Guidelines for implementation of IMT in UHF bands

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Acknowledgements

This report was drafted by TMG, a consulting firm specializing in the information and communication technologies (ICT) sector. For over 30 years, TMG has assisted public and private sector entities around the world on ICT policy and regulatory matters. Our team focuses on providing insight and developing strategies to assist clients on technology and market trends, the development mobile services; spectrum policy and management; broadband and ICT strategies; economic assessments and valuations, among other matters.

This report was commissioned by the GSMA, a global organisation unifying the mobile ecosystem to discover, develop and deliver innovation foundational to positive business environments and societal change. GSMA's vision is to unlock the full power of connectivity so that people, industry, and society thrive. Representing mobile operators and organisations across the mobile ecosystem and adjacent industries, the GSMA delivers for its members across three broad pillars: Connectivity for Good, Industry Services and Solutions, and Outreach. This activity includes advancing policy, tackling today's biggest societal challenges, underpinning the technology and interoperability that make mobile work, and providing the world's largest platform to convene the mobile ecosystem at the MWC and M360 series of events.

Contents

1. Executive summary

This report provides technical and regulatory guidelines regarding mobile services using harmonised International Mobile Telecommunications (IMT) in the ultra-high frequency (UHF) bands. The guidelines are focused specifically on the 600 MHz band but are based on proven methodologies used to deliver co-existence for similar frequencies and are scalable to other new bands as well.

Low-band UHF frequencies such as 600 MHz are considered important by mobile operators because their superior signal propagation offers an opportunity to lower the digital divide between urban and rural areas. The use of the 600 MHz band for IMT has progressed since its initial identification at the ITU's 2015 World Radiocommunication Conference (WRC-15). In parallel, the broadcasting service also uses UHF spectrum, with various levels of digital television (DTV) implementation in different markets. Digital switchover is also still ongoing in some countries,[1] and appropriate technical and regulatory measures to be employed between countries must take all these factors into account.

These measures are usually implemented through bilateral agreements, which provide a framework to facilitate spectrum use in border regions. This coordination is essential to ensure effective use of spectrum on both sides of a border, whether by the same service or by different services.

Bilateral agreements for the 600 MHz band help countries to:

- Have flexibility to meet spectrum demands for both IMT and DTV broadcasting applications.
- Ensure interference-free operations in their border areas.
- Review their spectrum needs in border areas and update their spectrum plans while facilitating border agreements.
- Understand the needs of the communities in border areas and identify possible cooperation initiatives with neighbouring countries.

Bilateral agreements provide certainty to operators wishing to deploy networks in these areas and help ensure that operation of both broadcasting and mobile services is interference-free at borders. This is especially relevant when one country is implementing IMT while an adjacent country is still using DTV in the same band.

1.1. Existing experiences in the use of UHF bands

As IMT has been deployed in UHF spectrum bands previously used by the broadcasting before, there are already examples of bilateral agreements for sharing IMT bands along national borders in the 700 MHz and 800 MHz bands. The technical characteristics of different UHF bands are similar, although in the case of the 700 MHz band, many countries moved towards IMT implementation in a similar timeframe, which facilitated the coordination process among neighbouring countries. The timeline for the 600 MHz implementation may differ from this.

Cases of cross-border interference affecting broadcasting and mobile services in different countries, have been overcome through bilateral agreements in the past. The 600 MHz band is still in the early stages of

[1] GSMA, Digital Switchover in Sub-Saharan Africa, October 2022, https://www.gsma.com/spectrum/resources/digital-switchover-sub-saharan-africa/.

IMT implementation and there are fewer examples of bilateral agreements for this band. However existing bilateral and multilateral agreements provide a useful framework 600 MHz as well.

EXAMPLE OF BILATERAL AGREEMENT

Colombia

Colombia is currently implementing a bilateral agreement in the 600 MHz band.

During WRC-15, Colombia was the only country in South America that identified the 614-698 MHz frequency range for IMT. Following WRC-15, the Colombian Administration began discussions with some of its neighbouring countries - including Brazil, Ecuador, and Peru - to develop a framework composed of bilateral agreements with each country. The efforts include a set of technical studies with measurement protocols and a methodology to identify possible interference scenarios and how to resolve them. The Colombian Administration's goal is to use the 600 MHz band for IMT, whereas neighbouring countries would simultaneously use the same band for broadcasting services. The process is ongoing.

EXAMPLE OF MULTILATERAL AGREEMENT

GE06 Agreement

The ITU developed the Regional Agreement Geneva 2006 (GE06) for the use of DTV broadcasting in countries in ITU Region 1,[2] as well as Iran. The GE06 Agreement establishes coordination conditions between broadcasting and other services, including mobile services. The key concept of the process is that a new station needs to coordinate to prove that existing stations of other services are protected before entering into service. The protection not only involves the geographic area but also requires an agreement if the band is in use at the border of two nearby countries. One issue identified is that existing values for the implementation of stations from the mobile service in the GE06 Agreement may overprotect existing broadcasting stations, and thus should be considered with caution.

Cross-border agreements ensure co-existence when spectrum uses and plans differ across borders. By agreeing on measures to minimise interference, users on both sides of a border benefit from improved service quality.

1.2. Recommendations

The use of the 600 MHz band for IMT is a valuable option for countries looking for cost-effective methods to increase the capacity of mobile networks in rural areas, including providing service to critical infrastructure such as roads, ports, and mines.

1.2.1. General 600 MHz band recommendations

Administrations should establish a clear roadmap with dates and milestones to provide a framework for developing bilateral agreements. Even if countries do not plan to use the 600 MHz band for IMT in the short term, they should be mindful of the evolving spectrum needs of different actors in the telecommunications industry. They may also want to review their spectrum planning for DTV broadcasting to facilitate sharing arrangements in the border areas.

As part of their national spectrum planning, countries should frequently review all services' spectrum needs, including for broadcasting and IMT, to ensure spectrum provides the maximum societal return. This may allow them to accommodate mobile operators' capacity requirements while maintaining adequate spectrum for the provision of broadcasting services.

[2] ITU Region 1 comprises Africa, the Middle East, and Europe.

