 5G Broadcasting, and PMSE in Europe. Section IV explores and analyzes the potential future uses of the sub-700 MHz band in Europe. Section V concludes this article.

II. BENEFITS OF USING DIGITAL DIVIDEND BANDS FOR IMT AND BBPPDR

The term "IMT" (International Mobile Telecommunications) is used to refer to IMT-2000, IMT-Advanced, and IMT-2020 collectively, i.e., the 3G, 4G, and 5G generations of cellular communications systems [11]. IMT systems seek to provide worldwide communication services, regardless of the location, network, or terminal being utilized (global roaming).

IMT systems operating in the digital dividend bands differ from earlier mobile technologies in several aspects, including frequency allocations, modulation schemes used in uplink and downlink, and resource block allocations in channel bandwidth [12]. The digital dividend bands are crucial for deploying IMT systems, especially in some developing countries and sparsely populated areas, to assist them in reducing the digital divide with urban areas and achieving digital equality [13]. Digital dividends provide wide coverage in rural areas with new technology. Additionally, the propagation characteristics of lower frequencies improve indoor coverage in built-up areas, making access to communications services more inclusive [13]. Figure 2 compares coverage ranges based on frequencies in the open environment. Notably, base stations operating in the digital dividend bands offer broader coverage than those in any other bands above 1 GHz. However, it is essential to consider that propagation within the frequency range of 700-2600 MHz is influenced by various factors, including diffraction, reflection, scattering, and attenuation. These factors significantly differ from ideal free-space propagation, especially when considering the power-law path loss exponent in different scenarios such as urban, suburban, and outdoor-to-indoor environments.

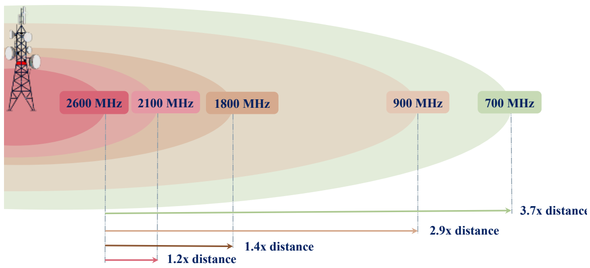

Fig. 2. Coverage comparison in free space depending on frequency.

In urban areas, the power-law path loss exponent tends to be higher compared to free space propagation. This means that the signal strength decreases more rapidly with increasing distance. The power-law path loss exponent in suburban areas is generally lower than in urban areas but still higher than in free space propagation. Consequently, signal strength attenuates faster than in ideal free space conditions but less severely than in densely populated urban areas. Moreover, when a 5G signal transitions from an outdoor environment to an indoor space, additional challenges arise due to building materials and construction elements. In this scenario, the power-law path loss exponent can be quite high, leading to significant signal attenuation as the signal penetrates walls and windows. Besides, indoor reflections and multipath propagation further complicate signal propagation.

The benefits of broadband spectrum are passed on to customers in a competitive market through lower prices, which can increase the take-up and usage of the services.

Global demand for mobile data traffic and broadband multimedia capacity is rising simultaneously with data usage growth. This endangers mobile broadband in emerging markets, rural areas, and inside buildings. The upcoming WRC-23 is a chance to investigate mobile allocations and possibly identify additional spectrum for IMT in the sub-700 MHz band.

The digital dividend frequencies are not just limited to commercial IMT systems; Many countries in ITU Region 1 have deployed BBPPDR services in certain parts of these frequencies by the EU Decision 2016/687 on the harmonization of the 700 MHz band [14], [15]. BBPPDR refers to radio applications utilized by national authorities or relevant operators in response to public safety and security concerns, including emergency situations [14], [15]. Digital dividend spectrum meets the PPDR requirements in broadband by supporting higher data rates, higher capacity, and enhanced multimedia capabilities.

III. CURRENT SITUATION AND FUTURE DEVELOPMENT OF DTT, 5G BROADCASTING, AND PMSE IN EUROPE

A. *Digital Terrestrial Television*

The phrase "linear television" refers to any television programs transmitted (from one to many) following a predetermined schedule to be received by households at certain times on specific channels [16]. Live television content is transmitted in real-time as it is produced, albeit not always linearly. Thus, linear television is essential for both live and non-live content [16]. Linear television content is delivered by broadcasting platforms (DTT, satellite, cable, IPTV). DTT is the most appropriate and viable way to deliver linear TV content to wide audiences in many developing countries.

Technological innovations and advancements in DTT have improved capacity, spectrum efficiency, and service. Initially, the switch from analog to digital terrestrial television broadcasting has increased spectrum efficiency, content diversity, and improved reception/signal quality. The transition of the transmission standard from Digital Video Broadcasting - Terrestrial (DVB-T) (1997) to DVB-T2 (2009) increased capacity by 50-100% for television services in the same amount of radio spectrum. Digital video encoding and compression technologies have evolved over time from the standard Moving Picture Experts Group 2 (MPEG-2) (1996) to H.264 MPEG-4 (1999, Standard Definition (SD)) to H.265 High Efficiency Video Coding (HEVC) (2013, High definition (HD)) and ultimately H.266 Versatile Video Coding (VVC) (2020); each upgrade uses a smaller proportion of the available capacity for each video stream [17]. The requirement for spectrum for DTT services was reduced by around 25% thanks to Single Frequency Networks (SFNs), which allowed multiple transmitters to simultaneously transmit the same signal over the same frequency channel without utilizing additional frequencies [18]. Any additional changes to DTT platforms to boost efficiency (where practicable) would incur high costs.

