EBU

OPERATING EUROVISION AND EURORADIO

TR 064

COMPATIBILITY BETWEEN 5G BROADCAST AND OTHER DTT SYSTEMS IN THE SUB-700 MHZ BAND

SOURCE: S-SPT

Geneva

August 2021

This page is intentionally left blank

Abstract

The way in which the content and services of Public Service Media (PSM) organizations are delivered is evolving, driven particularly by the popularity of personal devices (smartphones, tablets) for accessing audio visual media (AV).

Whilst PSM content and services can be accessed on smartphones and tablets, this is only under conditions that do not comply with the fundamental requirements of PSM organizations. In particular, the need to deliver linear services free to air to all audiences, everywhere and at any time. This so-called universality principle lies at the core of the PSM remit.

Since the early 2000’s, therefore, PSM organisations have tried to establish full access to such devices by including a broadcast receiver within them. All these attempts, which used different broadcast technologies – DVB-H, MediaFlo, ISDB-T Seg1, DVB-T2 Lite etc., have been unsuccessful.

The new technology called LTE-based 5G Terrestrial Broadcast (abbreviated to “5G Broadcast” in this report), developed and specified as part of the general mobile communication technology of 3GPP, is a broadcast mode of operation that seems to be a promising candidate for finally allowing all PSM services, both linear and nonlinear, to reach smartphones and tablets.

Many PSM organizations around the world are considering 5G Broadcast. However, before adopting this new technology it is crucial for PSM organisations to understand what the implications of such a decision would be. This refers to the potential and pitfalls of this new audio-visual distribution option in terms of technology, regulatory constraints and business implications. This report sheds some light on frequency planning of 5G Broadcast networks, including sharing and compatibility between 5G Broadcast and DTT in the spectrum range 470 – 694 MHz. The network planning aspects, including studies on coverage and capacity offered by different network topologies for 5G Broadcast are dealt with in a separate EBU Technical Report, TR 063.

Information on the status of 5G standardization, including 5G Broadcast, and deployment opportunities can be found in EBU Technical Report TR 054 “5G for the Distribution of Audiovisual Media content and services”.

The main findings of the studies carried out in this report can be summarised as follows:

1. The use of coordinated yet unused GE06 DTT entries by 5G Broadcast seems to be the most practical way for early introduction of 5G Broadcast in the sub-700 MHz band. The compatibility between 5G Broadcast and DTT in this scenario, including at border areas between neighbouring countries, is manageable with mitigation measures and solutions currently applied to DTT networks. This might include filtering out 5G Broadcast frequencies in the DTT installations surrounding 5G Broadcast sites, when possible and as needed. It might also include implementing additional constraints (e.g. EIRP reduction, polarisation, antenna adjustments) on 5G Broadcast sites, as needed.

2. The 5G Broadcast User Equipment (receiver) will need to have suitable RF characteristics for operation in the interleaved spectrum in the presence of high levels of adjacent DTT signals in some areas.

3. 5G Broadcast signals with bandwidth of 5 or 8[1] MHz can be deployed within the GE06 plan with minimal constraints. The 8 MHz option provides the highest efficiency of spectrum usage.

[1] 8 MHz is not a standardized bandwidth in 3GPP. Specification of a new 8 MHz bandwidth for 5G Broadcast would be needed, taking into account the specifications and requirements defined in ETSI EN 302 296.

4. Trials are needed to verify the conclusions and the assumptions of the studies.

List of Acronyms and Abbreviations

Abbreviation / Acronym	Expansion
3GPP	3rd Generation Partnership Project
ACLR	Adjacent channel leakage ratio
ACS	Adjacent channel selectivity
BNO	Broadcast Network Operator
BS	Base Station
BW	Bandwidth
CAS	Cell Acquisition Subframe
CDF	Cummalative distribution function
CE	Channel estimation
CEPT	Conference of European Post and Telecommunications Administrations
C/I	Commercial Off-The-ShelfCarrier to interferer ratio
C/N	Carrier to noise ratio
CM	Car mounted
CP	Cyclic prefix (mobile term) - equivalent to Guard Interval (broadcast term)
DAB	Digital Audio Broadcasting
DTM	Digital Terrain Model
DTT	Digital Terrestrial Television
DVB	Digital Video Broadcasting
DVB-H	Digital Video Broadcasting — Hand held
DVB-T	Digital Video Broadcasting — First Generation Terrestrial
DVB-T2	Digital Video Broadcasting — Second Generation Terrestrial
EIRP	Equivalent Isotropically Radiated Power
eMBMS	Evolved Multimedia Broadcast Multicast Services
FeMBMS	Further Evolved Multimedia Broadcast Multicast Services
FFT	Free-to-airFast Fourier Transform
GE06	Geneva Agreement 2006
GI	Guard interval
HH	Handheld
HPHT	High-Power High-Tower
ICI	Inter carrier interference
IMT	Intenational Mobile Telecommunication
ISD	Inter site distance
ISDB-T 1 seg	Integrated Services Digital Broadcasting -- Terrestrial for handheld mobile reception
ITU	International Telecommunication Union
LPLT	Low-Power Low-Tower
LTE	Long Term Evolution
LTE-B / MediaFlo	Qualcomm proprietary broadcast system aimed at handheld reception

MER	Multicast Adaptive Bit-RateModulation Error Ratio
MCL	Minimum coupling loss
MCS	Modulation and Coding Scheme
MFN	Multi Frequency Network
MNO	Mobile Network Operator
MPMT	Medium-Power Medium-Tower
OFDM	Orthogonal Frequency-Division Multiplexing
PLP	Physical Layer Pipes
PMCH	Physical Multicast Channel
PO	Portable outdoor
PSM	Public Service Media
QAM	Quadrature amplitude modulation
QPSK	Quadrature phase shift keying
RB	Resource block
RMS	Root mean squared
SDN	Software-Defined Network
SFN	Single Frequency Network
SINR	Signal to interference plus noise ratio
SNR	Signal to noise ratio
TV	Television
UE	User Equipment
WiB	wideband reuse-1 based DTT concept

Contents

Compatibility between 5G Broadcast and other DTT systems in the sub-700 MHz band

EBU Committee	First Issued	Revised	Re-issued
TC	2021		

Keywords: LTE, 5G Broadcast, Digital Terrestrial Television, DTT, coexistence, interference, Digital Dividend, GE06 allocation, Interleaved spectrum, Band segmentation.

1. Introduction

It is understood that 5G Broadcast is a Standalone Downlink system. This makes it similar to existing broadcasting systems (such as DTT) on the RF side, i.e., to cover an area it consists of an omnidirectional or directional transmission from one or more fixed locations. Each 5G Broadcast transmitter uses a determined RF channel with a specified bandwidth and set of characteristics, e.g., transmit power, maximum antenna gain, horizontal and vertical antenna patterns and the height of the antenna above ground level.

A 5G Broadcast network could use High Power High Tower (HPHT) transmitters (like most DTT networks designed for Fixed Reception using rooftop antennas), Medium Power Medium Tower (MPMT, transmitters (like most DAB networks designed for mobile and/or portable reception) or Low Power Low Tower (LPLT) transmitters (like most cellular networks designed for Unicast transmissions for mobile and portable indoor reception).

Furthermore, 5G Broadcast, being based on COFDM, can operate in Single Frequency Network (SFN) mode or in Multi Frequency Network (MFN) mode, much like current DTT systems based on COFDM.

The provisions of the Geneva 2006 Agreement (GE06) apply to the introduction of 5G Broadcast within spectrum currently used for DTT in ITU Region 1 (Europe, Africa, Middle East and Parts of Asia). The Agreement regulates the use of the 470 – 694 MHz band in Region 1 for DVB-T/T2 and includes the frequency plans, the technical elements and criteria to develop and implement the frequency plan and the necessary procedures to modify the plan and to coordinate with neighbouring countries.

The GE06 frequency plan gives administrations rights to use certain frequencies over certain geographical areas for broadcasting services, without specifying exactly which technologies should be used, the so called ‘envelope concept’. This flexibility has been used to facilitate the transition from DVB-T to DVB-T2 in some countries and may also be used for the implementation of 5G Broadcast technologies by some countries while neighbouring countries retain DVB systems.

§ 2 presents the identified scenarios of introduction of 5G Broadcast.

Based on the identified scenarios, §§ 3 & 4 deal with the related co-channel and adjacent channel compatibility issues with existing DTT systems and their possible solutions.

§ 5 provides an analysis of the possible 5G broadcast Band Plans. Conclusions are provided in § 6, and further supporting information is provided in Annexes A to D.

2. Scenarios for introducing 5G Broadcast in the sub-700 MHz band

Three scenarios for how 5G Broadcast may be introduced have been identified and evaluated:

Scenario 1: Use of coordinated GE06 DTT entries by 5G Broadcast.

In this scenario, 5G Broadcast transmissions could make use of existing GE06 allocations under § 5.1.3 of the GE06 Agreement (the so-called envelope concept). In this case they shall neither cause more interference than the original DTT proposals nor claim more protection. This scenario assumes that some of the existing GE06 allocations in one area are unused by DTT and could be used by 5G Broadcast; this might not be the case in all countries. In addition, the availability of unused GE06 entries will be very different from area to area; for example, in urban areas and in areas close to national borders the availability may be more limited.

Scenario 2: Interleaved use in GE06.

5G Broadcast transmissions could be introduced into the band alongside and between existing DTT transmissions, making use of the so-called “white spaces” in the band, where available. These white spaces could correspond to existing, unused allocations in the GE06 Plan, or not. Clearly each of these will have different implications.

Note that in many countries, the “white spaces” between DTT transmissions are already used for PMSE services (primarily radio microphones for programme production). Further, many administrations use non-coordinated low-power DTT in the spaces between GE06 allocations (e.g. for local TV).

Scenario 3: Band segmentation

By restricting DTT to just part of the UHF band, the remaining part of the band could be freed for 5G Broadcast use. Different countries could choose to clear different parts of the band.

From a frequency planning point of view, there could be co-channel and adjacent channel compatibility issues between 5G Broadcast and existing DTT broadcasting systems. These are discussed with possible related solutions in the next sections.

3. Issues and solutions for co-channel compatibility

3.1 Scenario 1: Use of coordinated GE06 DTT entries by 5G Broadcast

The outgoing interference from 5G Broadcast into DTT may not be an issue if the conditions for the use of the DTT entry (envelope concept in GE06) are respected. However, the coverage area for the 5G Broadcast may not be the same as the coverage area of the DTT entry, as coverage will depend on the reception mode (portable or mobile versus fixed) and differences between system parameters and network topologies used for the DTT and 5G Broadcast networks.

With Scenario 1, the availability of spectrum for 5G Broadcast in each country will depend on the level of usage of the planned GE06 entries for DTT in the concerned country. A high level of unused GE06 entries would allow for high availability. Countries may also choose to replace some of their GE06 entries used by existing DTT for 5G Broadcast.

3.2 Scenario 2: Interleaved use of spectrum between GE06 entries

Given the scarcity of clear spectrum, and the fact that none is likely to be made available for a new broadcast application, any new broadcast service would most probably have to be introduced in spectrum already occupied by existing DTT services. In such a case this service would have to;

- Be compatible with existing DTT services -that is, it will cause no material damage to the coverage of the existing DTT and;
- Be compatible with DTT services in neighbouring countries

The impact on existing DTT will depend on the way DTT has been planned in each country. For example, a study done by Arqiva, for the WiB DVB study mission, considered introducing an interleaved service in the UK [1]. This study showed that interleaved channels for WiB, on 48 main broadcasting sites covering 84% of the UK population, could be introduced with minimal impact on existing DTT services subject to the following measures/conditions:

1. A power reduction of 20 dB relative to the DTT (PSB channels) on the same site. This reduced operating power limiting the capacity of the service for a given coverage.
2. Use of horizontal polarization, i.e., similar to the DTT on the same site, but cross-polar with the UK relay stations (generally using vertical polarization).
3. To offset interference, the DTT network would need to be changed from DVB-T to DVB--T2 with use of a more robust system variant, which would then only slightly increase the DTT capacity compared to DVB--T.

These results apply only to the UK and to the case of using only HPHT sites for the new service (in this case WiB). If a LPLT network is used, the impact to existing services is likely to be less that of a HPHT network though not co-siting with the existing DTT network will raise issues with hole punching, see § 4.

The UK example relies on the fact that within the UK broadcast network, HPHT sites are horizontally polarized, and the relay sites (MPMT and LPLT) are vertically polarized. In the case of countries using the same polarization for all DTT sites (for example, France), the impact to existing DTT coverage will be higher than the UK example above, as no polarization discrimination could be considered between the new system and DTT.

In the case of countries that would have unused channels in all or large parts of their territories the impact on co-channel DTT inside the country will be less than the two cases above. However, the impact on co-channel DTT in the neighbouring countries will be the main issue.

The need to protect DTT by restricting operating power, along with levels of interference from existing DTT, mean that coverage for a given data rate from individual interleaved channels will vary and will be lower than existing DTT. Matching DTT coverage would result in much lower data rates (more robust modulation) which vary between channels when compared with existing DTT services. The possible coverage of a new system using interleaved channels can be estimated from a study by Arqiva on WiB.

This showed that for Fixed Reception in the UK scenario:

- In the worst-case channel, the new system would need to operate at -14 dB SINR to cover the same population as DTT from the 48 considered sites.
- In an average channel, the new system would need to operate at -3 dB SINR to match the same coverage above.

- Inversely, in the worst-case channel, the use of a new system with 10 dB SINR would cover 24% of the UK population.
- In an average channel, the use of a new system with 10 dB SINR would cover 46% of the UK population.

For Scenario 2, coordination of new assignments or allotments, using the GE06 procedures, with neighbouring countries would be mandatory.