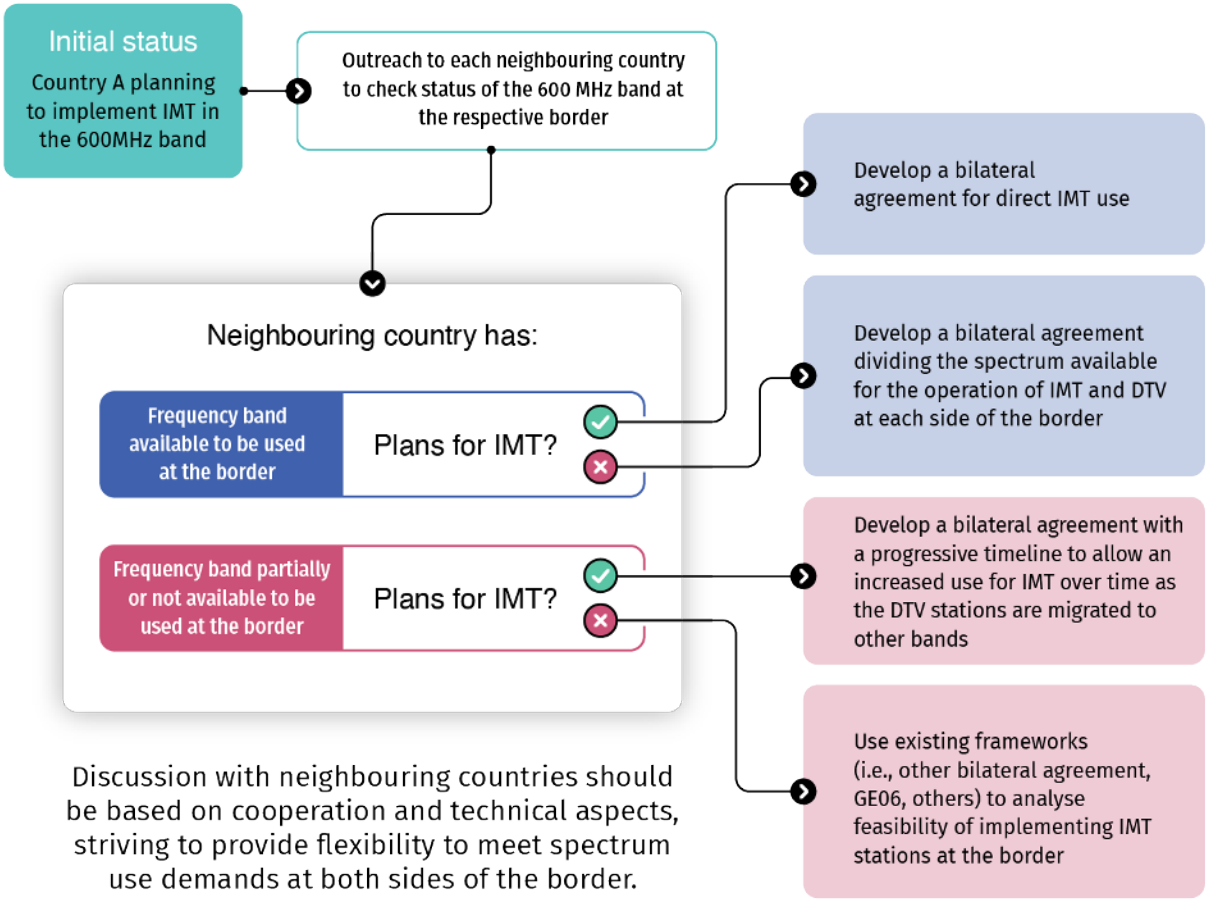
1.2.2. Bilateral agreements to address border region use

Countries wishing to use the 600 MHz band for IMT networks will first benefit from understanding their neighbours' plans for the band, including the level of deployment of DTV in each channel. Depending on the initial assessment of the current and future spectrum use in the border area, agreements may be:

(i) straightforward border agreements to enable interference-free deployment of the same service in both countries.
(ii) agreements to accommodate plans for releasing the band for IMT use.
(iii) agreements to ensure the coexistence of DTV broadcasting and IMT emissions on either side of the border.

The flowchart in Figure 1 shows the main aspects and steps that countries wishing to implement IMT networks in the 600 MHz band should consider when developing bilateral agreements for spectrum use at the border with neighbouring countries. These general guidelines can be adjusted to consider the unique needs and characteristics of each country.

Figure 1: Recommendations for the development of a bilateral agreement for the 600 MHz band



Source: TMG.

An example of the structure of a bilateral agreement could be as follows:

Structure for a bilateral spectrum agreement

After the initial considerations, legal analysis, and other contextual information, as well as a brief description of the intent of the agreement, countries may want to include the following sections in their agreements:

- Scope
- Definitions
- Technical characteristics and standards under the agreement
    - Channels or frequency bands apportioned to each side of the border
    - Power limits at the border
    - Coordination zones
- Coordination triggers
- Procedures to measure the agreed technical parameters
- Procedures to inform about a harmful interference case
- Procedures to solve the detected and reported harmful interference cases
- Other administrative matters
    - Term of the agreement
    - Procedure for modifications/amendments to the agreement
    - Execution of the agreement

2. Guidelines for implementation of IMT in UHF bands

The guidelines provided in this section aim to help countries begin the process of developing bilateral agreements to use the 600 MHz band for IMT applications. Increasing demand for mobile broadband puts pressure on regulators to constantly seek available spectrum to support the market's needs. Regulators should strive to accommodate mobile operators' capacity requirements, supporting the expansion of their networks' coverage and quality of service, while maintaining adequate spectrum for the provision of broadcasting services.

The 600 MHz band is emerging as a potential solution to expand both the coverage and capacity of IMT networks in bands below 1 GHz. The 614-694/698 MHz frequency range is standardised by 3GPP as bands n71 (617-652 MHz/663-698 MHz) and n105 (612-652 MHz/663-703 MHz). Band plan n71 is widely available, supported by 388 commercial user devices currently, and growing.[3] Band plan n105 is under consideration in various countries in Asia, with great potential for economies of scale, and is compatible with n71.

The 600 MHz band is also widely used by DTV and perspectives on the use of the band by either IMT or DTV vary from country to country due to historical, cultural, economic, and technological factors. Because neighbouring countries may have different timelines for the implementation of the 600 MHz band for IMT, adequate coordination at border areas is needed, usually through bilateral agreements.

Bilateral agreements facilitate spectrum use at the border, providing certainty to operators wishing to deploy networks on both sides of border areas. These agreements ensure the interference-free operation of both broadcasting and mobile services. Agreements for the use of the 600 MHz band can benefit from lessons learned from bilateral and multilateral agreements implemented for the use of other spectrum bands and services.

Countries often develop bilateral agreements to use spectrum for the same service (e.g., broadcasting, mobile). In these agreements, countries take different approaches, such as dividing the use of the band (e.g., establishing different possible TV channels for each side of the border) or setting a coordination zone with associated trigger values to require coordination when necessary. Coordination and cooperation are essential prerequisites for using a particular spectrum range for the same service. Those prerequisites become even more important when nearby countries differ in their use of a spectrum range, either in terms of services allowed or band plans.

This section provides general recommendations for countries regarding the development of bilateral agreements while maintaining the necessary flexibility to accommodate different uses of the band in border areas. The section also analyses the main technical parameters and considerations to be included when developing such agreements.

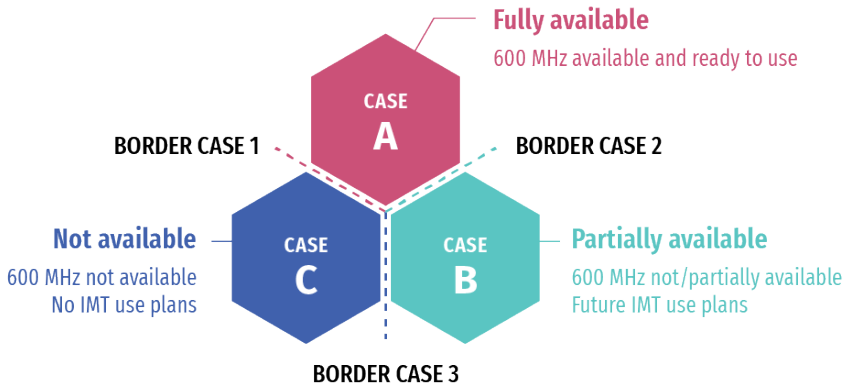
2.1. 600 MHz use scenarios among neighbouring countries

Differences in current or future 600 MHz use, including the pace of IMT deployment, are likely to exist between neighbouring countries. As a consequence, there are three main possible cases when considering the status of the 600 MHz band for IMT implementation in each country, as depicted in Figure 2 and further explained in Sections 2.1.1 and 2.1.2. The band can be: (i) fully available for immediate use by IMT;

[3] GSA, 5G device ecosystem, May 2023, https://gsacom.com/paper/5g-ecosystem-may-2023-member-report/.

(ii) partially available, with the full 600 MHz band not available for IMT and/or IMT use planned but not yet available for deployment; or (iii) not available in the short term, with an administration having no plans to use the band for IMT.

Figure 2: Status of the 600 MHz band for IMT implementation in different cases



Source: TMG.