These upgrades have permitted the resolution improvement from SD to HD services with the same amount of spectrum. Other improvements in resolution and service quality could be introduced on the DTT platform, such as the introduction of Ultra-High Definition (UHD), 4K, High Frame Rate (HFR), High Dynamic Range (HDR), and interactive broadcast broadband, but they would limit the number of video services offered due to their need for higher bandwidths.

However, the DTT platform alone is no longer sufficient to meet the demands of today's society. An examination of the market share of linear TV content delivery platforms in the EU shows that delivery means are heterogeneous across European TV markets [17]-[20]. Figure 3 shows the share of households by platform by member state [17], [19].

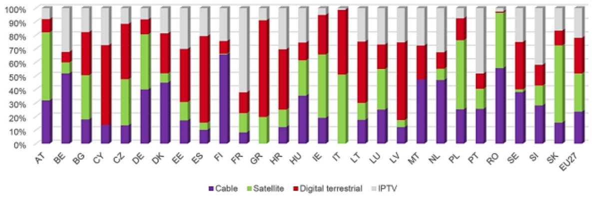

Fig. 3. Share of households by platforms, 2021 [17], [19].

The combined data for the EU27 shows that the shares are almost evenly split across the linear TV platforms. However, a predominant platform emerges for several member states. DTT clearly dominates in Greece (71%), Spain (64%), and Italy (48%). Instead, the cable platform dominates in Finland (66%). Satellite is the dominant platform in Slovakia (57%). Finally, IPTV is the most used platform in France (62%).

On the other hand, the future outlook indicates a decrease in linear TV viewing time, while non-linear viewing will continue to dominate daily TV viewing habits [20], [21]. Figure 4 shows viewing time across platforms by the country for the years 2020 and 2021 for some selected EU member states, the United States and Australia, according to new research from OMDIA [21].

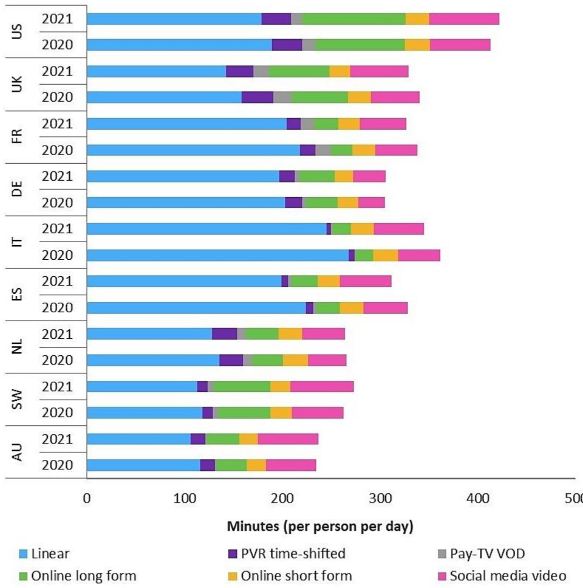

Fig. 4. Viewing time across platforms by country [21].

A clear growth is observed in daily viewing habits for the online long-form (Video on Demand (VoD), Over-the-Top (OTT) services like Netflix, Prime Video, Disney+, etc.) and social media video viewing [21].

Indeed, on a platform-by-platform level, pre-scheduled linear TV content still has an inherent value for audiences in the markets covered. Thus, VoD and OTT services complement linear viewing rather than being a replacement. Consequently, linear and non-linear TV will coexist for the foreseeable future.

However, for linear TV, particularly through DTT, to remain a part of the landscape in the ever-evolving TV market for many years to come, new technologies, such as standalone 5G broadcasting and collaborative content creation for television over various media must be developed to deliver more immersive content to the audience across multiple devices.

B. 5G Broadcasting

5G Broadcasting uses 5G technology to deliver linear broadcast content directly to multiple users on mobile devices (such as smartphones, tablets, and cars) without Wi-Fi or the Internet [22], [23]. 5G Broadcasting is seen as a promising supplement to DVB-T2, not a substitute for stationary reception. 5G Broadcasting can offer a similar capacity to DTT and transmit both linear TV and radio programs, assuming good reception conditions. Importantly, standalone 5G Broadcasting can utilize the sub-700 MHz band because it is intended to operate alongside DTT without interference [23], [24].

However, several challenges need to be tackled before 5G Broadcasting can be widely adopted. These issues include the spectrum that will be used (current DTT spectrum or another allocated spectrum), the networks that will be used (existing DTT networks or mobile networks), the requirements for free broadcast, and business models that can support 5G broadcasting. Additionally, since 5G broadcasting combines the broadcasting and telecom industries, creating a centralized approach between them is essential [23], [24].