The main solutions in Scenario 2 for co-channel operation of 5G Broadcast with DTT would be a mixture of the following:

1. Reduction of power on the HPHT sites compared to DTT or using different antenna patterns or polarization. These changes will depend on the existing DTT network topologies and parameters.
2. Selection of robust 5G Broadcast mode to improve coverage with the reduced power above
3. Addition of transmitting sites to increase coverage and improve portable/mobile reception, with appropriate polarization.

The above solutions may also help in coordination with neighbouring countries but overall, this scenario would be very challenging.

3.3 Scenario 3: Band segmentation

If a country can segment the sub-700 MHz band for use by 5G Broadcast, such use would need to co-exist with existing DTT and GE06 assignments/allotments in neighbouring countries.

The issues here are like the issues in Scenario 1 if 5G Broadcast uses an existing coordinated GE06 entry and like those in Scenario 2 if 5G Broadcast is not using an existing coordinated GE06 entry. In this last case, the same solutions as for Scenario 2 apply.

4. Issues and solutions for adjacent-channel compatibility

4.1 General analysis

4.1.1 Scenarios 1 & 2

4.1.1.1 Impact on DTT

For Scenarios 1 and 2, the protection of DTT reception requires adequate measures to solve the hole-punching issue[2,3]. Hole-punching is a problem that broadcasters are used to dealing with; past implementations of different types of system or applications subject to this issue being:

1. The introduction of DVB--H in the UHF band in Italy.
2. Non-co-located DAB or DTT transmitters in several countries

[2] Hole-punching would not be an issue if 5G Broadcast is co-sited with existing DTT and uses the same or similar antenna pattern to DTT.

[3] Also referred to as the ‘near-far-effect’ by the mobile community.

3. The introduction of white space devices in the interleaved spectrum (This is relevant mostly for Scenario 2).

For the protection of existing DTT in the adjacent channels, some or all the following measures would be needed:

- Appropriate site selection, avoiding where possible proximity with existing DTT receiving antennas. Co-siting between DTT and the 5G Broadcast is the preferred option.
- Appropriate design of the transmit power and antenna patterns to minimize impact on DTT reception in the vicinity of the 5G Broadcast site if not co-sited.
- Appropriate filtering of the 5G Broadcast transmitter is required, especially in the non-co-sited low-power-low-tower sites.
- In some cases, the addition of notch filters, typically in the antenna feeder of a DTT reception installation, inside a certain area around the 5G Broadcast site.

  The notch filter should be specifically designed for the used 5G Broadcast frequency. This notch filter helps avoiding adjacent channel interference and overloading of DTT active receiving installation. In the experience of DVB--H in Italy, on average, 1 to 2 DTT receiving installations per DVB-H site required filtering (using 1 or 2 notch filters). In the experience of introducing LTE800 in France, on average 4 to 5 DTT receiving installations required filtering (one low-pass filter) per LTE800 base station. The median interference distance between the interfering LTE800 base station and the fixed rooftop DTT reception installation was 572 m and the maximum interference distance reported was about 6.5 km, with 99% of cases of interference occurring within 2.1 km of the LTE800 base station [2].

4.1.1.2 Impact on 5G Broadcast Receivers

For the protection of the 5G Broadcast receivers, the main issues and possible solutions are:

- The received signal being scattered inside the band used by DTT, with possible large differences in the received signal levels, the main issue would be not respecting the required protection ratio at the receiver input (see § 4.2 on the Adjacent Channel Selectivity of the 5G Broadcast receiver).
- The main solutions are co-siting when possible or adding 5G Broadcast transmitters to increase the wanted signal level.
- To avoid interference into a 5G Broadcast handheld receiver, high level DTT signals could be removed using notch filters. However, for a hand-held receiver with an internal antenna, these filters would need to be integrated into the receiver. In addition, because the interference could be on any DTT channel, they would need to be frequency agile, controlled by software in the receiver. Whilst this would be technically feasible, it is likely to be impractical.

4.1.2 Scenario 3

For Scenario 3, the protection of broadcasting from 5G Broadcast adjacent channel interference is expected to be similar to that associated with the introduction of 800 MHz LTE. The mitigation techniques studied in CEPT Report 30 [3] and implemented according to the national experiences described in Report ITU-R BT.2301 [2], may be relevant for solving any adjacent channel compatibility issues that occur.

4.1.2.1 Protection of DTT

For the protection of existing DTT in the adjacent channels, some of or all the following measures would be needed:

- Additional Out-of-Band filtering of the 5G Broadcast transmitter, especially in the non-co-sited low-power-low-tower sites using channels adjacent to DTT.
- In some cases, appropriate filtering of the DTT reception installations inside a certain area around the 5G Broadcast site would be needed [2].

4.1.2.2 Protection of 5G Broadcast

For the protection of the 5G Broadcast receivers, the main issues and possible solutions are:

- The received signals from the 5G Broadcast sites operating adjacent to DTT services may be subject to adjacent channel interference due to the receiver having a poor adjacent-channel selectivity protection ratio or to overloading. This risk is likely to be localized around the concerned DTT transmitter.
- The main solution for possible 5G Broadcast overloading is adding suitable filtering inside the 5G Broadcast receiver. In this case of Scenario 3, this filter may filter-out the whole DTT segment. However, the filter would need to be different if the segment is chosen differently between different countries.
- Adding additional 5G Broadcast sites to improve the signal-to-interference ratio could also be useful in some cases.

Another potential issue not always or not sufficiently considered, is intermodulation generated inside the receiver in the presence of multiple received signals. Although this has not been a major issue in real networks so far, it may become more important with the increased number of signals present at the receiver input.

4.2 Specific issue of the 5G Broadcast receiver adjacent channel selectivity (ACS)

The 5G Broadcast receiver adjacent channel selectivity (ACS), the ability of the receiver to reject signals of services operating in adjacent channels, is important in determining whether 5G Broadcast services can be operated in the same spectrum as existing DTT services in the same area.

Using a minimum coupling loss (MCL) approach the signal at the 5G Broadcast receiver has been assessed from both an 5G Broadcast transmitter and a DTT transmitter operating in an adjacent channel. The 5G Broadcast receiver was located at distances ranging between 100 - 9000 m from the interferer.

Calculations over a range of distances are required as the point of minimum coupling loss will depend on the vertical radiation pattern of the transmitting antenna and the difference in height between the transmitting antenna and the 5G Broadcast receiver. As this is a generic calculation with no information on terrain or clutter, a free space, ‘flat earth’, approach is used for calculating the path loss. As such, the levels of interference predicted will be higher than those typically encountered in a real environment; this is a ‘worst case’ analysis.

Whilst such an approach may not be entirely representative of actual signal levels ‘on the ground’ it provides information on the upper bound of interference levels.

4.2.1 5G Broadcast Parameters

Using an MCL approach, the receiver parameters in Table 1 and the 5G Broadcast Base Station (BS) antenna characteristics and maximum EIRP provided in Table 2, the interfering signal level at a 5G Broadcast receiver from a BS operating on the adjacent block can be determined.

4.2.1.1 5G Broadcast receiver Parameters

Table 1: receiver Parameters for MCL calculation of interference

Parameters	Value	Reference
Receiver bandwidth (nominal for 5 MHz channel BW)	4.5 MHz	
UE receiver reference sensitivity	-98.5 dBm/5 MHz	ETSI TS 136.101 table 7.3.1-1 Reference Sensitivity Band 28
Protection criteria (INR – Interference to Noise Ratio)	-6 dB	1 dB desensitization
Maximum received interference	-104.5 dBm	
UE antenna pattern	Omnidirectional	CEPT Report 53 Table 59
UE antenna gain[4]	-5.86 dBi	
UE antenna height	1.5 m a.g.l.	CEPT Report 53 Table 59
UE receiver Adjacent Channel Selectivity (ACS)	33 dB	ETSI TS 136.101 table 7.5.1-1 Adjacent channel selectivity

The figure of interest is the maximum received interference -104.5 dBm for a receiver. In a balanced system[5], one where the burden of protection from interference is placed equally on the interferer and victim, an allowance should be made for both the receiver ACS and the transmitter adjacent channel leakage ratio (ACLR).

If it is assumed that ACLR = ACS, then in the absence of any other sources of interference, the maximum power an interfering transmitter can put into a 5G Broadcast receiver to limit desensitization to 1 dB is -104.5 dBm – 3 dB (Allowance for ACLR) = -107.5 dBm

If the receiver ACS does not equal the transmitter ACLR, interference will be dominated by whichever is lower. Consequently, because of the poor ACS of the 5G Broadcast UE (33 dB) relative to the 5G Broadcast transmitter ACLR (45 dB[6]) or DTT transmitter ACLR (64 dB[7]), system performance is dominated by the 5G Broadcast receiver ACS and no allowance needs to be made for either the DTT or 5G Broadcast transmitter ACLR.

4.2.1.2 5G Broadcast BS to receiver Geometry

As the receiver is below the height of the BS transmit antenna, the signal level at the receiver will vary with distance and change in the angle between the receiver and the BS antenna as shown in Figure 1. To carry out this calculation knowledge of the 5G Broadcast antenna height and VRP is required, Table 2 & Figure 2.

[4] -5.86 dBi is -8 dBd.

[5] CEPT Report 30 [3], Section 6.4.1, page 21.

[6] ETSI 36.104 [4], section 6.6.2 Adjacent Channel Leakage Power Ratio (ACLR).

[7] DTT critical mask.

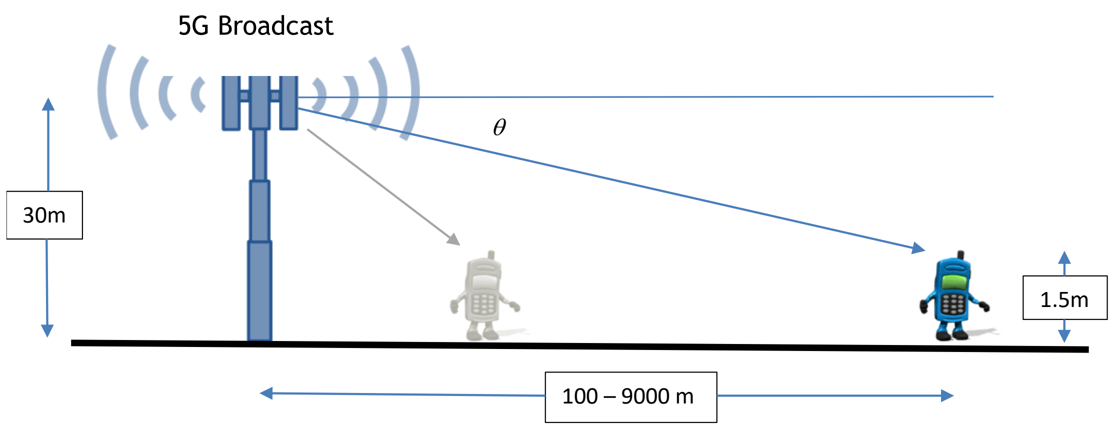


Figure 1: 5G Broadcast BS to receiver geometry

4.2.1.3 5G Broadcast Base Station Antenna

Table 2: Parameters for MCL calculation of BS to 5G Broadcast receiver

BS Antenna	
BS antenna pattern	ITU-R F.1336 [5] with k=0.7
BS antenna gain on horizon (down tilt)	-3 dB (nominal 6° beam tilt)[8]
BS antenna height	30 m a.g.l.
BS EIRP	64 dBm[9]

It should be noted that the ITU-R F.1336 [5] pattern represents an envelope which will not be exceeded by typical cellular antenna deployments.

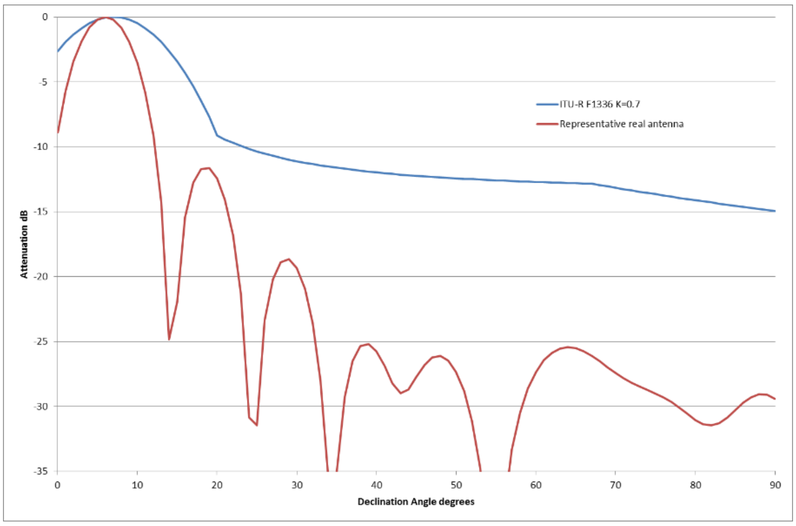


Figure 2: ITU-R F.1336 5G Broadcast Antenna Vertical Radiation Pattern below the horizon K=0.7

[8] Nominal 6° beam tilt based on value used in CEPT Report 53 [6], Annex 6, Table 66.

[9] CEPT Report 53 [6], page 29 Table 30 'BS in-block power limit'.

4.2.2 DTT Reference Transmitter Configuration

Using an MCL approach, the DTT reference parameters (in this section) and the receiver parameters in Table 4.2-1 the interfering signal level at a 5G Broadcast receiver from a DTT station operating on channel 56 can be determined.

4.2.2.1 Generic DTT station configuration

ITU-R Report BT.2383-3 [7] provides generic reference broadcast transmitter configurations for use in compatibility studies.