For example, some ITU Region 1 countries, including some from the Middle East and North Africa (MENA), have expressed interest in deploying IMT networks in the 600 MHz band.[4] The MENA administrations that may wish to deploy IMT networks in the 600 MHz band represent 35% of the population and 60% of the gross GDP of the region.[5]

2.1.1. Countries sharing borders with similar plans for the 600 MHz band

The creation of spectrum use agreements is simpler when both countries have the same plan for the use of the band. In the case of the 600 MHz band, key considerations for negotiating bilateral agreements between countries with similar band plans are set forth below:

- **Both countries in case A**: The agreement is similar to those signed for other IMT bands. In this case, administrations should work on reaching border agreements to deploy IMT in the 600 MHz band as soon as possible.
- **Both countries in case B**: Administrations are willing to develop agreements with a timeline to migrate the broadcasting stations at the border. Depending on the timeline on each side of the border, administrations might agree on dividing the use of the band to temporarily accommodate DTV broadcasting in parallel with IMT deployment. After the transition period, the agreements to implement IMT on both sides of the border are like agreements already signed for other IMT bands.
- **Both countries in case C**: While there is no need for immediate agreement, administrations should continue to engage with their neighbouring administrations regarding their respective broadcasting spectrum needs, potentially allowing future adoption of the 600 MHz band for IMT.

[4] ITU, Circular Letters 6/LCCE/104, February 2020, https://www.itu.int/md/R00-SG06-CIR-0104/en, and 6/LCCE/78, May 2012, https://www.itu.int/dms_pub/itu-r/md/00/sg06/cir/R00-SG06-CIR-0078!!PDF-E.pdf.

[5] World Bank, GDP and population data, 2021, http://databank.worldbank.org/data/reports.aspx?source=2&series=SP.POP.TOTL&country=MEA.

2.1.2. Countries sharing borders with different plans for the 600 MHz band

When countries have different plans for the 600 MHz band use, cooperation is key to providing flexibility for each country to use the spectrum for their specific application. In this sense, there are varying approaches when deploying bilateral agreements for spectrum use, depending on the plans and status of the band. In cases of different spectrum use on each side of the border, administrations can employ agreements that contain specific guidelines depending on each case at the border, as summarised in Table 1. The general tools for all cases include timelines for migration of the DTV broadcasting services, specific coordination triggers, and possible spectrum division in the use of the band.

Table 1: Possible combinations of cases at the border of two neighbouring countries

BORDER CASE 1	BORDER CASE 2	BORDER CASE 3
When IMT use is not planned on one side, but band is fully available for IMT deployment on the other	**When band is fully available for IMT deployment on one side, but only partially on other side**	**When IMT is not planned on one side, but band is partially available for deployment on the other**
An agreement to use the 600 MHz band for both broadcasting and IMT should be drafted with both parties considering the timing of the IMT implementation, including ways to accommodate IMT use in the border area. The agreement should aim to allow the country to use most of the 600 MHz band for IMT in the short term. To achieve this, additional analysis may be needed. For example, the actual spectrum being used around the border area and within the coordination zone may be needed to determine the stations affected. There may be a need to: (i) implement technical and mitigation measures to avoid harmful interference; and/or (ii) reallocate some of the DTV channels in the neighbouring country to free part of the band for IMT use.	An agreement to use the 600 MHz band for both broadcast and IMT should be drafted, with both parties considering the timing of the IMT implementation and proposing a timeframe for the necessary migration. The agreement can include a timeframe for the complete migration of broadcasting out of 600 MHz on the partially available side within the area likely to be affected by cross-border interference from IMT services. The agreement should be oriented to allow the country with IMT fully available to use most of the 600 MHz band for IMT in the short term. Initially, the agreement can also include the partial use of the 600 MHz band for broadcasting during a transitional period to give the country with partial IMT availability time to finalise the migration.	Countries should begin to consider plans for the spectrum use at the border area that consider the expected future use of the band. Discussions regarding a future agreement should start whenever one country foresees an increasing use of the 600 MHz band at the border. An agreement to use the 600 MHz for both broadcasting and IMT should be drafted, considering the timing of the IMT implementation, and proposing a timeframe for the necessary migration. The agreement should be oriented to allow the interested country to use most of the 600 MHz band for IMT.

Source: TMG.

2.2. Considerations when developing bilateral agreements on the use of the 600 MHz band

The development of bilateral agreements should consider the following:

- A clear analysis of spectrum uses at the border, including station registration and coordination procedures.

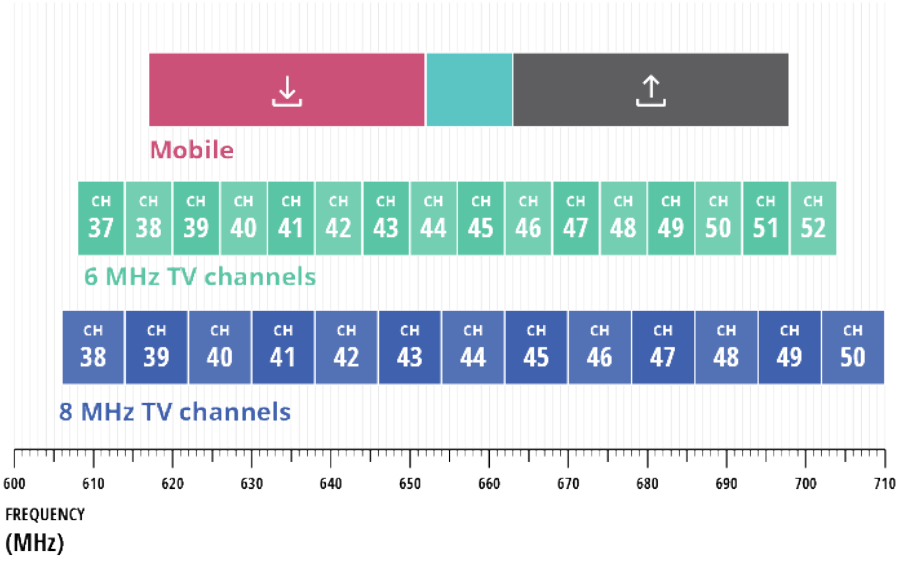
- Definition of the coordination zone as the area where the agreement will apply and technical measures that will be in place to protect emissions on both sides of the border.
- The definition of a coordination zone does not imply any restriction on deploying stations if countries comply with:
    - technical parameters (e.g., channels permitted, power levels at the border, orientation, shielding, among others); and
    - the process for exchanging administrative information, technical measurements, interference reports, and coordination actions.

The importance of bilateral agreements is highlighted by some cases where interference has occurred and affected both services in different countries, such as between Spain and France, among others. Experience with existing agreements on other frequency bands should also be considered, as that may serve as the basis for a future agreement. Additionally, there are examples of agreements among countries that are both implementing IMT in the 600 MHz band, such as the agreements between the United States and Mexico.[6] Countries that have the 600 MHz band fully available for IMT should be able to move ahead with their plans, even while their bilateral agreements are still under negotiation, such as in the Colombian case (see more in Section 3.1).

2.2.1. Identification of affected channels

As part of their spectrum management responsibilities, administrations should analyse current and future spectrum requirements for both broadcasting and IMT applications. This is relevant for developing bilateral agreements for spectrum use, as it helps to identify the mobile service frequency blocks that may conflict with existing or planned DTV channels. As shown in Figure 3, it is possible to identify which DTV channels fall into the IMT uplink and downlink frequency ranges, and in some scenarios, only one or the other may be relevant.

Figure 3: Identification of the affected DTV channels and IMT blocks in the 600 MHz band



Source: TMG.

[6] FCC, Mexico agreements by frequency, July 2023, https://www.fcc.gov/mexican-agreements-frequency.

2.2.2. Definition of trigger for coordination requirement

One important aspect of the bilateral agreement is the definition of a coordination zone - the area in which a proposed deployment would trigger the need for bilateral engagement. Based on technical studies between IMT and broadcasting, as described in detail in Section 4, it is possible to determine interference and service contours. As shown in Table 2, this gives insights into distances that would ensure that one system does not cause harmful interference to the other.