Trials to enhance the 5G broadcasting standard are now underway in Europe. The first phase of the 5G broadcasting trial in Vienna ended, which ran from Q4/2019 to Q2/2021 and compared the 5G broadcasting with DTT [25]. They are currently in the process of the second phase, which will extend until Q3/2023 and aims to investigate the applications and further develop the 5G broadcasting ecosystem [26]. This trial reached the following conclusions [25], [26]. 5G broadcasting significantly extends the reach of terrestrial broadcasting as enabled devices can be used for a portable outdoor reception. 5G broadcasting can achieve comparable performance compared to DVB-T2, with potential enhancements in upcoming 3GPP versions. 5G broadcasting networks supplement existing DVB-T2 networks for fixed and portable indoor reception. Consequently, 5G broadcasting is suitable to coexist with DTT in the sub 700 MHz band and enables innovation in terrestrial broadcasting, although the business models that could support 5G broadcasting are still unclear.

Given the concerns about the business models that could support 5G broadcasting, there is an opportunity to benefit from the factors essential for defining the business model and pricing of future industrial mobile networks, as outlined in [27]. This contribution delves into the classification of networks based on customer requirements, constraints, and motivations. It also presents illustrative use cases for each scenario, including the business advantages of cloud solutions, challenges related to frequency allocation, the potential of network slicing, and the importance of energy-efficient networks [27].

C. Program-Making and Special Events

Today, alongside DTT, the sub-700 MHz band in the UHF spectrum is widely used throughout Europe by PMSE equipment, such as wireless microphones, in-ear systems, talkback systems, camera control systems, audio/video links, and so forth [17], [28]. PMSE provides content production services to broadcasters, professional content producers, and various organizations in the community.

The demand for content created by PMSE is increasing steadily, driven by both the current audiences and the expanded worldwide audience realized by new delivery platforms. Moreover, the PMSE industry is characterized by innovation, as seen by the adoption of IP and cloud-based workflows, the introduction of digital audio technology, the usage of 5G for some PMSE applications, and the growing complexity of production [28]. Thus, it is difficult to quantify and average the required spectrum given the wide range of activities using PMSE equipment and the increasing demand for complicated and advanced productions. Additionally, the need for spectrum will significantly increase during special events such as championships, elections, and other large events.

The UHF band has the best conditions to meet the needs and demands of PMSE in terms of high spectrum efficiency, ultra-low latency, high transmission reliability, and high audio quality. Future use of this band for PMSE services will rely on decisions taken at the upcoming WRC-23.

IV. POSSIBLE OPTIONS FOR FUTURE USE OF THE 470-694 MHZ BAND IN EUROPE

Decisions taken at WRC-23 will affect future EU policies on using the 470-694 MHz band in Europe. Any EU action should adhere to the ITU Radio Regulations and the EU's policy objectives in order to promote the development of a single digital market supported by dependable high-speed networks and encourage the effective management and use of radio spectrum. This section considers four options for the future use of the 470-694 MHz band in Europe. Stakeholder viewpoints for each option are investigated.

A. Option 1 – no change in regulation sub-700 MHz band.

In this scenario, Europe will take no change on the frequency band 470-694 MHz. Mainly broadcasting services will continue to use the whole 224 MHz spectrum segment. No spectrum is available in the sub-700 MHz band for mobile services within the framework of EU harmonization. Figure 5 shows the sub-700 MHz band distribution according to option 1.

Fig. 5. Option 1 – no change in regulation the sub-700 MHz band.

European Broadcasting Union (EBU), and Broadcast Network Europe (BNE), support the "no change" option, justifying their viewpoint as follows [29]-[31]. Currently, DTT and PMSE in the sub-700 MHz band serve the community's public and commercial needs and may continue to be required to deliver public service media content well in many EU countries for many years.

Under the EU Decision 899/2017, the European Parliament, Council, and Commission have guaranteed access to the band 470-694 MHz for terrestrial broadcasting services until at least 2030 [2], [32]. Full access to the 470-694 MHz band for DTT with PMSE will maximize the economic benefits to the EU and ensure efficient spectrum use. Additionally, this will promote innovation and help broadcast networks use energy-efficient and environmentally friendly broadcasting. One of the key results of the ITU report BT.2302-1 is that most countries express a need for the whole 224 MHz spectrum segment for broadcasting [33]. Only Slovenia and Finland in Europe have declared a desire for less than 224 MHz.

On the other hand, the analysis of responses to ITU-R circular letter 6/LCCE/104 at task group TG 6/1 shows that the current spectrum available for broadcasting in the sub-700 MHz band is sufficient and essential for the broadcasting services, and most of the responding administrations have indicated that they plan to continue using this band for broadcasting services [34].

However, IMT is currently in a situation with increased demand for more low-band spectrum to provide cost-effective coverage solutions. In this "no-change" scenario, further investment in network infrastructure might address the current coverage inadequacies rather than additional spectrum in the UHF band.

Mobile network capacity can be increased through network densification and using previously available digital dividend bands [35]. The development of fiber networks complemented by Wi-Fi connectivity is also expected to meet a significant portion of the goal of digital connectivity in the digital decade [35]. Furthermore, reorganizing the sub-1 GHz mobile bands and phasing out outdated mobile operator technologies like 2G from 900 MHz will permit big contiguous frequency blocks, allowing their effective capacity to be almost trebled [36].

B. Option 2 – co-primary allocation to mobile service in the sub-700 MHz band.

In this scenario, the CEPT and/or EU would consider harmonized technical solutions on a new digital dividend band to the mobile service, for example, the "600 MHz band" (606-694 MHz), while the spectrum (470-606 MHz) would still be available for DTT and PMSE. Figure 6 shows the frequency allocation of the sub-700 MHz band according to option 2.