- **High power**
  - ERP: 200 kW
  - Effective antenna height: 300 m
  - Antenna height a.g.l.: 200 m
  - Antenna pattern:
    - Horizontal: Omnidirectional
    - Vertical antenna aperture: based on 24λ aperture with 1° beam tilt
- **Medium power**
  - ERP: 5 kW
  - Effective antenna height: 150 m
  - Antenna height a.g.l.: 75 m
  - Antenna pattern:
    - Horizontal: Omnidirectional
    - Vertical: based on 16λ aperture with 1.6° beam tilt
- **Low power**
  - ERP: 250 W
  - Effective antenna height: 75 m
  - Antenna height a.g.l.: 30 m
  - Antenna pattern:
    - Horizontal: Omnidirectional
    - Vertical: based on 8λ aperture with 3° beam tilt

4.2.2.2 Antenna Height

Recommendation ITU-R P.1546-4 [8] provides information on how to interpolate between antenna height above ground level and effective antenna height where no terrain information is available. When propagation predictions are being made, the height h_1 (m) of the antenna above ground is calculated according to path length, d (km), as follows:

$$h_1 = h_a \quad \text{m} \qquad \text{for} \qquad d \leq 3 \text{ km}$$

$$h_1 = h_a + (h_{eff} - h_a)(d-3)/12 \quad \text{m} \qquad \text{for} \qquad 3 \text{ km} < d < 15 \text{ km}$$

Where:

h_a is the antenna height above ground level.

h_{eff} is the effective antenna height.

4.2.2.3 Vertical radiation patterns

The field strength in the vicinity of the broadcast transmitting station is a function of the vertical radiation pattern of the transmitting antenna. The equation below is an approximation, provided in ITU-R Report BT.2383-3 [7], to be used for sharing studies.

$$E(\theta) = abs\left(\frac{Sin\Psi}{\Psi}\right)$$

Where;

$$\Psi = \pi\, ASin(\theta - \beta)$$

and;

A = the antenna vertical aperture in wavelengths.

β = the beam tilt below the horizontal.

To allow for null fill the value of $E(\theta)$ should not go below the value shown in Table 3.

Table 3: Null fill values to be applied to vertical radiation patterns

	Limit on $E(\theta)$
First null	0.15
Second null	0.1

For the third null and at all angles of θ beyond the third null the value of $E(\theta)$ should not fall below 0.05, see Figure 3.

$E(\theta)$ given above are linear values, to convert them to reduction values in dB the following equation is used:

$$Reduction\ in\ dB = 20 * log10\{E(\theta)\}$$

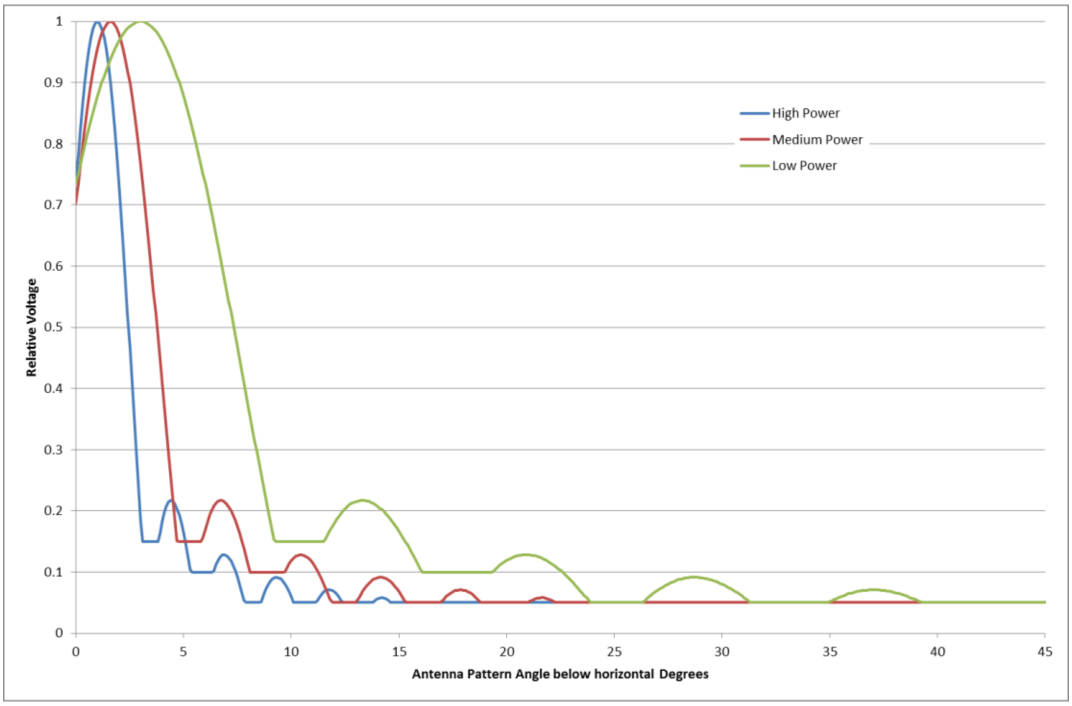


Figure 3: Vertical pattern of DTT reference transmitters

4.2.2.4 DTT to UE Geometry

With a height difference between the DTT antenna and 5G Broadcast antenna the calculation is a little more complicated. With changing distance, the elevation angle between the 5G Broadcast and DTT antennas changes, see Figure 4.2-4. This alters the vertical pattern discrimination meaning the point of minimum coupling loss (maximum interference) may occur when there is some distance between the 5G Broadcast receiver receiver and the DTT transmitter.

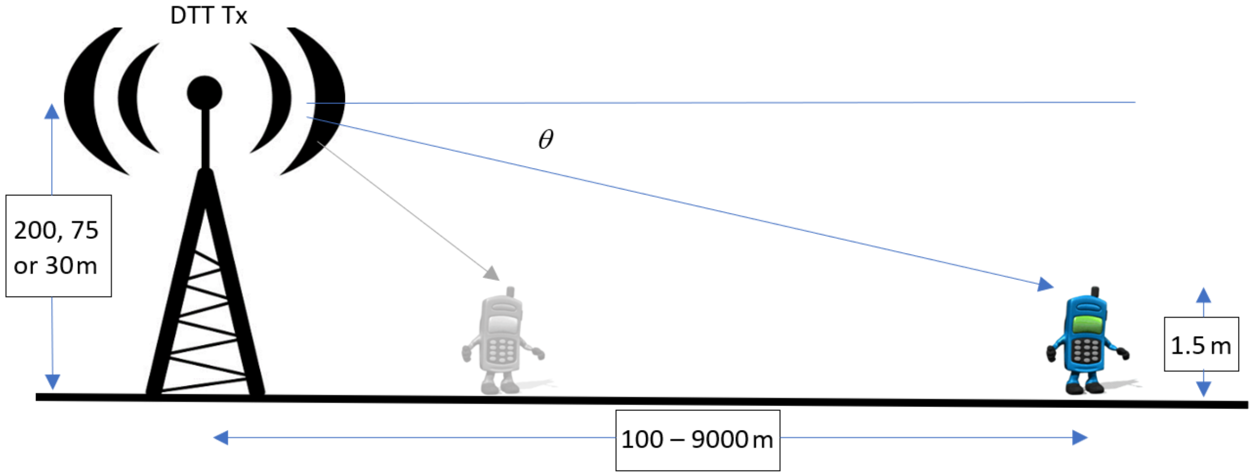


Figure 4: DTT to UE geometry

4.2.2.5 Depolarisation

5G Broadcast receiver systems have no polarisation discrimination so for compatibility calculations both signals are assumed to be co-polar.

4.2.3 DTT compatibility with 5G Broadcast downlink

The interfering signal level at the 5G Broadcast UE receiver (IntSig5G-Broadcast$_{RX}$) due to the DTT transmitter is given by:

DTTIntSig5G-Broadcast$_{RX}$ = DTT$_{EIRP}$ + DTT$_{pattern(\theta)}$ - PathLoss$_{(d,Freq)}$ - 5G-BroadcastUE$_{fiter}$ + 5G-Broadcast UE$_{gain}$ - Bodyloss dBm

The interfering signal level at the 5G-Broadcast UE receiver (IntSig5G-Broadcast$_{RX}$) due to the 5G-Broadcast BS transmitter is given by:

BSIntSig5G-Broadcast$_{RX}$ = 5G-BroadcastBS$_{EIRP}$ + 5G-BroadcastBS$_{pattern(\theta)}$ - PathLoss$_{(d,Freq)}$ - 5G-Broadcast UE$_{filter}$ + 5G-BroadcastUE$_{gain}$ - Bodyloss dBm

Where;

DTTIntSig5G-Broadcast$_{RX}$	Interfering signal level at the 5G Broadcast UE receiver due to the DTT transmitter.
BSIntSig5G-Broadcast$_{RX}$	Interfering signal level at the 5G Broadcast UE receiver due to the 5G Broadcast Base station.
DTT$_{EIRP}$	Maximum Radiated power of the DTT transmitter (dBm).
DTT$_{pattern(\theta)}$	Protection offered by the DTT antenna vertical radiation pattern (-ve value dB).

$5G\text{-}BroadcastBS_{EIRP}$	Maximum Effective Radiated power of the 5G Broadcast BS transmitter (dBm).
$5G\text{-}BroadcastBS_{pattern(\theta)}$	Protection offered by the 5G Broadcast antenna vertical radiation pattern -(ve value dB).
$5G\text{-}BroadcastUE_{filter}$	Protection offered by the 5G Broadcast UE filter (33 dB).
PathLoss	Free space path loss $20*LOG_{10}(d) + 20*LOG_{10}(Freq) - 27.56$ (dB)
$5G\text{-}BroadcastUE_{gain}$	Gain of the 5G Broadcast receiver antenna including feeder losses (typically -3 dB).
Bodyloss	dB
θ	Declination angle DTT or 5G BS to 5G Broadcast UE.
d	Slant distance between DTT or 5G BS and 5G Broadcast UE antenna (metres).
Freq	5G Broadcast 5 MHz block centre frequency (MHz).

4.2.4 Results

The calculated signal from a 5G Broadcast BS and from a DTT transmitter at the 5G Broadcast receiver receiver for the three DTT station reference configurations are shown in Figure 5[10].

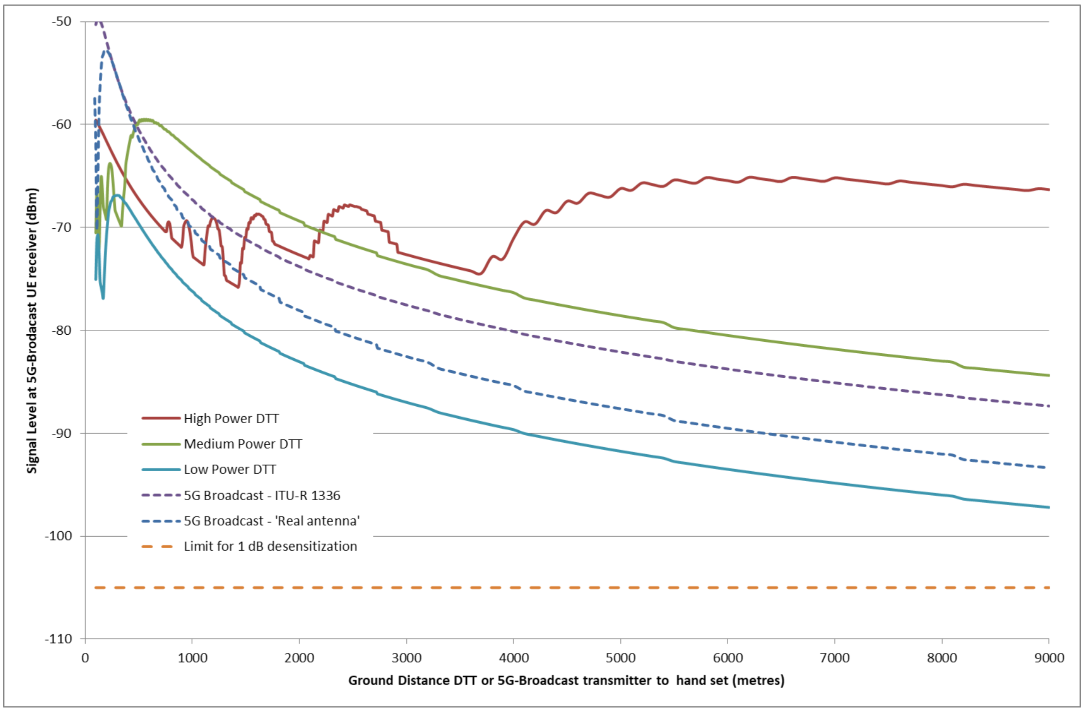


Figure 5a: DTT and adjacent block 5G Broadcast signal level at 5G Broadcast UE receiver: Free space loss

[10] The irregularities in the plotted curves are a consequence of discrete sampling of the VRP and the use of the "vlookup" function in Excel.