Table 2: Examples of distances to support the determination of coordination zones

Interference scenario	Interference contour	Service area contour
IMT into broadcasting	13 km (from IMT base station)	39 km (from DTV station)
Broadcasting into IMT	70 km (from DTV station)	12 km (from IMT base station)

Source: TMG.

Some bilateral agreements consider shorter distances as triggers for coordination zones, such as 6 km from the border to IMT base stations and 15 km from the border to DTV stations in the case, for example, of the agreements signed between Colombia and Ecuador for the use of the 700 MHz band for IMT and DTV, respectively.[7] Distances may also in some cases be longer.

It is worth noting that the values proposed in Table 2 are a reference for countries wishing to establish bilateral agreements with their neighbouring countries. Factors such as the geographic conditions, the location of the stations, and other technical conditions are needed when establishing an appropriate value as the trigger for coordination. This coordination zone is one of the aspects to negotiate as it limits the number of stations that would need to be regulated under cross-border agreements while still ensuring protection from harmful interference for the services at each side of the border.

2.2.3. Review of existing stations

There might be situations where only a few DTV channels are used around the border areas, allowing for partial use of the spectrum for IMT, or even for a reorganisation of the DTV channels to eliminate possible overlap. For instance, in ITU Region 1, there are relatively few DTV stations planned to occupy the lowest channel (i.e., channel 39) that conflicts with the 600 MHz band for IMT.[8] There is also a channel that is within the duplex gap of the IMT band plan (i.e., channel 44).

There could be situations when only the mobile downlink (or uplink) conflicts with existing DTV stations. Furthermore, when considering the geographical location of each station, it is possible to determine which service area, if any, could be realistically affected. This type of information allows countries to further refine what IMT stations, if any, would require additional steps for coordination. A specific analysis can be done for each country when there is information available on the actual deployment of each service in the band.

[7] Interview with the international office of the ICT Ministry in Colombia, June 2023. Also, MINTEL Ecuador published a press release describing the 6 km coordination zone for the IMT agreements,
MINTEL, *Ministros de Ecuador y Colombia firmaron convenio para mejorar la comunicación móvil terrestre en zona de frontera*, February 2015, https://www.telecomunicaciones.gob.ec/ministros-de-ecuador-y-colombia-firmaron-convenio-para-mejorar-la-comunicacion-movil-terrestre-en-zona-de-frontera/ and https://www.telecomunicaciones.gob.ec/servicios-moviles-libres-de-interferencias-en-zona-de-frontera-ecuador-colombia/.

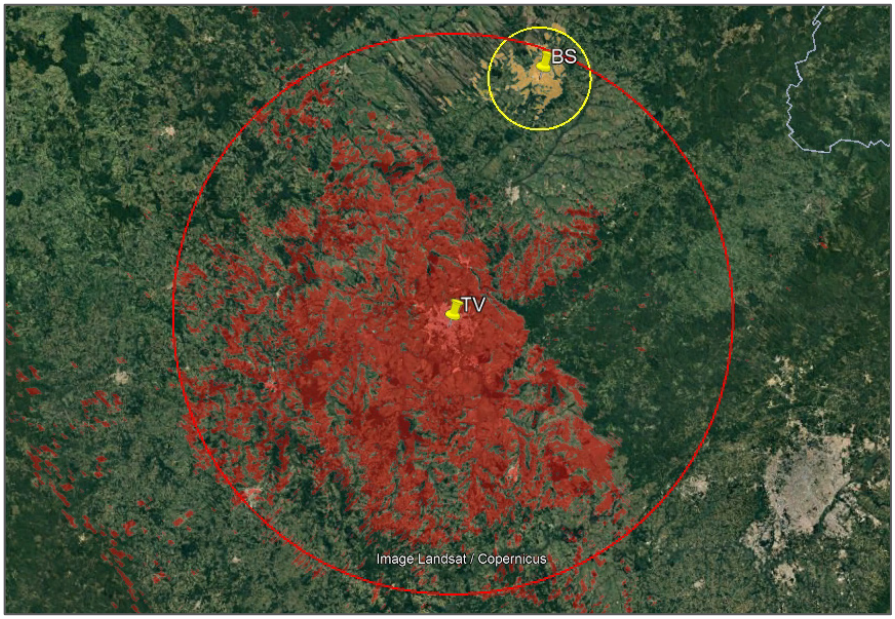
[8] ITU, Master international frequency register (MIFR), extracted provided by the ITU in June 2023.

2.2.4. Analysis of real-world cases

Bilateral agreements should also determine the type of analysis to be considered when a new IMT or DTV station is proposed within the coordination zone, and the relevant interference contours overlap with the service contour of the stations in the neighbouring country. The compatibility with a neighbouring country's stations may be proved by studying a real-world example of a specific location. For instance, coverage analysis considering the terrain information may prove that no risk of harmful interference exists even when both stations are within a short distance of each other.

Figure 4 shows a case where, due to the geographic conditions and technical configurations, a DTV station and an IMT base station can coexist. While this situation could theoretically trigger the need for coordination, an additional analysis that considers the terrain shows that the actual DTV station's interference area does not reach the IMT base station coverage area.

Figure 4: DTV station interference contour and area (red) vs. IMT base station service contour and coverage area (yellow)



Source: TMG.

2.2.5. Mitigation measures

Depending on the particular scenarios of the stations requiring coordination, several mitigation measures can be described in the agreement that would support a flexible implementation of IMT stations while protecting services against harmful interference, including:

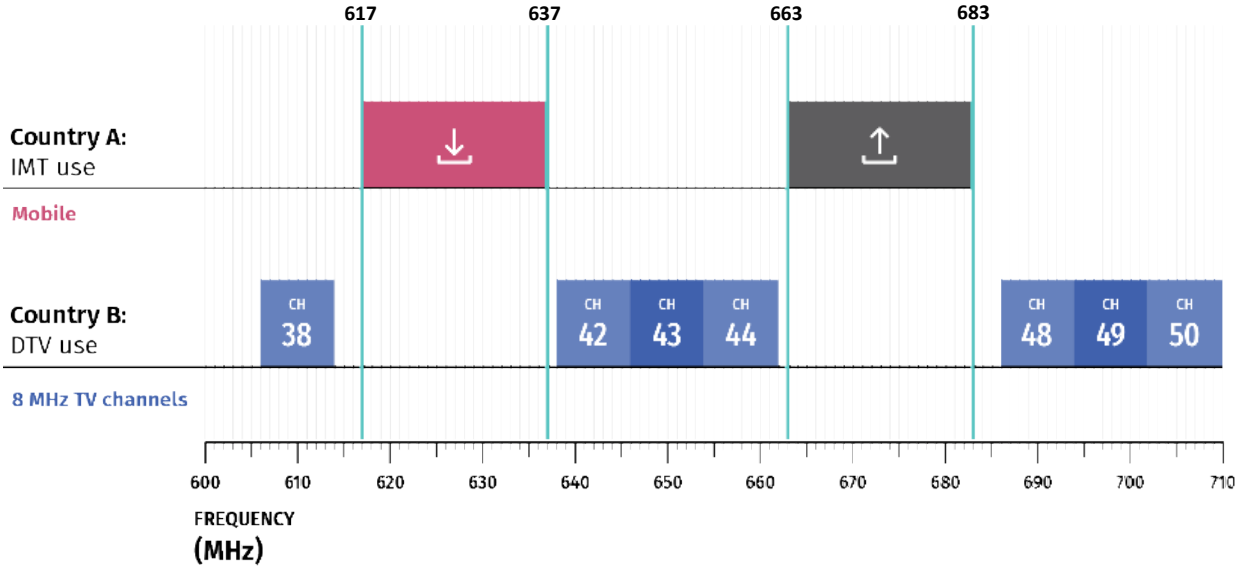
- coordination zone segmentation:
  - distance for DTV station,
  - distance for IMT uplink, and
  - distance for IMT downlink.
- protective measures for IMT base stations:
  - antenna pointing, shielding, filters.
- protective measures for DTV stations:
  - antenna pointing and power adjustment.
- channel reorganisation.