There is a consensus that mobile traffic is growing worldwide, and therefore more spectrum is needed to increase the capacity of mobile networks. Given the historical allocation of prior digital dividend bands for mobile purposes during previous WRCs, could raise expectations that the 606-694 MHz spectrum may be taken away from broadcasting services if a co-primary allocation is agreed upon at WRC-23.

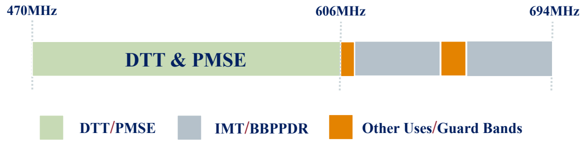

Fig. 6. Option 2 – co-primary allocation to mobile service in the sub-700 MHz band.

The Groupe Special Mobile Association (GSMA) supports allocating additional spectrum for IMT, arguing that access to the 600 MHz band has several advantages [13], [37]. The additional spectrum in the 600 MHz band may reduce the cost of extending coverage to rural residents by 33% and improve rural and deep-indoor broadband speeds by 30-50% [37]. Utilizing the 600 MHz frequency for specific broadband services like BBPPDR could also benefit society.

However, introducing a co-primary allocation for 470-694 MHz to IMT at WRC-23 would also lead to negative impacts. The loss of any further spectrum is likely to undermine the public and commercial value that DTT and PMSE services already provide in the sub-700 MHz band, as well as inhibit the innovation and investments necessary to maintain and grow this value in the future [29], [30]. Indeed, according to the report on spectrum inventory by the European Commission, the demand for future spectrum consumption was at the same level for both the broadcasting and mobile industries in the short, medium, and long term [38].

On the other hand, enabling the fragmented approach to the sub-700 MHz band would require more time and effort on a large scale throughout Europe in terms of planning, preparations, international frequency coordination, technical activities, as well as the cost of migrating DTT transmitters onto new frequencies. Various studies have demonstrated that mobile and broadcasting services cannot operate on the same frequencies in the same or nearby areas without causing mutual harmful interference [39], [40]. In practice, if a country used the 600 MHz band for mobile purposes before its neighbors, it could cause interference to DTT users in neighboring countries in areas up to tens of kilometers from the border, representing about 13% of the EU population [41].

This issue would be particularly important for EU members that border non-EU countries, like Hungary. They have to switch off the broadcasting services in the 600 MHz band, but they cannot launch IMT until the necessary cross-border coordination agreements with their neighbors have been concluded. GE-06 agreement and ITU-R report BT.2383 include the final acts for planning and protecting DTT in cross-border territories [2], [42].

Thus, EU action will have to include effective management of interference with DTT outside the EU borders. Interference can be reduced by geographically separating mobile and broadcasting services. However, the required separation distances can sometimes be hundreds of kilometers. Compatibility studies of IMT and broadcasting services in the prior digital dividend bands can benefit administrations in developing bilateral agreements for the new band [39]-[45].

C. Option 3 – secondary allocation to mobile service in the downlink-only mode in the sub-700 MHz band.

In this scenario, Europe would consider a flexible use that allows the coexistence of mobile broadband services in the downlink-only mode (i.e., unidirectional) alongside traditional broadcasting services in the sub-700 MHz band, where there is no or decreasing demand for DTT at the national level. Figure 7 shows the frequency allocation of the sub-700 MHz band according to option 3.

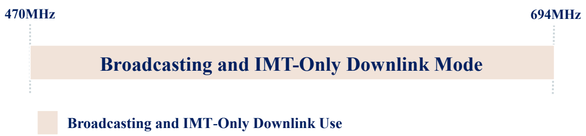

Fig. 7. Option 3 – flexibility approach to the sub-700 MHz band.

In practice, each country protects DTT's sub-700 MHz band spectrum access to the extent deemed necessary, while channels not used for DTT might become available for downlink-only services or applications served by mobile broadband technologies, depending on national conditions. To provide PMSE services, the “white spaces” in the sub-700 MHz band will be used.

Several broadcasting and mobile manufacturers support this flexibility option, justifying their viewpoint as follows [10], [46]. According to national demand, a combination of wireless broadband services in downlink-only mode and/or DTT services will be offered in the sub-700 MHz band to maximize positive economic benefits and minimize negative social repercussions.

By adopting this option, mobile operators can enhance their downlink capacity to satisfy the growing demand for mobile traffic where spectrum is available while also ensuring the availability of the necessary spectrum for the future development of DTT in Europe. Relevant statistics have indicated that traffic requires significantly more downlink capacity than uplink capacity, owing primarily to increased video and app-based mobile use [47].

Additionally, allowing only downlink services will limit the fragmentation of UHF spectrum utilization and sufficiently mitigate interference between IMT and DTT services. Uplink services won't be permitted since they would entail significant service restrictions due to the interference mitigation with broadcasting services needed to comply with the GE-06 agreement and the ITU Radio Regulations, particularly at the EU outer borders.

However, member states that allow IMT-only downlink services will have to guarantee cross-border coordination with neighboring countries where DTT is operational. Studies should be conducted to determine the technical coexistence conditions of DTT and IMT in the downlink-only mode in the sub-700 MHz band.