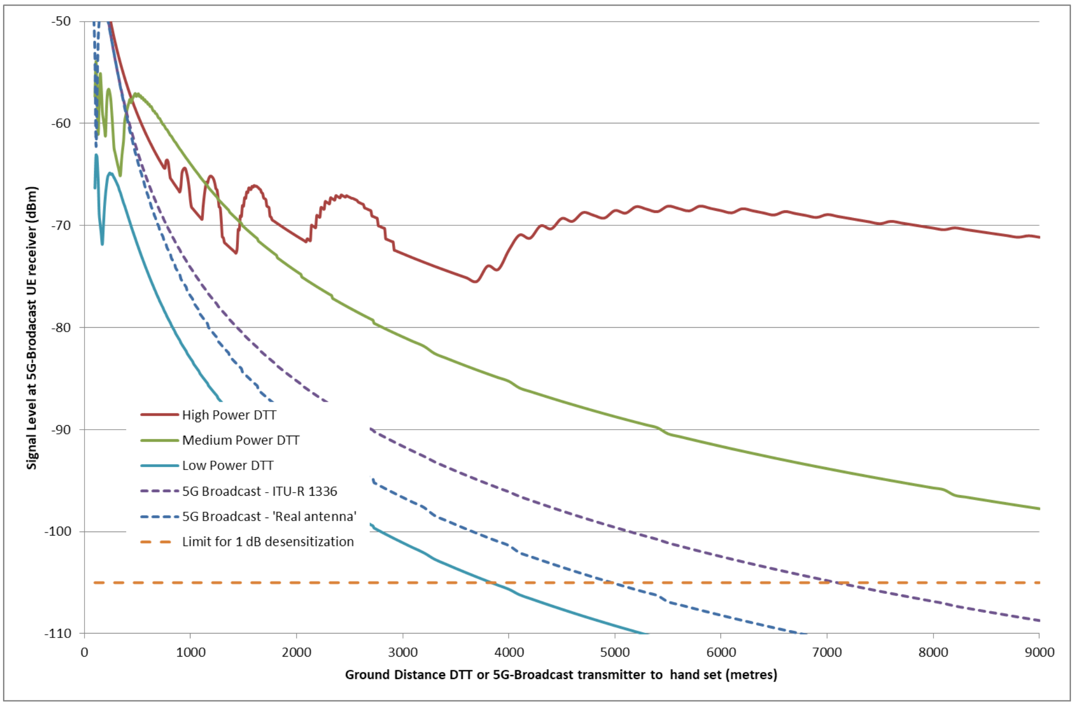


Figure 5b: DTT and adjacent block 5G Broadcast signal level at 5G Broadcast UE receiver: Hata open

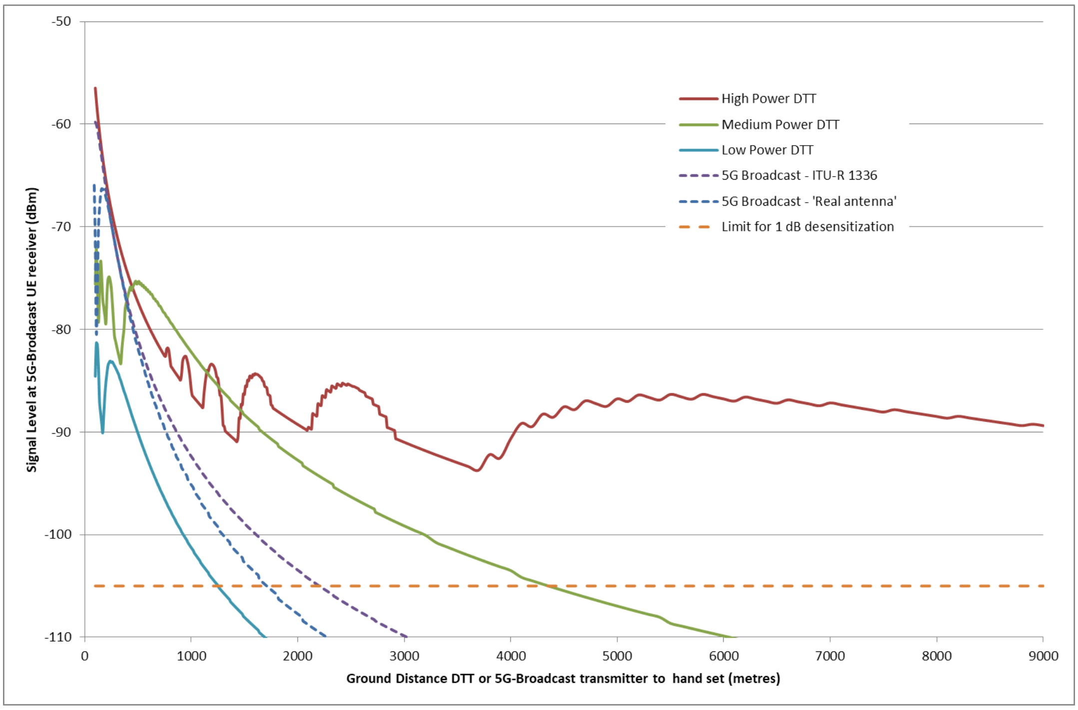


Figure 5c: DTT and adjacent block 5G Broadcast signal level at 5G Broadcast UE receiver: Hata suburban

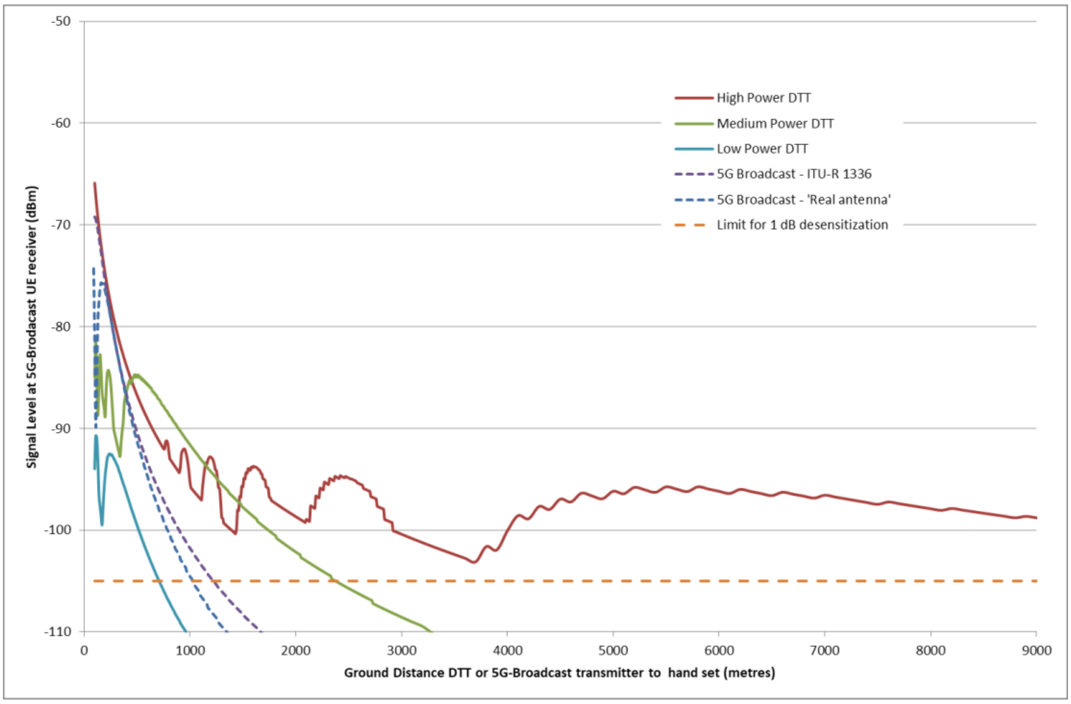


Figure 5d: DTT and adjacent block 5G Broadcast signal level at 5G Broadcast UE receiver: Hata urban

4.2.5 Conclusion

The poor specified ACS of the receiver (3GPP) significantly limits performance in the presence of strong adjacent channel signals.

To mitigate against this the 5G Broadcast service would need to be transmitted from the same site as the interfering DTT service at a power level equal to or greater than that of the service DTT minus the receiver ACS plus the wanted carrier to noise ratio.

To avoid the need to transmit from the DTT site and to approach noise limited performance the ACS of the receiver would need to be improved relative to the 3GPP specification. Investigation is ongoing on real cases around DTT channel 60 and LTE800 first downlink block.

5. 5G Broadcast Band plans assessment

This section shows an evaluation of several band plans considered in studies on 5G Broadcast introduction in the sub-700 MHz band.

§ 5.1 shows a quantitative evaluation. It explains the methodology and assumptions used for this evaluation, and a summary of the results.

§ 5.2 deals with GE06 envelope concept and its applicability to signals with bandwidth greater than 8 MHz.

§ 5.3 provides further considerations about the use of 5G Broadcast with 10 MHz bandwidth in an 8 MHz channel raster.

§ 5.4 provides conclusions and recommended further studies.

Detailed and supporting material are provided in Annexes:

> **Annex A:** Measurement of adjacent and overlapping channels Protection ratios.

Annex B: Detailed calculation results.

Annex C: Example of calculation of power reduction on a real case.

5.1 Quantitative evaluation

5.1.1 Methodology and assumptions

The evaluation is based on the following methodology and assumptions:

1. It considers a cross border situation, where country A continues using the sub-700 MHz band for DTT and country B replacing some of its existing or planned DTT transmissions with 5G Broadcast.
2. It starts from a situation where the channels (in the current 8 MHz channel raster) are allocated to a regular broadcasting network, assumed to be similar on both sides of the border, considering the principle of equitable access.
3. The initial coordinated frequency plan is assumed to be based on a frequency reuse 3 on both sides of the border.

(See Figure 6 that illustrates the three previous points – Country A is north to the border which is represented with the thick black line).

4. Every cell in the network is assumed to be served by a site or multiple sites forming an SFN. The required ERP to serve the cell with a DTT transmitter on each of the allocated channels of the cell is considered as the reference ERP.
5. Two representative Border cells in Country B (the circled Green and Blue cells in Figure 6) are analysed. The Green cell has three allocated 8 MHz channels (CH2, CH5 and CH8). The Blue cell has also three allocated 8 MHz channels (CH3, CH6 and CH9. We also consider that it might be able to use CH2, CH5 and CH8 in SFN with the Green cell in the same country B as these channels are not used in immediate adjacent cells in the country A). Taking each cell respectively and all the band plan options, and the following steps are made:
    a. Identify those channels in each band plan that could use the allocated or useable channels in the analysed cell. These are coloured in Green for the green cell in Figure 7 and in Blue in for the blue cell in Figure 8. The band plan channels that overlap by more than 2 MHz any of the channels allocated in an immediately adjacent cell of country A are excluded. The measurement and calculation results will show later that this selection criterion is reasonable, as overlaps even smaller than 2 MHz were shown to be impractical, which excludes any possible use of channels with greater overlaps.
    b. A calculation is made of the required power reduction of each retained channel, to recover the same level of protection of DTT (co-channel or adjacent channel) in the neighbouring country. The required power reduction is the difference between the new protection ratio (between the candidate 5G Broadcast channel in the analysed cell and the concerned DTT channel in the neighbouring cell) and the old protection ratio (between the initially planned DTT channel in the analysed cell and the concerned DTT channel in the neighbouring cell). The protection ratios for the adjacent and overlapping channels are determined by measurements. (*See Annex A*). (*See Annex C for an example of calculation of power reduction on a real case*)

c. The total bandwidth (sum) of the identified channels and the associated power reduction are noted for each band plan option and for each of the two analysed cells.

The summary of the results is shown in § 5.1.2.

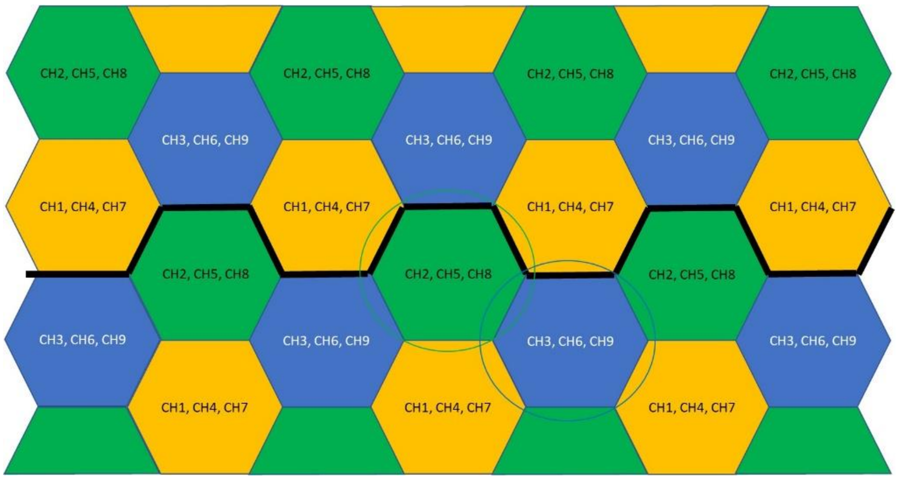


Figure 6: Regular network with reuse 3, showing a hypothetical national border line (bold black line)

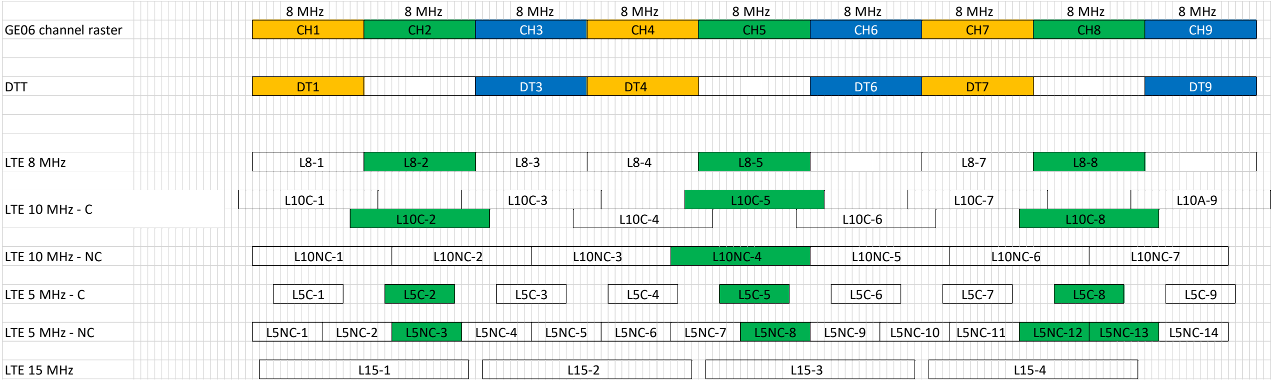


Figure 7: Retained channels in each considered band plan, for the Green circled border cell in Figure 6

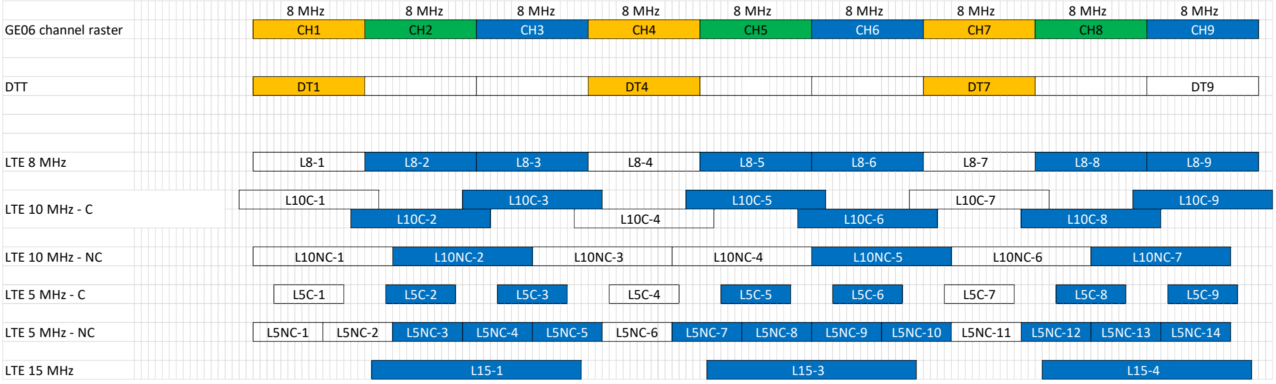


Figure 8: Retained channels in each considered band plan, for the Blue circled border cell in Figure 6

5.1.2 Summary of the quantitative evaluation

The following two tables show the available total bandwidth and the required power reduction relative to the planned DTT channel(s), for each band plan options and for the two analysed cells.