2.2.6. Determination of how to divide the spectrum use on each side of the border

In some cases, the coexistence of IMT base stations and DTV stations in the same frequency range may prove to be infeasible at the border area, and the DTV stations could not be migrated to channels below 614 MHz. Understanding that the migration of DTV channels should be the first option, as it reduces the possibility of harmful interference, it is possible to explore the prospect of dividing the use of the band to accommodate the implementation of IMT on one side of the border, while still protecting DTV channels operating on the other side of the border. This approach can help countries deploy their IMT networks more quickly, and progressively increase the amount of spectrum available for mobile operation.

When considering how to divide the spectrum, one option, as shown in Figure 5, is that the country implementing IMT could prioritise the use of the lower part of the 600 MHz band and allow the use of channels 42-44 and 48-50 for DTV broadcasting in the neighbouring country. Countries may also agree on certain channels remaining unused at the border area. Furthermore, the implementation of Single Frequency Networks (SFN) can reduce the spectrum demand for DTV channels. In some cases, of course, it may be possible to concentrate DTV below 614 MHz.

Figure 5: Example of dividing the use of the 600 MHz band at the border between neighbouring countries



Source: TMG.

Administrations can continue working together to review the progress of their spectrum needs and band plans on each side of the border to update the bilateral agreements as needed. The exact amount of spectrum to be used on each side of the border will depend on the existing needs of each country.

2.3. Structure for a bilateral agreement

Countries need to agree on the technical parameters for protecting the applications on each side of the border and the size of the coordination. Other aspects, such as the timeline for implementation of the agreement and the process of reporting stations' administrative information, also need to be agreed upon.

3. Relevant border agreement experiences

Implementing a mobile broadband network in a country while neighbouring countries are still using the same band for DTV broadcasting requires attention to a range of details and appropriate interference-mitigating measures.[9] The process requires a coordination plan, based on calculated or measured values, to identify possible harmful interference scenarios.

Methods to facilitate spectrum sharing can be based on separation, which can be created through:

(i) **frequency**: segmentation of band and channel plans;
(ii) **geography**: creation of a geographical separation between the sites, space diversity, differentiation of antennas, addition of physical barriers, and site shielding;
(iii) **time**: time division multiple access, duty cycle control, dynamic assignment of frequencies; and
(iv) **signal**: coding modulation, power, bandwidth adjustments, and adaptive signal processing.[10]

The countries involved would sign a coordination agreement, identifying the frequency ranges and categories involved, as well as the services and systems concerned, based on a common propagation model and interference calculation method.[11] The agreement can also include solutions to resolve unexpected interference, and how to exchange information on spectrum management matters. There are also cases where multilateral agreements have been put in place to achieve these same goals.

3.1. Examples of bilateral agreements

Several examples of bilateral agreements exist for different IMT bands, such as in the 700 MHz and 800 MHz. In the case of the 700 MHz band, most countries moved towards IMT implementation at similar timescales, which facilitated the coordination process among neighbouring countries. The number of bilateral agreements for the 600 MHz band is more limited since IMT implementation is still in its early stages in this band. Examples in the 600 MHz band include a bilateral agreement between Mexico and the United States on the use of the band for IMT on both sides of the border, and ongoing discussions for proposed agreements between the proposed use of IMT in Colombia while its neighbouring countries such as Brazil, Ecuador, and Peru continue using the band for DTV.[12] Nigeria has also begun the process of updating existing 700/800 MHz agreements with its neighbours to include the 600 MHz band.

[9] ITU, Report ITU-R M.2480-1, National approaches of some countries on the implementation of terrestrial IMT systems in bands identified for IMT, December 2021, https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2480-1-2022-PDF-E.pdf.
[10] ITU, Cross-border coordination issues for fixed and mobile services, 2020, https://www.itu.int/en/ITU-R/terrestrial/workshops/WRS-20/Documents/Cross_border_coordination_for_FXM_WRS-2020.pdf.
[11] Id.
[12] Conversations with the Colombian government on the progress of ongoing agreements, June 2023.

Mexico/United States bilateral agreements for IMT on both sides of the border

In 2018, Mexico's Federal Telecommunications Institute (IFT) approved the relocation of 48 digital television channels from the 600 MHz band (614 MHz-698 MHz).[13] The migration aligned with the standardisation of the frequency arrangement for the 600 MHz band, as submitted by IFT to the ITU.[14]

While the United States auctioned the band in 2017 (with a 39-month transition period finalised in August 2020), Mexico has not decided on the auction date for this band. However, both countries have cooperated to accelerate the relocation of the DTV stations in the border area.[15]

The same frequency arrangement has been adopted by Mexico and the United States, facilitating coordinated spectrum use by the two countries. As the two countries adopted the same band plans for the major IMT bands in use along the border, there was no need to divide the spectrum. The available spectrum is shared equally along the border between the two countries, and licensees should coordinate between the two sides of the border to avoid harmful interference.

Colombia bilateral agreements to use IMT while neighbours still use DTV

Colombia was the only South American country to identify the 600 MHz band for IMT at WRC-15.[16] After this identification, the Colombian administration conducted technical studies of the parameters and measurement techniques required to identify possible interference cases between IMT networks and DTV broadcasting. In parallel, the Colombian administration started conversations regarding the deployment of bilateral agreements for the use of the 600 MHz band for IMT on the Colombian side of the border while the neighbouring areas of Brazil, Ecuador, and Peru used the same band for DTV.[17]

Although conversations are still ongoing and no agreements have been signed, the Colombian administration analysed and identified different levels of difficulty depending on the actual use of the band in each country. In particular, the size and geographical conditions of Ecuador, as well as the size of the towns on each side of the border, may cause specific challenges in developing a mutually acceptable agreement.

There are various reasons why the 600 MHz agreement is taking time to complete. Colombia assigned the 700 MHz band very recently in 2019, after a long time of having the band freed for IMT use. Also, the ASO (analogue switch-off), initially planned for 2019 is still in progress, with more than 170 stations due for migration to DTV. The ICT Ministry announced that the status of such stations will be reviewed in 2023 and the new ASO date will be set.

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[13] IFT, *México se convertirá en el primer país del mundo en liberar la banda de 600 MHz para 5G*, March 2018, https://www.ift.org.mx/comunicacion-y-medios/comunicados-ift/es/mexico-se-convertira-en-el-primer-pais-del-mundo-en-liberar-la-banda-de-600-mhz-para-5g-comunicado.

[14] HB Radiofrequency, Mexico approves release of 600 MHz band for 5G, March 2018, https://halberdbastion.com/intelligence/news/mexico-approves-release-600-mhz-band-5g#:~:text=The%20Plenary%20of%20the%20IFT%20approves%20the%20migration,to%20offer%20fifth%20generation%20%285G%29%20mobile%20broadband%20services.

[15] IFT, *Reubicación de los canales de televisión, localizados en la zona de coordinación, por debajo del canal 37*, https://www.ift.org.mx/espectro-radioelectrico/reubicacion-de-los-canales-de-television-localizados-en-la-zona-de-coordinacion-por-debajo-del-canal

[16] ITU Radio Regulations, 2020, No. 5.308 and 5.308A, https://www.itu.int/hub/publication/r-reg-rr-2020/.

[17] Conversations with the Colombian government on the progress of ongoing agreements, June 2023.