On the other side, when option 3 is adopted, the densification of DTT networks will make it more difficult for PMSE users to access “white spaces”.

D. Option 4 – allocation to the mobile service in the whole sub-700 MHz band.

In this option, the regional coordination will define a common roadmap for clearing DTT from the sub-700 MHz band and allocating the full 224 MHz spectrum segment to mobile broadband services and possibly other sectorial services such as PMSE and BBPPDR. Figure 8 shows the frequency allocation of the sub-700 MHz band according to option 4.

Fig. 8. Option 4 – allocating the whole sub-700 MHz band for mobile services.

In practice, the 470-694 MHz spectrum will be available to mobile broadband services, and DTT transmission will cease. Thus, in the absence of the DTT platform, there are two possible scenarios for providing linear broadcast television services to all EU households in future.

The first scenario would be based on the migration of DTT viewing to alternative platforms (a mixture of satellite, cable, and IPTV). Aetha Consulting Ltd has considered this alternative scenario and estimated the economic costs and benefits arising for EU citizens over a 15-year period (from 2015 to 2029) [16].

The potential costs associated with migrating DTT viewing to alternative platforms encompass several aspects. Firstly, there are costs related to acquiring client premises equipment and transponder capacity necessary to deliver linear TV content on these alternative platforms. Another significant cost implication lies in the potential increase in expenses for broadcast companies. With fewer platforms competing for viewers after the migration, broadcasters may face higher costs as they strive to retain their audience and remain competitive in the evolving media landscape. In countries like Spain and Italy, where many local channels are provided through the DTT platform, ceasing DTT could result in losing access to these local TV services. In countries like Spain and Italy, where many local channels are provided through the DTT platform, ceasing DTT could result in losing access to these local TV services. Additionally, there may be a loss due to consumers' preference for DTT, as it provides free-to-view services. On the other hand, when the DTT platform is ceased, the spectrum previously allocated for broadcasting may become unavailable for PMSE use. As a result, moving PMSE users to new frequencies could become more expensive and logistically challenging.

Whereas the availability of the 470-694 MHz band for mobile services could bring about several significant benefits. Mobile operators stand to gain cost savings since they won't have to invest in deploying new base station sites to increase capacity, and thus, these savings will be passed on to consumers through lower prices. Moreover, there will be additional savings from no longer needing to maintain and operate the DTT network, including expenses related to power, staff, equipment maintenance, and future equipment upgrades. Another advantage is the potential for faster adoption of high-speed broadband services, which could effectively address digital inequalities and bridge the digital divide. On the other side, the 470-694 MHz spectrum could also be utilized by other broadband services like BBPPDR.

The economic evaluation of this scenario indicated that the costs associated with migrating DTT viewing to alternative platforms would be many multiples of the benefits that would arise from making the whole sub-700 MHz band available for mobile services [16]. However, this assessment may differ between EU member states depending on the current levels of adoption of existing television platforms.

The second scenario explores and evaluates the possibility of delivering television channels currently provided through DTT via Mobile Broadband (MBB) networks. This scenario is investigated as a case study in Finland [48], [49]. The objective is to assess the required investment to continue providing TV channels via MBB networks in Finland by 2030. To employ this scenario, public service broadcasting must be accessible to everyone through the open Internet, technically functional, and be cost-free at the point of use.

Unicast delivery of linear TV content to all viewers requires a significant investment in rural unicast capacity. The existing network grids would need to be densified to provide uniform 5G coverage on higher bands. Alternatively, evolved Multimedia Broadcast Multicast Service (eMBMS) or 5G Xcast would be required to optimize the low-band capacity in mobile broadband networks [48]. However, with 4G and 5G mobile networks, broadcast and multicast functionality can be deployed together with typical 4G/5G unicast. This means the same content can be delivered to numerous users with one transmission, effectively saving spectrum capacity when multiple viewers watch the same content simultaneously [49].

The main challenge for this scenario is securing wireless broadband capacity during peak viewing times in sparsely populated rural areas. On the other hand, PMSE technologies will need to adapt to changes in the available spectrum.

V. Conclusion

Future EU policy on the 470-694 MHz spectrum after 2030 is expected to consider decisions taken at the upcoming WRC-23. This article provided an overview of the most recent trends and advancements concerning the future uses of the sub-700 MHz spectrum in Europe.

Analysis of the current situation and future development of broadcasting services currently operating in the 470-694 MHz band in the EU showed that while linear TV watching, mainly through DTT, continues to be popular with EU many member states, the demand for VoD services and OTT subscriptions are increasing to adapt to user behavior.

Consequently, the TV future will result in higher quality, improved sound, interactive TV, VoD and OTT offerings that complement DTT (DTT for live TV viewing, Hybrid TV through VoD and OTT for non-linear TV), as well as 5G broadcasting that complements DTT (DTT at home, 5G broadcasting on the move).

Analysis of options for future use of the 470-694 MHz band showed that all future strategies should be able to adjust to the reality of broadcasting and the growing mobile market while considering technology advancements and consumer behavior.

The continued use of the whole sub-700 MHz band for broadcasting services, as envisaged in option 1, will ensure the spectrum needed to support further growth and innovation in broadcasting services. Nevertheless, this will delay the deployment of mobile broadband networks, particularly in border rural areas where coverage will be poor or nonexistent. Additionally, border urban areas may experience capacity limitations for high-speed broadband due to a lack of spectrum.