Table 4: Summary of the evaluation of 5G band plans for the Green circled border cell in Figure 6

Green Border Cell	Potential available total bandwidth and power reduction relative to planned DTT	
	Bandwidth (MHz)	Power reduction (dB)
8 MHz bandwidth centred on 8 MHz channel raster	24	1
10 MHz bandwidth centred on 8 MHz channel raster	30	26.1
10 MHz bandwidth Not-centred on 8 MHz channel raster	10	42.6
5 MHz bandwidth centred on 8 MHz channel raster	15	1
5 MHz bandwidth Not-centred on 8 MHz channel raster	10	1
	10	32
15 MHz bandwidth centred on the middle point between two 8 MHz	0	

Table 5: Summary evaluation results of 5G band plans for the Blue circled border cell in Figure 6

Blue Border Cell	Potential available bandwidth and power reduction relative to planned DTT	
	Bandwidth (MHz)	Power reduction (dB)
8 MHz bandwidth centred on 8 MHz channel raster	48	1
10 MHz bandwidth centred on 8 MHz channel raster	60	26.1
10 MHz bandwidth Not-centred on 8 MHz channel raster	20	1
	10	42.6
5 MHz bandwidth centred on 8 MHz channel raster	30	1
5 MHz bandwidth Not-centred on 8 MHz channel raster	10	1
	10	32
	10	44
15 MHz bandwidth centred on the middle point between two available 8 MHz channels	45	1

These summary results show that:

1. Using centred 8 MHz 5G Broadcast channels allows for the highest bandwidth with only 1 dB power reduction (see Note under detailed calculation table in Annex B for explanation).

2. Using centred 5 MHz 5G Broadcast channels with only 1 dB power reduction offers capacity but 38% less than the centred 8 MHz option.

3. Using Not-centred 5 MHz 5G Broadcast channels also offers some, but lower, capacity with only 1 dB power reduction.

4. The use of 15 MHz 5G Broadcast channels depends on the existing DTT plan. When contiguous 8 MHz channels are available, this would offer significant capacity, with only 1 dB power reduction. However, the position of the 15 MHz channels may need to be flexible (not fixed on a predefined raster) to make use of every contiguous pair of 8 MHz channels that is available in a given area.

5. In some cases (border cell with only one immediately neighbouring cross border cell), using Not-centred 10 MHz 5G Broadcast channels provides some capacity with only 1 dB power reduction.

6. In most cases, with 10 MHz 5G Broadcast channels, a severe power reduction would be required (between 26 and 44 dB) to maintain the same level of protection of DTT channels in the neighbouring cross border cells.

The detailed calculation and results are provided in Annex B.

5.2 The GE06 envelope concept

The "envelope concept" has been introduced in the GE06 agreement to allow the use of a digital plan entry by another broadcasting technology than DVB-T or even by a technology for other services. The envelope concept is described in the agreement as follows (Article 5, clause 5.1.3 of the GE06 Final Acts [9]):

"5.1.3 A digital entry in the Plan may also be notified with characteristics different from those appearing in the Plan, for transmissions in the broadcasting service or in *other primary terrestrial services* operating in conformity with the *Radio Regulations*, provided that the peak power density in any 4 kHz of the above-mentioned notified assignments shall not exceed the spectral power density in the same 4 kHz of the digital entry in the Plan. Such use shall not claim more protection than that afforded to the above-mentioned digital entry."

Figure 9 illustrates this concept (extract from EBU Tech Review 308 - OVERVIEW OF THE SECOND SESSION (RRC-06) – October 2006 [10]

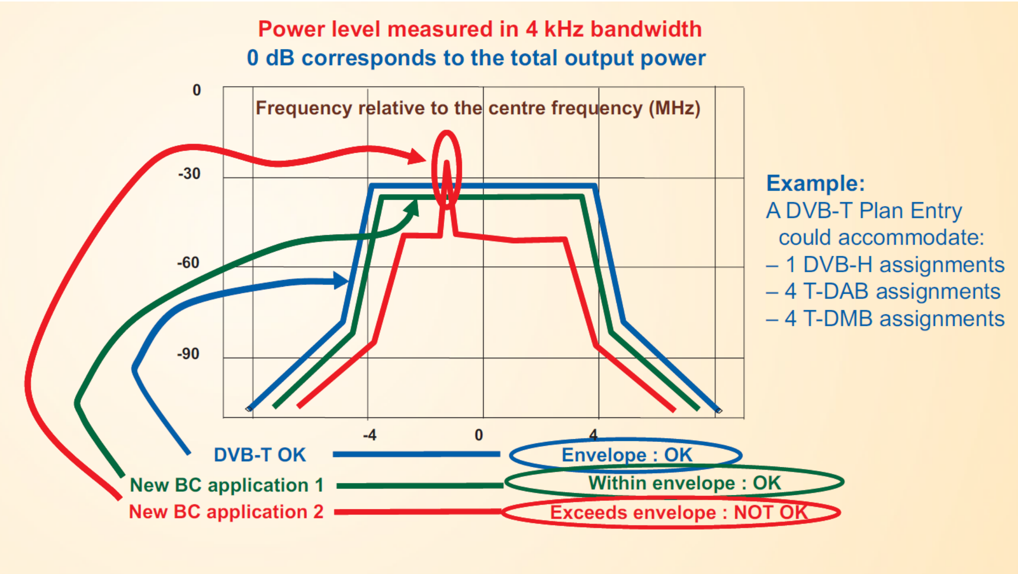


Figure 9: The GE06 "envelope concept"

Signals with bandwidths of more than 8 MHz can comply with the envelope concept constraint only if the whole signal power is reduced enough to meet the condition of the peak power density in any 4 kHz. This is likely to result in a considerable reduction of the maximum transmit power of this signal compared to the original plan entry.

Section 3.6 of Chapter 3 to Annex 2 of the GE06 agreement [12] "Spectrum Mask" gives the conditions under which the Plan may be modified (e.g., to accommodate another service). It says that "a spectrum mask with a performance at least equivalent to that of the non-critical mask for both T-DAB and DVB-T shall be used."

The DVB-T mask is given in [12] section 3.6.2 (Figure 3-3 and Table 3-11, reproduced below under Figure 5.3-2 and Table 5.3-1). All numbers are relative to the total output power. At any frequency, radiated power is assessed in a 4 kHz bandwidth. Full power is allowed out to ±3.9 MHz, with a reduction in power of 40.2 dB by ±4.2 MHz. By ±6 MHz, power must be 52.2 dB down (linear interpolation in dB applies).

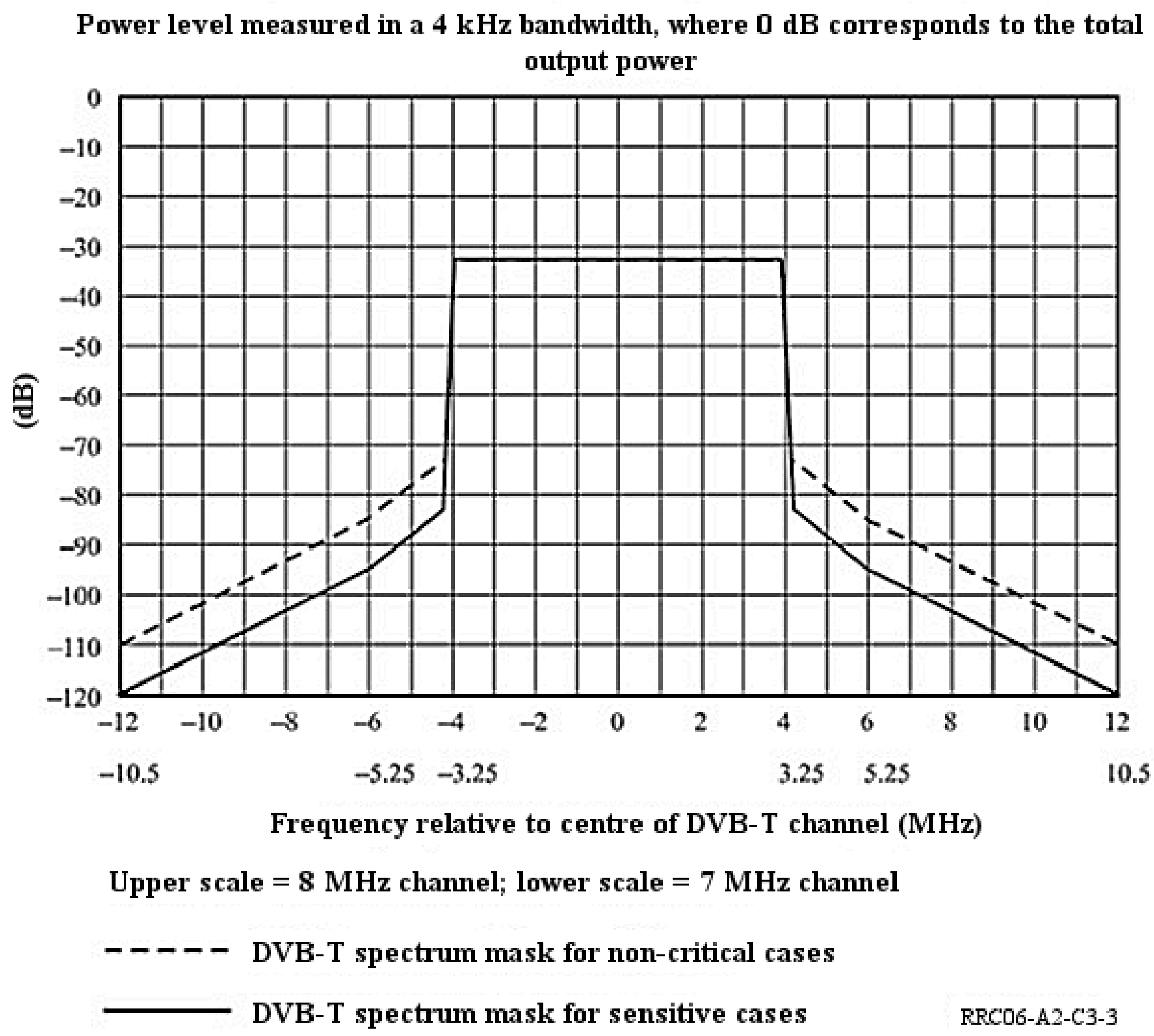


Figure 10: Symmetrical spectrum masks for non-critical and sensitive cases
(reproducing Figure 3-3 of section 3.6.2 of Chapter 3 to Annex 2 of the GE06 agreement)

Table 6: Symmetrical spectrum masks for non-critical and sensitive cases
(reproducing Table 3-11 of section 3.6.2 of Chapter 3 to Annex 2 of the GE06 agreement)

Breakpoints					
8 MHz channels			7 MHz channels		
	Non-critical cases	Sensitive cases		Non-critical cases	Sensitive cases
Relative frequency (MHz)	Relative level (dB)	Relative level (dB)	Relative frequency (MHz)	Relative level (dB)	Relative level (dB)
-12	-110	-120	-10.5	-110	-120
-6	-85	-95	-5.25	-85	-95
-4.2	-73	-83	-3.7	-73	-83
-3.9	-32.8	-32.8	-3.35	-32.8	-32.8
+3.9	-32.8	-32.8	+3.35	-32.8	-32.8
+4.2	-73	-83	+3.7	-73	-83
+6	-85	-95	+5.25	-85	-95
+12	-110	-120	+10.5	-110	-120

Based on the above, for a 5G Broadcast signal with 9 MHz active bandwidth (10 MHz nominal), the power in 4 kHz located at ± 4.5 MHz from the channel centre should be more than 40 dB below the power in the 4 kHz located in the centre of the channel. This would require a reduction of the whole 5G Broadcast 10 MHz signal by more than 40 dB to fit in the “envelope”.

For a 5G Broadcast signal with 15 MHz bandwidth, the constraint of the GE06 envelope would prevent its use unless coordination with neighbouring countries is made successfully.