3.2. Examples of multilateral agreements

3.2.1. Harmonised use of the 800 MHz band

The European Commission Decision of May 6, 2010, harmonised the technical condition of use in the 790-862 MHz frequency range (800 MHz band) for terrestrial systems capable of providing electronic communications services in the EU.[18] Since 2013, the 800 MHz band has been repurposed to allow the operation of mobile broadband services in the region.

Some interference cases did arise from the use of IMT and DTV applications in the same band or in adjacent bands, as TV equipment was designed to receive across 470-862 MHz (channels 21-69). A few countries reported interference perceived by broadcasting users of channels 59 and 60 from the emissions of mobile stations. The existing agreement included frameworks that supported the resolution of such issues.

3.2.2. The GE06 Agreement and new services

The GE06 Agreement defined the plan for the use of DTV broadcasting channels and established how other terrestrial services could be implemented within its geographic area.[19] The agreement provides the relevant procedures for the allocation and utilisation of:

- 174-230 MHz
- 470-582 MHz
- 582-862 MHz[20]

Two key articles in the GE06 Agreement govern changes to assignments for terrestrial services. An administration wishing to use a new assignment in other primary terrestrial services or to modify the characteristics of an existing assignment first has to apply the procedure described in Article 4, which:

- prescribes a precise, mandatory coordination procedure for the modification of a service or assigning a band to a new service;
- lists specific coordination requirements, some of which may create obstacles for new services; and
- requires specific characteristics of the notified frequency assignment to be submitted.[21]

[18] European Commission, Decision on harmonised technical conditions of use in the 790-862 MHz frequency band for terrestrial systems capable of providing electronic communications services in the European Union, May 2010, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32010D0267&qid=1685102834745.

[19] ITU, Primary terrestrial services other than broadcasting in the planning area and bands governed by the Regional Agreement GE06, https://www.itu.int/en/ITU-R/terrestrial/fmd/Documents/fxm-GE06-report.pdf.

[20] ITU, Terrestrial Services Department, Regional Agreement Geneva 2006, 2020, https://www.itu.int/dms_pub/itu-r/md/19/wrs20/c/R19-WRS20-C-0022!!PDF-E.pdf.

[21] ITU, Rules of Procedure, Part A10, Rules concerning the Regional Agreement relating to the 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 (GE06), 2020, https://www.itu.int/pub/R-REG-ROP/en.

If the new plan proposes changing an existing assignment to another primary terrestrial service, it must meet the requirements set in Article No. 5.1.3., which governs new digital broadcasting allotments under the GE06 Agreement.[22]

After the successful completion of the coordination procedure, the administration should then follow the notification procedure described in Article 5 of the GE06 Agreement. The notification procedure allows the modification or the re-allocation to a new service to be recorded in the Master International Frequency Register (MIFR).[23]

The requirements of Articles 4 and 5 of the GE06 Agreement are designed to ensure co-existence between new service assignments and existing services, including broadcasting services, where they intersect with the border of country.

The GE06 Agreement specifies (in Appendix 1 to Section I of Annex 4) the coordination trigger field strength of other primary services for the protection of broadcasting from the modifications to the plan. In the case of the 600 MHz band, the trigger field strength is defined as 23 dB(μV/m), which corresponds to the median interference field strength at the border of a neighbouring country. These definitions tend to overprotect the broadcasting station, first because they consider the protection of the neighbouring country independently whether there is a DTV station close to the border, and second because the trigger field strength is up to 9 dB different from other analysis (see Section 4.3), increasing the potential area that requires coordination.

3.3. Cases of cross-border interference issues

Broadcasting services in ITU Region 1, including Europe, are governed by regional frameworks, and the DTV channels are planned in accordance with the GE06 Agreement. Even with this framework, cases of interference have occurred between mobile and broadcasting services, as well as within the broadcasting service. These cases provide additional information on how to deal with interference issues in the UHF bands and emphasise the need for continued cooperation among neighbouring countries, as well as for the establishment of appropriate measures in the bilateral agreements to resolve issues of harmful interference.

Interference from Spain DTV into France IMT in 800 MHz

In 2015, the Spanish DTV channels 66 to 69 covered the whole mobile uplink band and operated on the same frequencies as the 800 MHz IMT base stations in France.

A simulation study on 27 transmitters from the Spanish DTV network in channel 68 (846-854 MHz) was carried out, considering two different propagation models - Recommendation ITU-R 1546-6, and Recommendation ITU-R 1812-6 – and concluded that the IMT uplink receivers in one country could be interfered by DTV transmissions in a neighbouring country. The simulation was also corroborated by

[22] ITU, Rules of Procedure, Part A10, Rules concerning the Regional Agreement relating to the 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 (GE06), 2020, https://www.itu.int/pub/R-REG-ROP/en.

[23] ITU, Primary terrestrial services other than broadcasting in the planning area and bands governed by the Regional Agreement GE06, https://www.itu.int/en/ITU-R/terrestrial/fmd/Documents/fxm-GE06-report.pdf.

the French government.[24] The Spanish government, in order to minimise or eliminate the interference in the 800 MHz band, requested an early change of frequencies in several sites in the bordering areas.

Interference from Spain DTV into Portugal IMT in 800 MHz

Portugal experienced interference to some IMT base stations in the 800 MHz band while Spain was freeing up the band.[25] In Spain, DTV channels 67 to 69 were operating in the same frequency range as the IMT uplink. Spain cleared the band only in 2015, but to avoid and minimise interferences in cross-border zones, the government asked for border DTV sites to clear the band earlier in 2014.[26] The interferences that Portugal reported were in the South - Lagos, Ajustrel and Quateira - and in the centre of the country – Arraiolos.[27]

Interference cases in Spain DTV and IMT stations

In 2021, DTV channels in the southern region of Spain experienced interference originating from Moroccan DTV networks. There were two main causes of the interference: (i) powerful TV repeating stations in the mountains; and (ii) elevated temperature.[28] Resolving these issues required cooperation among the different countries to identify the causes of interference and provide technical alternatives.

Spain also experienced DTV signal interference in the Asturias region from a French mobile service until 2020. To resolve the issue, Spain proposed to increase its DTV signal strengths, change polarity, and even use streaming broadcasts to guarantee the reception of terrestrial DTV services.[29] The region had faced interference problems before, as in 2018 two national providers for mobile and broadcasting services experienced interference in the same area. The Market and Competition Commission was able to solve the issue in 2022.[30]

In another case, in 2022, with the development of 5G networks, Spain's Markets and Competition Commission (CNMC) requested a resolution that provided measures to avoid interference in the 700 MHz band, considering the continued DTV transmission in the 470-694 MHz band.[31] The CNMC noted that, as the TV service was still offered in a band (470-694 MHz) next to the 700 MHz used by mobile

[24] ITU, Radiocommunication Study Groups, Interference from broadcasting transmissions into mobile base-stations. Case study: Spain to France, 14 February 2022.

[25] ITU, National field reports on the introduction of IMT in the bands with co-primary allocation to the broadcasting and the mobile services, Broadcasting service (television), September 2022, p. 10, https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-BT.2301-4-2022-PDF-E.pdf.

[26] Id., p.21.

[27] Id., p. 23.

[28] David Del Valle, Spain probes DTT interference from Morocco, July 2021, https://advanced-television.com/2021/07/05/spain-probes-dtt-interference-from-morocco/.

[29] David del Valle, Spain probes DTT interference from France, July 2020, https://advanced-television.com/2020/07/01/spain-probes-dtt-interference-from-france/.

[30] CNMC, *Conflicto Gitpa vs Telecable De Asturias TV RF*, https://www.cnmc.es/expedientes/cftdtsa03017?overridden_route_name=entity.node.canonical&base_route_name=entity.node.canonical&page_manager_page=node_view&page_manager_page_variant=node_view-panels_variant-27&page_manager_page_variant_weight=10.