Allocating new digital dividend bands to IMT and BBPPDR systems in the sub-700 MHz band would help lower broadband prices, increase accessibility to communications services, and overcome the digital divide. However, enabling the fragmented approach to the 470-694 MHz band when allocating the new 600 MHz band to the mobile service on a primary basis, as envisaged in option 2, would undermine DTT and PMSE services and necessitate the EU countries adopt a national roadmap and reach all necessary cross-border coordination agreements while adhering to the transition deadline.

Whereas launching the mobile service in the downlink-only mode in the sub-700 MHz band on a secondary basis, as envisaged in option 3, would protect the interest of both broadcasting and mobile services in the 470-694 MHz band and allow the development of an innovation ecosystem for both. Banning mobile services in uplink mode would sufficiently mitigate the mutual interference between IMT and DTT systems. Therefore, it is recommended that this flexibility option be adopted at WRC-23. However, compatibility studies are still required to determine the technical coexistence requirements of DTT, PMSE, and IMT in the downlink-only mode in the sub-700 MHz band at the EU level.

On the other hand, the full-scale reallocating, as envisaged in option 4, is not currently considered suitable because DTT and PMSE continue to play a significant role in EU many member states.

References

[1] International Telecommunication Union (ITU), Geneva, Switzerland. [Online]. Available: https://www.itu.int/

[2] ITU, "Final Acts of the 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 (RRC-06)," Geneva, Switzerland, 15 May-16 June 2006 [Online]. Available: https://www.itu.int/pub/R-ACT-RRC.14-2006/en

[3] ITU, "The Final Acts of the World Radiocommunication Conference 2007 (WRC-07)," Geneva, Switzerland, 2007 [Online]. Available: http://handle.itu.int/11.1002/pub/802313bd-en

[4] ITU, "The Final Acts of the World Radiocommunication Conference 2012 (WRC-12)," Geneva, Switzerland, 2012 [Online]. Available: http://handle.itu.int/11.1002/pub/805627a4-en

[5] ITU, "The Final Acts of the World Radiocommunication Conference 2015 (WRC-15)," Geneva, Switzerland, 2015 [Online]. Available: http://handle.itu.int/11.1002/pub/80d4e1c0-en

[6] The European Parliament and the council of the European Union, "Decision (EU) 2017/899 of the European Parliament and of the Council of 17 May 2017 on the use of the 470-790 MHz frequency band in the Union," Strasbourg, France, 2017. pp. 1–7 [Online]. Available: http://data.europa.eu/eli/dec/2017/899/oj

[7] ITU, "The Final Acts of the World Radiocommunication Conference 2019 (WRC-19)," Sharm El-Sheikh, Egypt, 2019 [Online]. Available: http://handle.itu.int/11.1002/pub/813b5921-en

[8] ITU, World Radiocommunication Conference 2023 (WRC-23), Agenda items and status of studies, Dubai, United Arab Emirates, 20 November to 15 December 2023 [Online]. Available: https://www.itu.int/wrc-23/

[9] Latest CEPT Briefs and ECPs developed by CPG in preparation of WRC-23, last updated: 21 February 2023 [Online]. Available: https://www.cept.org/ecc/groups/ecc/cpg/page/cept-briefs-and-ecps-for-wrc-23/

[10] P. Lamy, "Results of the work of the high-level group on the future use of the UHF band (470-790 MHZ)," Report to the European Commission 1, 2014, pp. 1–34 [Online]. Available: https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=6721

[11] ITU-R, Naming for International Mobile Telecommunications, Resolution 56-2 (2015) [Online]. Available: https://www.itu.int/pub/R-RES-R.56-2-2015

[12] H. Taha, P. Vári, and S. Nagy, "On the Challenges of Mutual Interference between Cable Television Networks and Mobile Fixed Communication Networks in the Digital Dividend Bands," Infocommunications Journal, Vol. XIV, No 3, September 2022, pp. 63–71. DOI: 10.36244/ICJ.2022.3.8

[13] Coleago Consulting Ltd and GSMA, Low-band spectrum for 5G report, the need for sub-1 GHz spectrum to deliver the vision of 5G, 9 May 2022, pp. 1–32 [Online]. Available: https://www.gsma.com/spectrum/wp-content/uploads/2022/07/Low-Band-Spectrum-for-5G.pdf

[14] European Commission, Commission Implementing Decision (EU) 2016/687 on the harmonisation of the 694-790 MHz frequency band for terrestrial systems capable of providing wireless broadband electronic communications services and for flexible national use in the Union, Brussels, 28 April 2016, pp. 1–12 [Online]. Available: http://data.europa.eu/eli/dec_impl/2016/687/oj

[15] Resolution 646 (Rev.WRC-19), Public protection and disaster relief, The World Radiocommunication Conference (WRC-2019), Sharm El-Sheikh, Egypt, 2019, pp. 443–448 [Online]. Available: https://www.itu.int/dms_pub/itu-r/oth/0C/0A/R0C0A00000F00133PDFE.pdf