5.3 Further considerations about the use of 5G Broadcast with 10 MHz bandwidth in an 8 MHz channel raster

The 5G Broadcast system is based on the LTE standard. This latter utilises 90% of available bandwidth, i.e., the active part of a 10 MHz 5G Broadcast block having fifty 180 kHz wide active Resource blocks (RB) would occupy 9 MHz of spectrum.

Option 1: 5G Broadcast 10 MHz block centred on DTT 8 MHz channel
(see line LTE 10 MHz - C in Figure 8)

A 5G Broadcast 10 MHz block will overlap each adjacent 8 MHz channel by 1 MHz, though as a 5G Broadcast 10 MHz channel only occupies 9 MHz, and a DTT 8 MHz channel only occupies 7.61 MHz if using DVB-T (expanded to 7.77 MHz if using DVB-T2 extended mode), the active overlap is only 0.305 MHz (0.385 MHz with DVB-T2).

The overlap will result in interference between both adjacent services DTT and 5G Broadcast.

As shown in the quantitative evaluation in § 5.1, the 0.305 MHz (0.385 MHz with DVB-T2) overlap (2 to 3 resource blocks) will impact the adjacent DTT service in neighbouring cells. A 5G Broadcast service that overlaps the adjacent DTT service will have a protection ratio that is higher than that of adjacent DTT service (but will also be impacted by DTT, with the 2-3 overlapping resource blocks (RB) subject to interference).

If two 5G Broadcast 10 MHz blocks operate adjacent to each other there will be a 1 MHz overlap of each service. This effectively means that of the 50 active blocks, where an overlap occurs, 6 RB will be impacted, i.e., potentially 12 RB or 24% of available bandwidth if both sides of a 10 MHz 5G Broadcast block are overlapped.

Option 2: 5G Broadcast 10 MHz block on a 10 MHz raster starting at 470 MHz
(see Line LTE 10 MHz – NC in Figure 8)

Four 10 MHz 5G Broadcast blocks will overlap five 8 MHz DTT channels, the pattern repeating every 40 MHz.

The first and fourth 10 MHz 5G Broadcast block will overlap the upper adjacent DTT channel (the second DTT channel) by 2 MHz of which 1.305 MHz for DVB-T (1.385 MHz with DVB-T2) will be active (around 8 Resource Blocks or 16% of active bandwidth). The impact on the adjacent DTT service of the 10 MHz 5G Broadcast block will be significantly higher than that caused by an 8 MHz DTT channel (see § 5.1).

The second 10 MHz 5G Broadcast block overlaps the second and third frequency DTT channels by 6 MHz and 4 MHz respectively. This is effectively co-channel interference.

The third 10 MHz 5G Broadcast block overlaps the third and fourth DTT channels by 4 MHz and 6 MHz respectively. This is effectively co-channel interference.

5.4 Summary on band plans

Based on the foregoing, it can be concluded that the 5G Broadcast signals with bandwidth of 5 or 8 MHz can be deployed within the GE06 plan with minimal constraints. An 8 MHz option would provide the highest efficiency of available spectrum usage.

At the time of writing, 8 MHz is not a standardized bandwidth in 3GPP. Specification of a new 8 MHz bandwidth for 5G Broadcast would be needed, taking into account the specifications and requirements defined in ETSI EN 302 296.

The use of the 10 MHz bandwidth in the sub-700 MHz band is subject to several major constraints:

- power reduction to protect DTT in the adjacent channels,
- non-compliance with the GE06 provisions, hence required case-by-case coordination with neighbouring countries, and
- interference into the 5G Broadcast system itself from adjacent channel interference from DTT.

The use of the 15 MHz bandwidth is subject to several even more significant constraints:

- availability of two contiguous 8 MHz channels in any given area is generally very limited. A study made on a border region between France and Germany (see Annex 4) shows that availability of pairs of contiguous DTT channels for a possible use by a 15 MHz LTE channel for 5G broadcast is constrained both by frequency and geography constraints.
- the position of the 15 MHz channels may need to be flexible (not fixed on a predefined raster) to make use of every contiguous pair of 8 MHz channels that is available.
- non-compliance with the GE06 provisions, hence required case-by-case coordination with neighbouring countries.

6. Conclusions

Three scenarios were considered for possible introduction of 5G Broadcast in the UHF band alongside existing DTT services:

Scenario 1: Use of coordinated GE06 DTT entries by 5G Broadcast.

Scenario 2: Interleaved use in GE06.

Scenario 3: Band segmentation

The studies concluded that:

1. Scenario 1 (Use of coordinated GE06 DTT entries by 5G Broadcast) seems to be the most practical for early introduction of 5G Broadcast in the sub-700 MHz band. The compatibility between 5G Broadcast and DTT in this scenario, including at border areas between neighbouring countries, is manageable with the same mitigation measures and solutions currently applied to DTT networks.
2. The ACS of the 5G Broadcast User Equipment (receiver) would need significant improvement from the basic ACS specified in the LTE standard, for operation near DTT stations.
3. 5G Broadcast signals with bandwidth of 5 or 8 MHz can be deployed within the GE06 plan with minimal constraints. An 8 MHz option would provide the highest efficiency of spectrum usage.

7. References

[1] Arqiva study for DVB-WiB study mission – September 2017

[2] Report ITU--R BT.2301--2. National field reports on the introduction of IMT in the bands with co-primary allocation to the broadcasting and the mobile services – October 2016

[3] CEPT Report 30. The identification of common and minimal (least restrictive) technical conditions for 790 - 862 MHz for the digital dividend in the European Union – October 2009

[4] ETSI 36.104. LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception (3GPP TS 36.104 version 16.8.0 Release 16) – January 2021

[5] Report ITU--R F.1336. Reference radiation patterns of omnidirectional, sectoral and other antennas for the fixed and mobile service for use in sharing studies in the frequency range from 400 MHz to about 70 GHz – January 2019

[6] CEPT Report 53. Report A from CEPT to the European Commission in response to the Mandate "To develop harmonised technical conditions for the 694-790 MHz ('700 MHz') frequency band in the EU for the provision of wireless broadband and other uses in support of EU spectrum policy objectives" – November 2014.

[7] Report ITU--R BT.2383--2. Characteristics of digital terrestrial television broadcasting systems in the frequency band 470-862 MHz – July 2019

[8] Recommendation ITU--R P.1546. Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 4 000 MHz.

[9] GE06 Final Acts. 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)- 2006

[10] EBU Technical Review 308. GE06 — OVERVIEW OF THE SECOND SESSION (RRC-06) – October 2006.

Annex A: Measurement of adjacent and overlapping channels Protection ratios

This annex provides a comparison between protection ratios for DVB-T (and DVB-T2) wanted systems interfered with by DVB-T and by LTE-based 5G Broadcast systems. The aim of these measurements is to assess the required reduction of power of an LTE-based 5G Broadcast channel using a given band plan option to meet the same level of protection of DTT (co-channel or adjacent channel) in the neighbouring country(ies) from an existing DVB-T entry of the GE06 Plan. See § 5.1.1 for further explanation.

To understand the impact of an OFDM service (DTT or LTE) overlapping a wanted DTT service (DVB-T & DVB-T2), measurements of adjacent and overlapping channel protection ratios were made. The measurements were carried out with the interfering OFDM service being an 8 MHz DVB-T service and a 10 MHz LTE service, respectively.

The interfering source was moved in 0.1 MHz steps from the position where there was no overlap with the wanted DVB service to a position of full overlap. The protection ratio (C/N) was assessed at each step. Measurements were made in a Gaussian channel using a Rohde & Schwarz SFU generator and a Rohde & Schwarz ETL receiver/TS/spectrum analyser. The wanted DTT service was Ch 45 (centred on 666 MHz). Results for DVB-T as wanted service are provided in § A1 and for a DVB-T2 wanted service in § A2.

A1. DVB-T as wanted system

Table A1: DVB-T 64-QAM ¾ 8K interfered with by DTT

Wanted -71.55 dBm		-38		DVB-T centre frequency MHz		666
		-39.45		DVB-T Active bandwidth MHz		7.61
		1.45		DVB-T interferer active bandwidth MHz		7.61
	Int. Level dBm	Int. Level dBm				
Freq. MHz	measured	corrected	Prot. Rat.	Overlap MHz		
658	-33	-34.45	-37.1	-0.39		
658.1	-33	-34.45	-37.1	-0.29		
658.2	-33	-34.45	-37.1	-0.19		
658.3	-39	-40.45	-31.1	-0.09		
658.4	-47	-48.45	-23.1	0.01		
658.5	-50	-51.45	-20.1	0.11		
658.6	-52	-53.45	-18.1	0.21		
658.7	-59	-60.45	-11.1	0.31		
658.8	-62	-63.45	-8.1	0.41		
658.9	-64	-65.45	-6.1	0.51		
659	-66	-67.45	-4.1	0.61		
659.1	-68	-69.45	-2.1	0.71		
659.2	-70	-71.45	-0.1	0.81		
659.3	-72	-73.45	1.9	0.91		
659.4	-74	-75.45	3.9	1.01		
659.5	-75	-76.45	4.9	1.11		
659.6	-75	-76.45	4.9	1.21		
659.7	-76	-77.45	5.9	1.31		
659.8	-77	-78.45	6.9	1.41		
659.9	-78	-79.45	7.9	1.51		
660	-79	-80.45	8.9	1.61		
660.1	-79	-80.45	8.9	1.71		
660.2	-80	-81.45	9.9	1.81		
660.3	-80	-81.45	9.9	1.91		
660.4	-81	-82.45	10.9			
660.5	-82	-83.45	11.9			

661	-83	-84.45	12.9		
662	-85	-86.45	14.9		
663	-86	-87.45	15.9		
664	-87	-88.45	16.9		
665	-88	-89.45	17.9		
666	-88	-89.45	17.9		

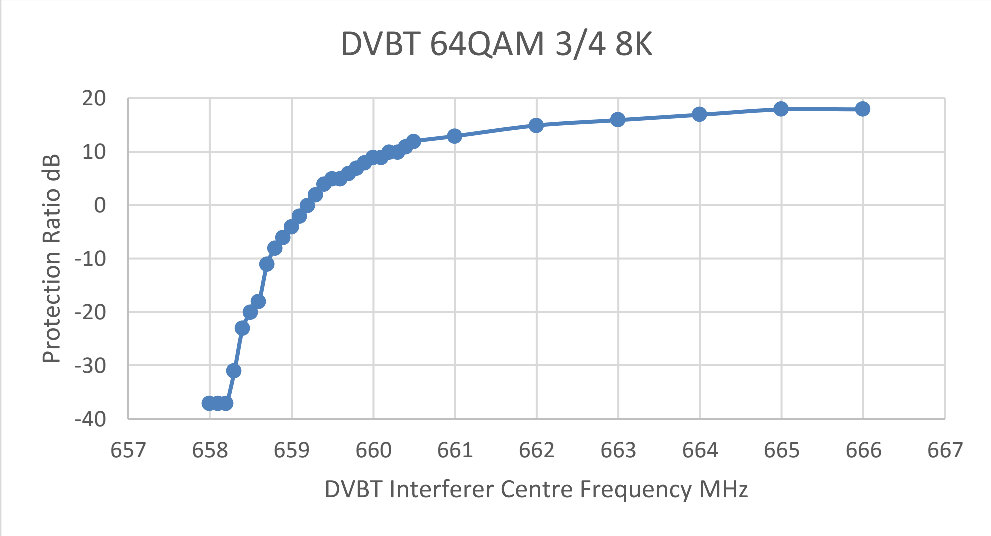


Figure A1: DVB-T 64-QAM ¾ 8K interfered with by DTT

Table A2: DVB-T 64-QAM ¾ 8K interfered with by LTE 10 MHz

Wanted -71.55 dBm		-38		DVB-T centre frequency MHz	666
		-39.5		DVB-T Active bandwidth MHz	7.61
		1.5		LTE interferer active bandwidth MHz	9
	Int. Level dBm	Int. Level dBm			
Freq. MHz	measured	corrected	Prot. Rat.	Overlap MHz	
657	-34	-35.5	-36.05	-0.695	
658	-59	-60.5	-11.05	0.305	
658.1	-61	-62.5	-9.05	0.405	
658.2	-64	-65.5	-6.05	0.505	
658.3	-66	-67.5	-4.05	0.605	
658.4	-67	-68.5	-3.05	0.705	
658.5	-70	-71.5	-0.05	0.805	
658.6	-71	-72.5	0.95	0.905	
658.7	-73	-74.5	2.95	1.005	
658.8	-74	-75.5	3.95	1.105	
658.9	-75	-76.5	4.95	1.205	
660	-81	-82.5	10.95	2.305	
660.1	-82	-83.5	11.95	2.405	
660.2	-82	-83.5	11.95	2.505	
660.3	-82	-83.5	11.95	2.605	
660.5	-83	-84-5	12.95	2.805	
661	-84	-85.5	13.95	3.305	
662	-86	-87.5	15.95	4.305	
663	-86	-87.5	15.95	5.305	
664	-87	-88.5	16.95	6.305	
665	-88	-89.5	17.95	7.305	
666	-88	-89.5	17.95	8.305	