[31] David del Valle, Spain: CNMC wants 5G DTT interference action, February 2022, https://advanced-television.com/2022/02/14/spain-cnmc-wants-action-on-dtt-interference-from-5g/.

services, the action had to be taken immediately.[32] Notably, the CNMC's first suggestion was to inform citizens of the matter through an extensive campaign.[33]

Interference of Italy DTV into Croatia DTV in the 700 MHz band

Italy and Croatia have had a long history of spectrum interference along the sea border area. These issues were addressed in 2022 when Italy removed DTV transmitters which had been causing longstanding interference in the reception of Croatian DTV signals. During the preceding 11 years, the Croatian regulator sent more than 7,000 reports of disturbances to the Italian administration requesting the removal of the source of the interference[34] and ultimately reported the issue to the ITU.[35]

The solution was based on measures set forth in the Radio Spectrum Policy Group (RSPG) Opinion in 2021.[36] While the longstanding interference was between DTV stations, the resolution was a critical issue for the Croatian regulator, before preceding to auction the 700 MHz band for IMT networks, as the Italian DTV channels in the 470-694 MHz band could be a source of interference to their mobile networks.[37]

[32] CNMC, request of the SETID on draft order establishing the actions to be carried out by operators providing mobile electronic communications services in the frequency bands of the first and second digital dividend, January 25, 2022. At https://www.cnmc.es/expedientes/ipncnmc05321?overridden_route_name=entity.node.canonical&base_route_name=entity.node.canonical&page_manager_page=node_view&page_manager_page_variant=node_view-panels_variant-27&page_manager_page_variant_weight=10.

[33] CNMC, Report on the actions so that the deployment of 5G in the band of the second digital dividend does not affect television reception, February 14, 2022. At https://www.cnmc.es/prensa/ipn-tdt-segundo-dividendo-digital-20220214.

[34] Chris Dziadul, Italian interference of Croatian TV channels ends, May 2022, https://www.broadbandtvnews.com/2022/05/12/italian-interference-of-croatian-tv-channels-ends/ .

[35] ITU, Reports received by the BR concerning harmful interference between Italy and its neighbouring countries, https://www.itu.int/md/R11-MMHI-SP/en.

[36] European Commission, Radio Spectrum Policy Group (RSPG), Opinion on a Radio Spectrum Policy Programme, June 2021, p. 7, note 8, https://radio-spectrum-policy-group.ec.europa.eu/system/files/2023-01/RSPG21-033final-RSPG_Opinion_on_RSPP.pdf.

[37] Chris Dziadul, Italy stops Croatia TV signal interference, August 2022, https://www.broadbandtvnews.com/2022/08/12/italy-stops-croatia-tv-signal-interference/.

4. Technical aspects of defining coordination zones

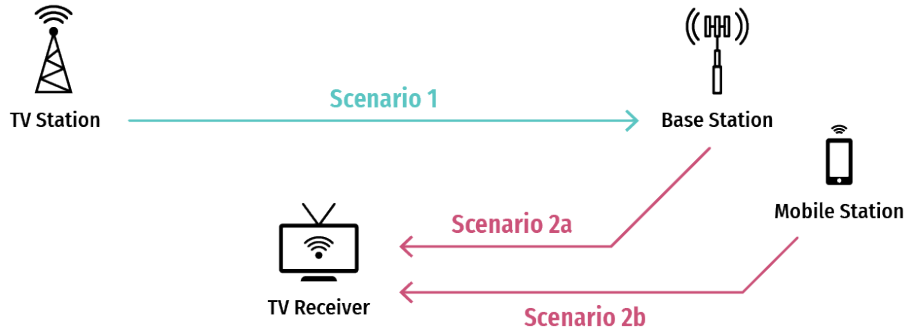
This section assesses the technical conditions for implementing DTV stations and IMT base stations in the nearby geographical areas when both are using spectrum in the 600 MHz band, which can support the definition of coordination measures among different countries.

4.1. Possible interference scenarios

The main scenarios for possible harmful interference cases considered are shown in Figure 6:

- Scenario 1: Possible interference from TV station transmitter into IMT base station receiver,
- Scenario 2a: Possible interference from IMT base station transmitter into TV receiver, and
- Scenario 2b: Possible interference from IMT mobile station transmitter into TV receiver.

Figure 6: Identification of possible harmful interference scenarios



Source: TMG.

4.2. Technical parameters for the analysis

The technical specifications used for mobile networks internationally are summarised in Table 3, based on parameters defined by the 3GPP and used in the ITU technical studies.[38]

Table 3: IMT parameters for bands below 1 GHz

Base station characteristics	
Antenna height	30 m
Sectorisation	3 sectors
Downtilt	3 degrees
Antenna pattern	Recommendation ITU-R F.1336
Antenna polarisation	Linear/±45 degrees

[38] ITU, Characteristics of terrestrial component of IMT for sharing and compatibility studies in preparation for WRC-23, June 2021, https://www.itu.int/dms_ties/itu-r/md/19/wp5d/c/R19-WP5D-C-0716!H4-N4.04!MSW-E.docx, based on 3GPP, TS 38.104 v.16.6.0 and TS 38.101-1 v.16.6.0, December 2020, http://www.3gpp.org/ftp/Specs/archive/38_series/38.104/38104-g60.zip and http://www.3gpp.org/ftp/Specs/archive/38_series/38.101-1/38101-1-g60.zip.

Cross-polarisation	3 dB
Antenna discrimination	1.19 dB
Feeder loss	3 dB
Noise figure	5 dB
Sensitivity	-105 dBm
Protection criteria (I/N)	-6 dB
Typical channel bandwidth	10 MHz
Maximum base station output power (Report ITU-R M.2292)	46 dBm in 10 MHz
Maximum base station antenna gain (Report ITU-R M.2292)	15 dBi
Duplex mode	FDD
Mobile station characteristics	
Mobile station height	1.5 m
Typical antenna gain for user terminals	-3 dBi
Sensitivity	-100.2 dBm
Body loss	4 dB
Maximum user terminal output power	23 dBm

Source: TMG based on ITU.

The parameters for DTV stations vary widely depending on the situation and country of implementation. This example considers parameters that are deemed more relevant in the majority of cases in a border situation, but different cases could be considered when taking into account the specific information of the stations in each country. For scenarios of interference analysis around bordering areas, which are usually in suburban and rural areas, a medium-power DTV station is more representative of the different cases, with the parameters as summarised in Table 4.

Table 4: DTV medium power station parameters

Antenna height	150 m
Equivalent radiated power (e.r.p.)	5 kW
Protection criteria (C/N)	-19 dB

Source: TMG.

4.3. Calculation of interference levels

The calculation of the service and interference levels is done by defining, for the DTV station and IMT base station, the relevant field strength levels. It is then possible to calculate the distance to the respective contour using the appropriate propagation method.

For the DTV station, a service field strength of 51 dB(μV/m) is considered. This value is considered to be adequate for outdoor antenna coverage, although different values may be applicable depending on

specific coverage targets. Taking into account a DTV protection criterion of C/N = -19 dB, the maximum level of interference would be the service value minus the protection criterion, thus the IMT base station interference field strength can be considered as 32 dB(μV/m), equivalent to -104 dBm.

Additional outdoor DTV receiver antenna discrimination may be considered, such as 16 dB, which is widely applied in some of the compatibility studies between IMT and DTV carried out in the ITU process. As such, a level of -88 dBm is considered for the calculation of the interference from IMT base station into the DTV receiver.