[16] Aetha Consulting Limited, "Report on the future use of the 470-694 MHz band in the EU," Cambridge, United Kingdom, 31 October 2014, pp. 1–89 [Online]. Available: https://aethaconsulting.com/wp-content/uploads/2021/05/Future-use-of-the-470-694MHz-band-in-the-EU-October-2014.pdf

[17] European Commission, Directorate-General for Communications Networks, Content and Technology, Study on the use of the sub-700 MHz band (470-694 MHz): final report, Publications Office of the European Union, 2022, pp. 1–273 [Online]. Available: https://data.europa.eu/doi/10.2759/94757

[18] EBU Technical Report 016, Benefits and limitations of single frequency network (SFN) for DTT, October 2012, pp. 1–9 [Online]. Available: https://tech.ebu.ch/docs/techreports/tr016.pdf

[19] European Audiovisual Observatory, 2021, [Online]. Available: https://www.obs.coe.int/en/web/observatoire/

[20] L. Chiariglione and C. A. Szabó, "Multimedia Communications: Technologies, Services, Perspectives, Part II. Applications, Services and Future Directions," Infocommunications Journal, V ol. VI, No 3, September 2014, pp. 51–59., [Online]. Available: https://www.infocommunications.hu/documents/169298/831299/InfocomJ_2014_3_8_Chiariglione.pdf

[21] R. Moyser and A. Thomas, Cross-Platform Television Viewing Time Report – 2022, OMDIA, London, UK, 22 July 2022, [Online]. Available: https://omdia.tech.informa.com/OM025343/Cross-Platform-Television-Viewing-Time-Report--2022

[22] ETSI and EBU, Technical Specifications 103 720 V1.1.1, 5G Broadcast System for linear TV and radio services; LTE-based 5G terrestrial broadcast system, 2020, pp. 1–44 [Online]. Available: https://www.etsi.org/deliver/etsi_ts/103700_103799/103720/01.01.01_60/ts_103720v010101p.pdf

[23] EBU Technical Report 063, 5G Broadcast Network Planning and Evaluation, Geneva, August 2021, pp. 1–93 [Online]. Available: https://tech.ebu.ch/publications/tr063

[24] EBU Technical Report 064, Compatibility between 5G Broadcast & other DTT systems in the sub-700 MHz band, Geneva, August 2021, pp. 1–47 [Online]. Available: https://tech.ebu.ch/publications/tr064

[25] CEPT, Input Paper, 5G Broadcast Vienna Field Trial, Vienna, Austria 2021, pp. 1–11 [Online]. Available: https://www.ors.at/fileadmin/user_upload/ors/5G_Broadcast/PTD_21_012_Technical_implementation_status_of_5G_Broadcast_-_Vienna_Field_Trial_.pdf

[26] ORS group, Austrian Broadcasting Services (ORS), 5G Broadcast, Vienna, Austria, [Online]. Available: https://www.ors.at/en/5g-broadcast/

[27] G. Soós, D. Ficzere, T. Seres, S. Veress and I. Németh, "Business opportunities and evaluation of non-public 5G cellular networks – A Survey", Infocommunications Journal, Vol. XII, No 3, July 2020, pp. 31–38. DOI: 10.36244/ICJ.2020.3.5

[28] ECC Report 323, Spectrum use and future requirements for PMSE, Denmark, 12 February 2021, pp. 1–54 [Online]. Available: https://docdb.cept.org/download/3470

[29] European Broadcasting Union (EBU), white paper, "'No Change' at WRC-23 maximizes public value and innovation in the UHF band," Geneva, November 2021, pp. 1–6 [Online]. Available: https://tech.ebu.ch/publications/white-paper-20.11.2021

[30] Broadcast Networks Europe (BNE), "'No change' to the UHF band at WRC-23 enables the ongoing success of essential broadcasting services," Brussels, May 2022, pp. 1–6 [Online]. Available: https://broadcast-networks.eu/wp-content/uploads/No-change-on-WRC23-AI1.5-BNE-position-paper.pdf

[31] European Conference of Postal and Telecommunications (CEPT), "Draft CEPT Brief on WRC-23 agenda item 1.5," Yverdon-les-Bains, Switzerland, 07–11 November 2022, pp. 1–57 [Online]. Available: https://cept.org/Documents/cpg/74230/cpg-22-042-annex-iv-05_draft-cept-brief-on-wrc-23-agenda-item-15

[32] European Parliament and the Council of the European Union, "Decision (eu) 2017/899 of the European Parliament and the Council of 17 May 2017 on the use of the 470-790 MHz frequency band in the Union," Strasbourg, France, 17 May 2017, pp. 1–7 [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017D0899

[33] ITU-R report BT.2302-1, "Spectrum requirements for terrestrial television broadcasting in the UHF frequency band in Region 1 and the Islamic Republic of Iran," Geneva, Switzerland, 2021, pp. 1–54 [Online]. Available: https://www.itu.int/pub/R-REP-BT.2302-1-2021

[34] Radiocommunication Bureau (BR), Circular letter 6/LCCE/104, Questionnaire on spectrum use and spectrum needs for terrestrial television broadcasting in the UHF frequency band in connection with WRC-23 agenda item 1.5, Geneva, Switzerland, 27 February 2020 [Online]. Available: https://www.itu.int/dms_pub/itu-r/md/00/sg06/cir/R00-SG06-CIR-0104!!PDF-E.pdf