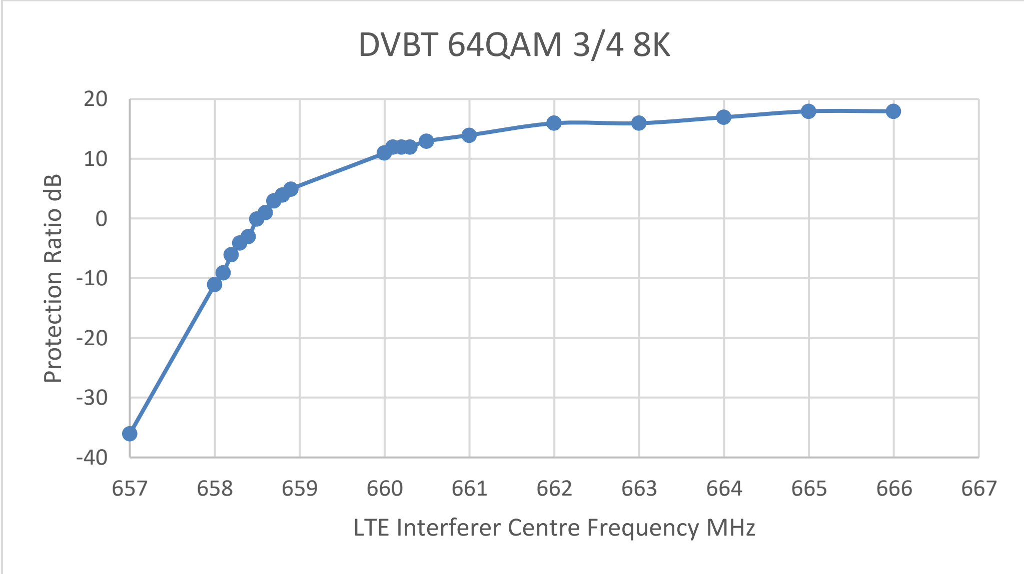


Figure A2: DVB-T 64-QAM ¾ 8K interfered with by LTE 10 MHz

A2. DVB-T2 as wanted system

A2.1 Measurements done by Arqiva

Table A3: DVB-T2 256-QAM 2/3 32K interfered with by DTT

Wanted -71.47 dBm		-38		DVB-T2 centre frequency MHz	666
		-39.45		DVB-T2 Active bandwidth MHz	7.77
		1.45		DVB-T interferer active bandwidth MHz	7.61
	Int. Level dBm	Int. Level dBm			
Freq. MHz	measured	corrected	Prot. Rat.	Overlap MHz	
658	-35	-36.45	-35.02	-0.31	
658.1	-35	-36.45	-35.02	-0.21	
658.2	-36	-37.45	-34.02	-0.11	
658.3	-37	-38.45	-33.02	-0.01	
658.4	-42	-43.45	-28.02	0.09	
658.5	-52	-53.45	-18.02	0.19	
658.6	-59	-60.45	-11.02	0.29	
658.7	-60	-61.45	-10.02	0.39	
658.8	-59	-60.45	-11.02	0.49	
658.9	-61	-62.45	-9.02	0.59	
659	-64	-65.45	-6.02	0.69	
659.1	-83	-84.45	12.98	0.79	
659.2	-83	-84.45	12.98	0.89	
659.3	-83	-84.45	12.98	0.99	
659.4	-84	-85.45	13.98	1.09	
659.5	-84	-85.45	13.98	1.19	
660	-85	-86.45	14.98	1.69	
660.5	-86	-87.45	15.98	2.19	
661	-87	-88.45	16.98	2.69	
662	-88	-89.45	17.98	3.69	
663	-89	-90.45	18.98	4.69	
664	-90	-91.45	19.98	5.69	
665	-90	-91.45	19.98	6.69	
666	-91	-92.45	20.98	7.69	

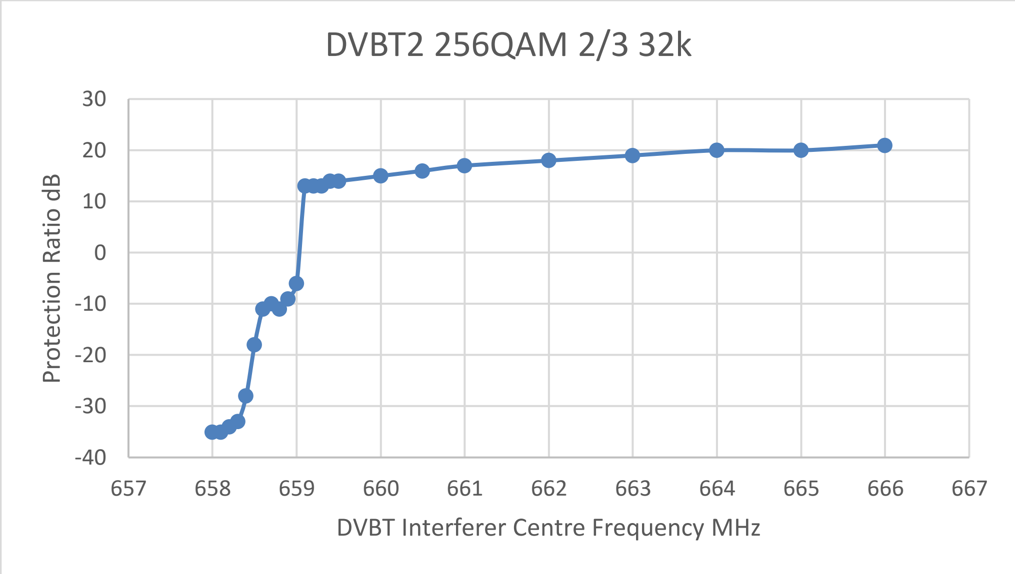


Figure A3: DVB-T2 256-QAM 2/3 32K interfered with by DTT

Table A4: DVB-T2 256-QAM 2/3 32K interfered with by DTT LTE 10 MHz

Wanted -71.47 dBm		-38		DVB-T2 centre frequency MHz	666
		-39.4		DVB-T2 Active bandwidth MHz	7.77
		1.4		LTE interferer active bandwidth MHz	9
	Int. Level dBm	Int. Level dBm			
Freq. MHz	measured	corrected	Prot. Rat.	Overlap MHz	
657	-35	-36.4	-35.07	-0.615	
658	-49	-50.4	-21.07	0.385	
658.1	-57	-58.4	-13.07	0.485	
658.2	-61	-62.4	-9.07	0.585	
658.3	-82	-83.4	11.93	0.685	
658.4	-82	-83.4	11.93	0.785	
658.5	-83	-84.4	12.93	0.885	
659	-84	-85.4	13.93	1.385	
659.5	-85	-86.4	14.93	1.885	
660	-86	-87.4	15.93	2.385	
661	-87	-88.4	16.93	3.385	
662	-89	-90.4	18.93	4.385	
663	-90	-91.4	19.93	5.385	
664	-90	-91.4	19.93	6.385	
665	-91	-92.4	20.93	7.385	
666	-91	-92.4	20.93	8.385	

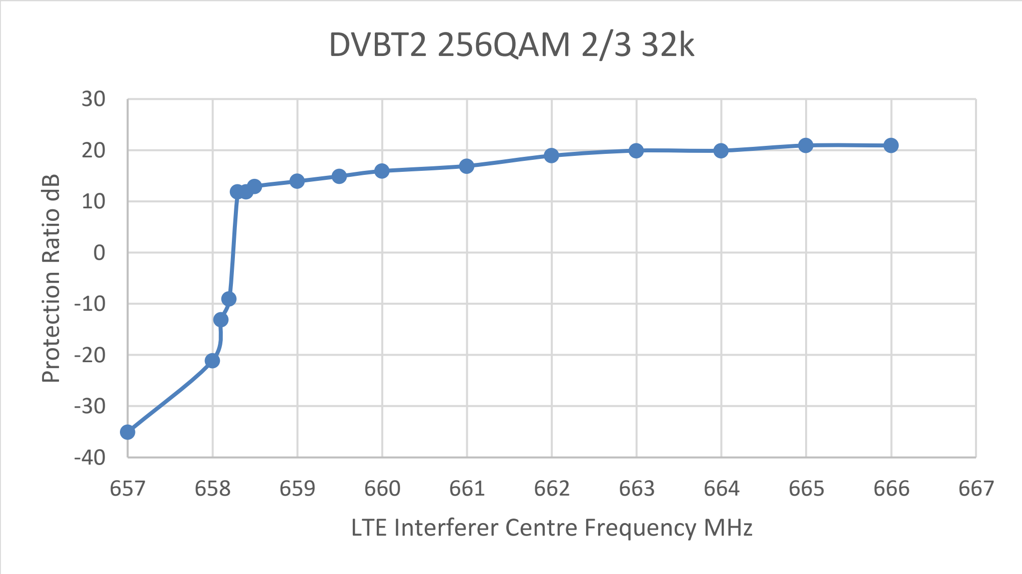


Figure A4: DVB-T2 256-QAM 2/3 32K interfered with by DTT LTE 10 MHz

A2.2 Measurements done by EI-Towers

Measurement of overlapping channel protection ratio for DVB-T2 interfered with by LTE 10 MHz

Premise

Measurement was done using R&S generator SFU and a DTT professional receiver/spectrum analyser ETL, directly connected using a BNC cable.

Between others, SFU can generate an LTE signal with different possible characteristics. At this proposal, a file describing the LTE signal is charged in the arbitrary waveform generator of the SFU and, afterwards, the frequency and the level of the LTE signal can be set. Note that this waveform can be used only as “interference”; therefore, you cannot receive this signal with an LTE receiver.

Short description

SFU is generating a DVB-T2 signal with the (main) parameters in Table A3

Table A5: Main DVB-T2 parameters

parameter	value	Note
Centre Frequency	666 MHz	UHF CH 45
Bandwidth	8 MHz	
Nldpc	64800	
MOD	256-QAM	
CR	2/3	
FFT	32KN	
GI	1/16	GI is 224 μs. The GI is not relevant for the result
PP	PP4	
SISO/MISO	SISO	
Lf	60	
TR-PAPR	No	
L1MOD	16-QAM	

SFU is connected to ETL receiver and the Level at the input of the ETL is set at -50 dBm.

This level is checked with the CP (Channel Power) function of the receiver. See Figures A5a & A5b.

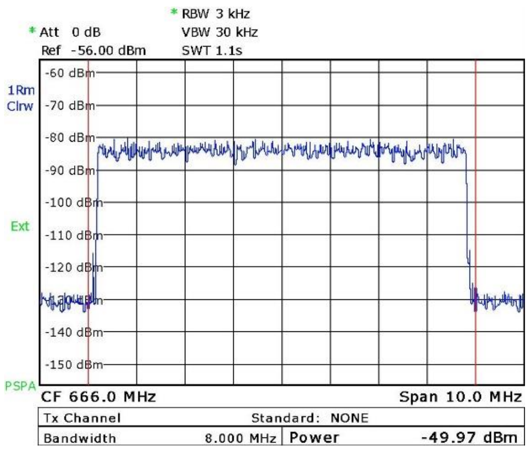


Figure A5a: Channel Power (useful signal)

Ch: 45 UHF 4/5 RF 666.000000 MHz DVB-T2 (base) 8 MHz
* Att 0 dB ExpLvl -56.00 dBm

	Pass	Limit	<	Results	< Limit	Unit
	Level	-60.0		-49.9	10.0	dBm
	Sideband			Normal		
	FFT Mode			32k		
	Guard Interval			1/16		
	Carrier Freq. Offset	-30000.0		0.2	30000.0	Hz
Ext	Bit Rate Offset	-20.0		0.0	20	ppm
	MER (L1, rms)	24.0		39.1	----	dB
	PLP Data (Decoded PLP ID 1)					
OLim	MER (PLP, rms)			40.2	----	
	BER before BCH			2.5E-6 (100%/1E9)	1.0E-2	
	LDPC Iterations			1.12		
	BER before BCH			0.0E-9 (29%/1E5)	1.0E-5	
PSPA	BBFRAME error ratio			0.0E-4 (65%/1E5)	1.0E-10	
	Errored second ratio			0% /20/20)	10	%
	TS Packet error ratio			N7a (HEM)		

Lvl -49 dBm | BER 0.0E-9 | MER 40.2 dB DEMOD PLP:1

Figure A5b: Received parameters

LTE Interference is set using the file “E-TM1_2__10MHz.wv”.

As a starting point, the frequency offset of the LTE to the DTT centre frequency is set to the value -10 MHz and the (maximum) level of this interferer is set to have -10 dB of PR on the useful DTT signal. This value should change as a function of the selected LTE configuration. Note that SFU automatically takes account of the CP of the useful signal and the CP of the interference, therefore the relative attenuation. See Figure A4.

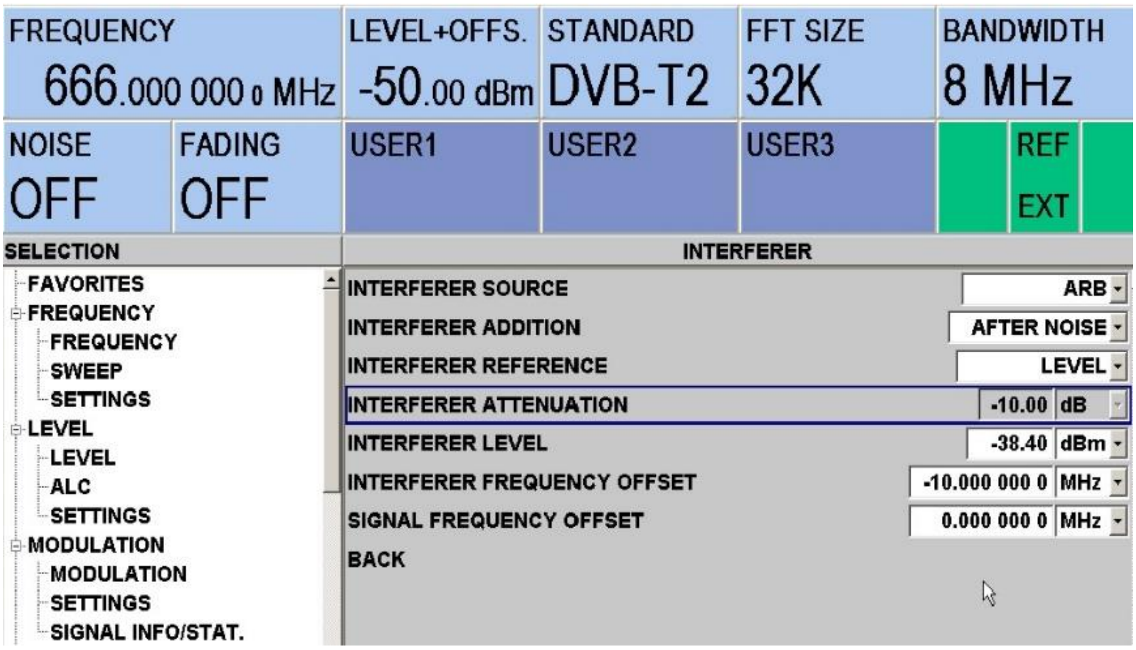


Figure A6: Setting the ARB generator

The level of the LTE signal is checked with the CP (Channel Power) function of the receiver. See Figure A7.