The coverage area of the IMT base station depends on the sensitivity of the mobile station, for which the value of -100.2 dBm is considered. The following calculation is done to determine the DTV station interference field strength:

$$E_{dB(mV/m)} = 77.2 + 20\log(F_{MHz}) + I_{dBm} - G_{dBi} + A_d = 37 \text{ dB(mV/m)}$$

where:

I_{dBm} is the received interference power;

G_{dBi} is the isotropic antenna gain, including feeder losses;

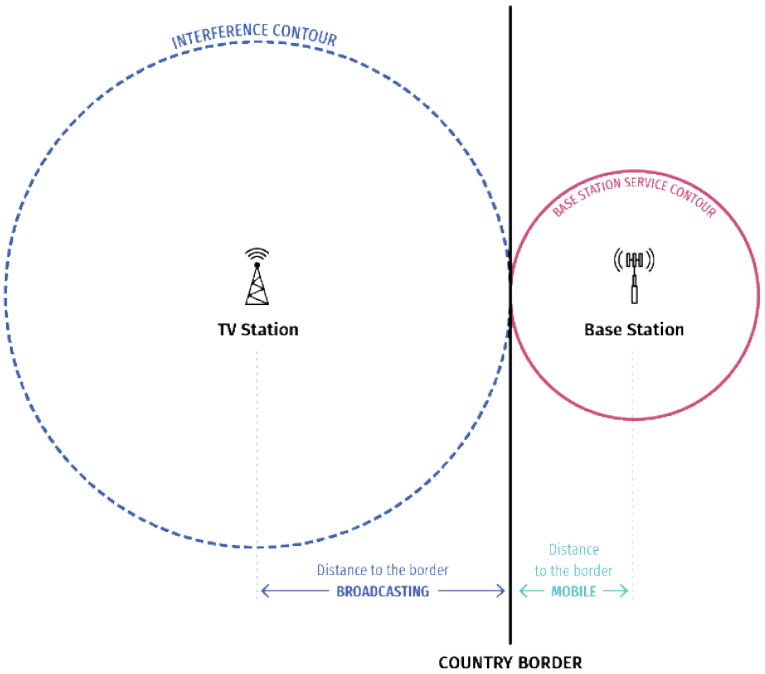
A_d is the antenna directivity discrimination; and

F_{MHz} is the frequency in MHz.

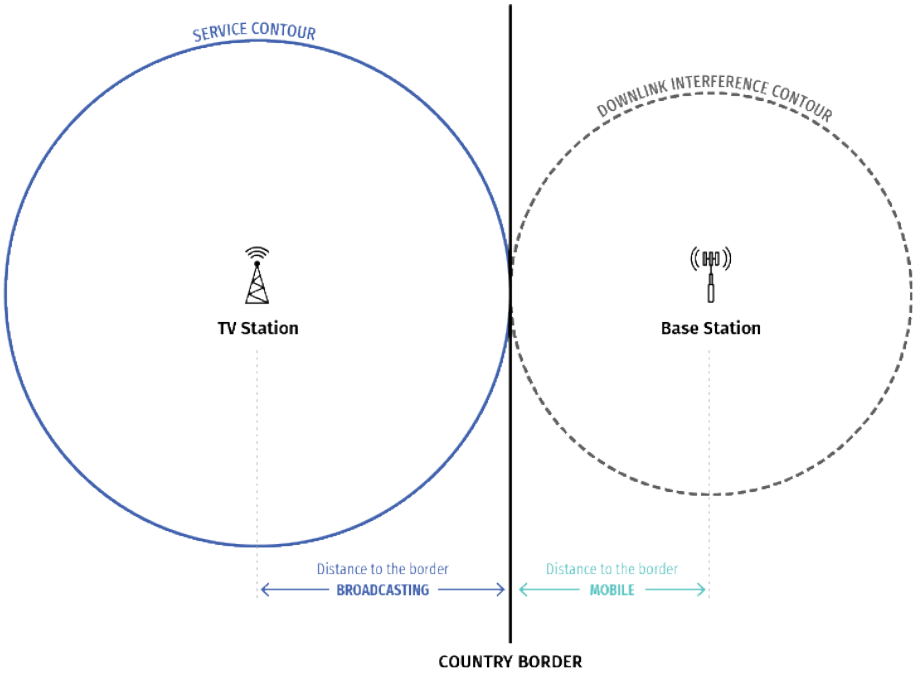
The propagation model used for IMT is Okumura-Hata, and for DTV is Recommendation ITU-R P.1546. The scenario and contours are shown in Figure 7, with the results of the calculation summarised in Table 5.

Figure 7: DTV and IMT stations service and interference contours in different scenarios

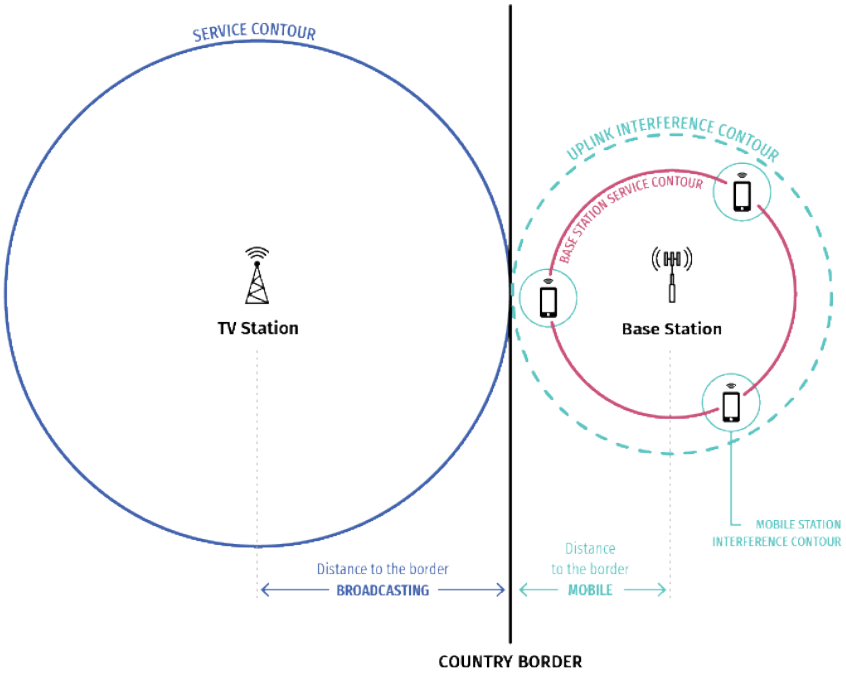
SCENARIO 1



SCENARIO 2A



SCENARIO 2B



Source: TMG.

Table 5: Interference calculation results for each scenario

Scenario 1	Scenario 2a	Scenario 2b
DTV station may interfere with the IMT base station receiver	IMT base station may interfere with the DTV receiver	IMT mobile station may interfere with the DTV receiver
DTV station interference contour is 70 km when considering a field strength of 37.1 dB(μV/m) and using Recommendation ITU-R P.1546.	IMT base station interference contour is 9 km when considering an interference level of -88 dBm and Okumura-Hata.	IMT mobile station interference contour is 1 km, which should be added to the IMT base station service contour of 12 km, resulting in 13 km, based on the different levels for each part of the network and Okumura-Hata.
IMT base station service contour is 12 km when considering transmission power of 46 dBm and Okumura-Hata.	DTV station service contour is 39 km when considering a power level of 5 kW, field strength of 51 dB(μV/m), and Recommendation ITU-R P.1546.	DTV station service contour is 39 km when considering a power level of 5 kW, field strength of 51 dB(μV/m), and Recommendation ITU-R P.1546.

Source: TMG.

4.4. Conclusion of the technical analysis

This analysis shows possible distances when considering standard IMT base stations and a specific DTV station, which can be used as a reference for countries wishing to establish bilateral agreements with their neighbouring countries. Factors such as the geographic conditions, the location of the stations, and other technical parameters are needed when establishing an appropriate value as the trigger for coordination. Separation distances will depend on individual circumstances of different cases, for example, transmitter powers, sea or land path, including terrain and clutter along paths between DTV and IMT stations.

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