[35] European Commission, Digital Economy and Society Index (DESI), 2020, page 44 and page 15 [Online]. Available: https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=67086

[36] GSMA, Legacy mobile network rationalization; Experiences of 2G and 3G migrations in Asia-Pacific, May 2020, pp. 1–62 [Online]. Available: https://www.gsma.com/spectrum/wp-content/uploads/2020/06/Legacy-mobile-network-rationalisation.pdf

[37] Coleago Consulting Ltd and the GSMA, Vision 2030: Low-Band Spectrum for 5G, June 2022, pp.1–20 [Online]. Available: https://www.gsma.com/spectrum/wp-content/uploads/2022/07/5G-Low-Band-Spectrum-1.pdf

[38] European Commission, "Report from the Commission to the European Parliament and the Council on the Radio Spectrum Inventory," COM (2014) 536 final, Brussels, Belgium, 1 September 2014, pp. 1–14 [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52014DC0536

[39] ITU-R report BT.2337, "Sharing and compatibility studies between digital terrestrial television broadcasting and terrestrial mobile broadband applications, including IMT, in the frequency band 470-694/698 MHz," Geneva, 2017, [Online]. Available: https://www.itu.int/pub/R-REP-BT.2337

[40] ITU-R report BT.2301, "National field reports on the introduction of IMT in the bands with co-primary allocation to the broadcasting and the mobile services," Geneva, Switzerland, 2022, [Online]. Available: https://www.itu.int/pub/R-REP-BT.2301

[41] ESPON & University of Geneva, “European Perspective on Specific Types of Territories,” 2013, pp. 1–140 [Online]. Available: https://www.espon.eu/sites/default/files/attachments/GEOSPECS_Final_Report_v8___revised_version.pdf

[42] ITU-R report BT.2383, “Typical frequency sharing characteristics for digital terrestrial television broadcasting systems in the frequency band 470-862 MHz,” Geneva, Switzerland, 2022 [Online]. Available: https://www.itu.int/pub/R-REP-BT.2383

[43] ITU-R report BT.2338, “Services ancillary to broadcasting/services ancillary to programme making spectrum use in Region 1 and the implication of a co-primary allocation for the mobile service in the frequency band 694-790 MHz,” Geneva, Switzerland, 2014 [Online]. Available: https://www.itu.int/pub/R-REP-BT.2338

[44] ITU-R report BT.2339, “Co-channel sharing and compatibility studies between digital terrestrial television broadcasting and international mobile telecommunication in the frequency band 694-790 MHz in the GE06 planning area,” Geneva, Switzerland, 2014 [Online]. Available: https://www.itu.int/pub/R-REP-BT.2339

[45] H. Taha, P. Vári, and S. Nagy, “Survey on Coexistence of Terrestrial Television Systems and Mobile Fixed Communications Networks in Digital Dividend Bands,” *Proceedings of the Technical University of Sofia (TU-Sofia)*, Bulgaria, 2022, pp. 29–36
DOI: 10.47978/TUS.2022.72.01.005

[46] RSPG Secretariat, “RSPG Opinion on a long-term strategy on the future use of the UHF band (470-790 MHz) in the European Union,” Brussels, Belgium, 19 February 2015, pp. 1–34 [Online]. Available: https://circabc.europa.eu/d/a/workspace/SpacesStore/c88af26c-0f24-4431-8647-56deaa917307/RSPG15-595_final-RSPG_opinion_UHF.pdf

[47] Data Report, We Are Social and Hoot suite, “Distribution of global monthly mobile data volume as of January 2021, by category,” Chart, 27 January 2021, Statista, [Online]. Available: https://www.statista.com/statistics/383715/global-mobile-data-traffic-share/

[48] Omnitele Ltd and Yle Finnish Broadcasting Company, the first study, “Assessment for YLE; Linear content in mobile networks; Case: Finnish mobile networks and unicast delivery,” Finland, May 2019, pp.1–58 [Online]. Available: https://drive.google.com/file/d/1mMA4ZAeXCMJfRzcbWeuUtcxzt4jd-TV0

[49] Omnitele Ltd and Yle Finnish Broadcasting Company, the second consultant study, “Assessment for Yle; Broadcast Investment Assessment in Mobile Broadband Networks,” Finland, December 2019, pp. 1–81 [Online]. Available: https://drive.google.com/file/d/19HvvBxq1fB7D6q3jYSNlv7mdhDHiYKfg/view?usp=sharing

Hussein Taha is a PhD candidate at the Doctoral School of Multidisciplinary Engineering Sciences at Széchenyi István University in Hungary. He holds a BSc in Communication and Electronics Engineering from Tishreen University in Syria and MSc in Telecommunication Engineering from the same university in 2019. His areas of interest are Mobile and Wireless Communications, and Broadcasting.

Péter Vári is an AssociateProfessor in the Department of Telecommunications at Széchenyi István University, the university of Győr in Hungary. He is now Deputy Director-General for Technical Affairs at the National Media and Infocommunications Authority in Hungary. His general interests span the areas of Radiocommunications, Mobile Services, and Broadcasting.

Szilvia Nagy is a Professor in the Department of Telecommunications at Széchenyi István University, the university of Győr in Hungary. Her research interests include Digital Image Processing, Information and Coding Theory, DSP , EMC, Quantum Information Theory, and Semiconductors.