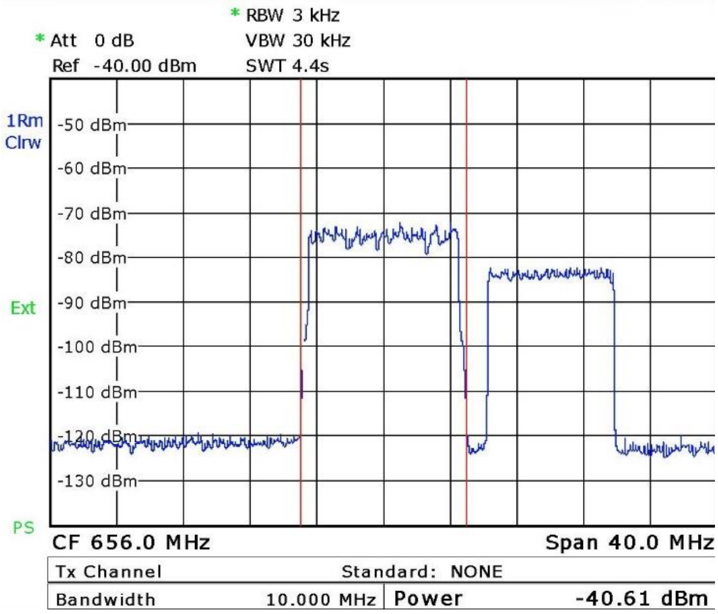


Figure A7: Channel Power (interfering signal at -10 MHz)

In this example, the interferer level is -40.6 dBm and the attenuation is -9.4 dB (interference is 9.4 dB greater). Adjustment of 0.6 dB to the "Interference Attenuation" can be applied to the results[11].

For any of the considered frequencies, the value of the PR is changed until the "failure point" (BB frame is corrupted) is reached. Then the value is released to have a stable useful signal and then the DTT parameters are registered.

Some results

Figure A8 shows the value of the PR (Protection Ratio) as a function of the centre frequency of the LTE interferer. If f_{LTE} is 656 MHz the frequency offset between the two centre frequencies is -10 MHz, while if f_{LTE}= 666 MHz, the two signals have the same centre frequency.

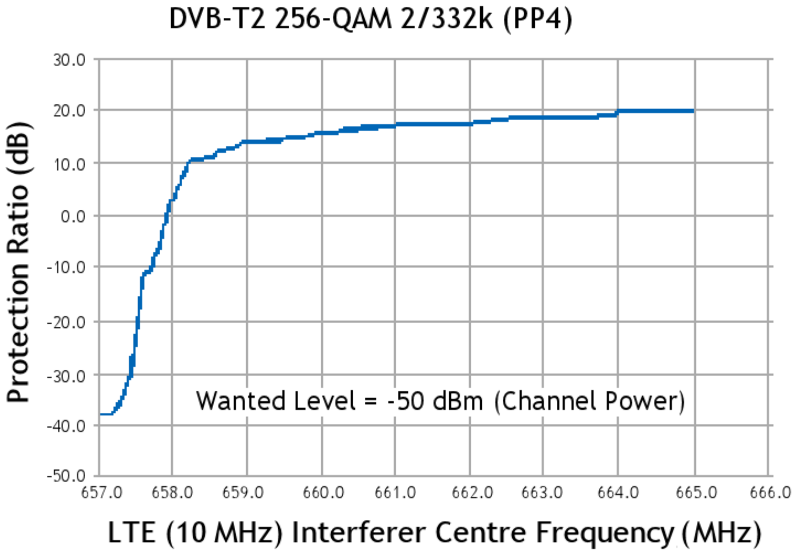


Figure A8: PR (Protection Ratio) values, function of the LTE Centre frequency

11 Useful signal is -50.0 dBm and Interfering signal is -40.6 dBm, therefore the ratio is -9.4 dB and "Interference Attenuation" can be corrected accordingly.

Table A6a is a (partial) summary of the results. Note that the value of MER PLP (RMS value, dB) is a function of the percentage of overlapping; an example is shown in Figure A9.

Table A6a: Summary of the results (first part)

	Results of measurements							
Δ f (MHz)	Iter. Numb.	BER Before LDPC	BER Before BCH	MER PLP (dB)	MER L1 (dB)	f	Δ f (MHz)	Protection ratio (dB) yellow interp. Val.
10						656.0	10.0	-39.0
9.9						656.1	9.9	-38.9
9.8						656.2	9.8	-38.8
9.7						656.3	9.7	-38.8
9.6						656.4	9.6	-38.7
9.5	20.5	7.8E-02	0.0E+00	18.4	17.3	656.5	9.5	-38.6
9.4	20.0	7.8E-02	0.0E+00	18.4	17.3	656.6	9.4	-38.5
9.3	21.0	7.9E-02	2.0E-09	18.4	17.3	656.7	9.3	-38.5
9.2	20.0	7.8E-02	0.0E+00	18.3	17.4	656.8	9.2	-38.4
9.1	21.5	7.8E-02	1.0E-09	18.4	17.3	656.9	9.1	-38.4
9	20.2	7.9E-02	0.0E+00	18.3	17.4	657.0	9.0	-38.3
8.9				18.9		657.1	8.9	-38.3
8.8				18.8		657.2	8.8	-38.1
8.7				19.3		657.3	8.7	-35.2
8.6				22.8		657.4	8.6	-31.4
8.5				24.9		657.5	8.5	-21.6
8.4				26.7		657.6	8.4	-10.9
8.3				25.4		657.7	8.3	-10.9
8.2				27.6		657.8	8.2	-5.9
8.1				25.2		657.9	8.1	0.1
8				27.0		658.0	8.0	3.6
7.9	15.0	1.5E-02	5.5E-05	27.1	15.7	658.1	7.9	6.6
7.8				29.2		658.2	7.8	10.6
7.7				28.4		658.3	7.7	10.6
7.6				27.7		658.4	7.6	10.6
7.5				27.2		658.5	7.5	10.6
7.4				28.4		658.6	7.4	12.6
7.3				28.0		658.7	7.3	12.6
7.2				27.7		658.8	7.2	12.6
7.1				28.2		658.9	7.1	13.6
7				27.9		659.0	7.0	13.6
6.9						659.1	6.9	13.8
6.8						659.2	6.8	14.0
6.7						659.3	6.7	14.2
6.6						659.4	6.6	14.4
6.5				27.0		659.5	6.5	14.6
6.4						659.6	6.4	14.8
6.3						659.7	6.3	15.0
6.2						659.8	6.2	15.2
6.1						659.9	6.1	15.4
6				26.5		660.0	6.0	15.6

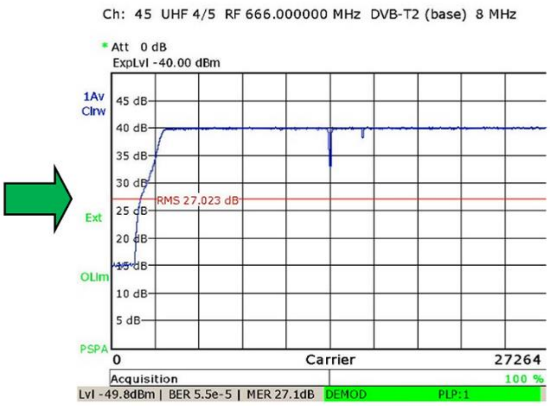


Figure A9: MER (rms) example 1

Table A6b is another (partial) summary of the results. The value of MER PLP (RMS value, dB) remains a function of the percentage of overlapping; an example is shown in Figure A10.

Table A6b: Summary of the results (first part)

	Results of measurements							
Δ f (MHz)	Iter. Numb.	BER Before LDPC	BER Before BCH	MER PLP (dB)	MER L1 (dB)	f	Δ f (MHz)	Protection ratio (dB) yellow interp. Val.
5.9						660.1	5.9	15.8
5.8						660.2	5.8	16.0
5.7						660.3	5.7	16.2
5.6						660.4	5.6	16.4
5.5				26.0		660.5	5.5	16.6
5.4						660.6	5.4	16.6
5.3						660.7	5.3	16.8
5.2						660.8	5.2	17.0
5.1						660.9	5.1	17.2
5	17.4	5.6E-02	7.6E-08	25.0	17.7	661.0	5.0	16.6
4.9						661.1	4.9	16.8
4.8						661.2	4.8	17.0
4.7						661.3	4.7	17.2
4.6						661.4	4.6	17.4
4.5				24.7		661.5	4.5	17.6
4.4						661.6	4.4	17.6
4.3						661.7	4.3	17.6
4.2						661.8	4.2	17.6
4.1						661.9	4.1	17.6
4				23.8		662.0	4.0	17.6
3.9						662.1	3.9	17.8
3.8						662.2	3.8	18.0
3.7						662.3	3.7	18.2
3.6						662.4	3.6	18.4
3.5				23.6		662.5	3.5	18.6
3.4						662.6	3.4	18.6
3.3						662.7	3.3	18.6
3.2						662.8	3.2	18.6
3.1						662.9	3.1	18.6
3				22.6		663.0	3.0	18.6
2.9						663.1	2.9	18.6
2.8						663.2	2.8	18.6
2.7						663.3	2.7	18.6
2.6						663.4	2.6	18.6
2.5				21.5		663.5	2.5	18.6
2.4						663.6	2.4	18.8
2.3						663.7	2.3	19.0
2.2						663.8	2.2	19.2
2.1						663.9	2.1	19.4
2				21.2		664.0	2.0	19.6
1.9						664.1	1.9	19.6
1.8						664.2	1.8	19.6
1.7						664.3	1.7	19.6
1.6						664.4	1.6	19.6
1.5				20.0		664.5	1.5	19.6
1.4						664.6	1.4	19.6
1.3						664.7	1.3	19.6
1.2						664.8	1.2	19.6
1.1						664.9	1.1	19.6
1				18.7		665.0	1.0	19.6
0.9						665.1	0.9	19.8
0.8						665.2	0.8	20.0
0.7						665.3	0.7	20.2
0.6						665.4	0.6	20.4
0.5				19.1		665.5	0.5	20.6
0.4						665.6	0.4	20.6
0.3						665.7	0.3	20.6
0.2						665.8	0.2	20.6
0.1						665.9	0.1	20.6
0				19.1		666.0	0.0	20.6

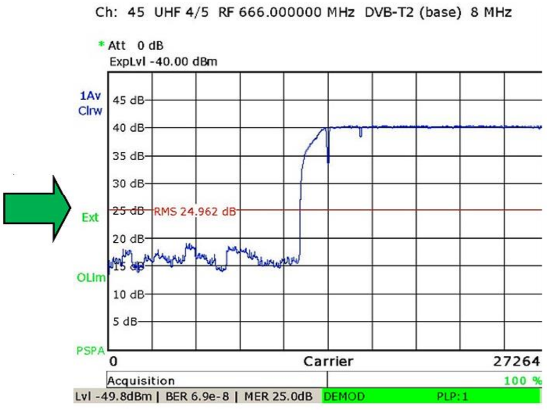


Figure A10: MER (rms) example 2

Annex B: Detailed calculation and results of the quantitative evaluation described in § 5.1

Table B1: detailed calculation related to § 5.1

CELL G (Green)
Adjacent DTT Cells (2 Yellow, 1 Blue)

Candidate channels	Bandwidth (MHz)	Overlapping bandwidth (MHz)	Protection ratio with DVB-T in neighbouring cells	Power reduction relative to planned DTT (dB)
L8-2, L8-5, L8-8	3x8	0	-36.1	1.0
L10C-2, L10C-5, L10C-8	3x10	0.305	-11.0	26.1
L10NC-4	10	1.305	5.5	42.6
L5C-2, L5C-5, L5C-8	3x5	0	-36.1	1.0
L5NC-3, L5NC-8	2x5	0	-36.1	1.0
L5NC-12, L5NC-13	2x5	0.555	-5.1	32.0
L15	0			

DVB-T active bandwidth (MHz)	7.61
LTE 10 MHz active bandwidth (MHz)	9

PR DVB-T vs DVB-T adjacent channel	-37.1

CELL B (Blue)
Adjacent DTT Cells (1 Yellow)

Candidate channels	Bandwidth (MHz)	Overlapping bandwidth (MHz)	Protection ratio with DVB-T in neighbouring cells	Power reduction relative to GE06 entry (dB)
L8-2, L8-3, L8-5, L8-6, L8-8, L8-9	6x8	0	-36.1	1.0
L10C-2, L10C-3, L10C-5, L10C-6, L10C-8, L10C-9	6x10	0.305	-11.0	26.1
L10NC-2, L10NC-7	2x10	0	-36.1	1.0
L10NC-5	10	1.305	5.5	42.6
L5C-2, L5C-3, L5C-5, L5C-6, L5C-8, L8C-9	6x5	0	-36.1	1.0
L5NC-3, L5NC-4, L5NC-8, L5NC-9, L5NC-13, L5NC-14	6x5	0	-36.1	1.0
L5NC-5, L5NC-12	2x5	0.555	-5.1	32.0
L5NC-7, L5NC-10	2x5	1.555	6.9	44.0
L15	3x15	0	-36.1	1.0

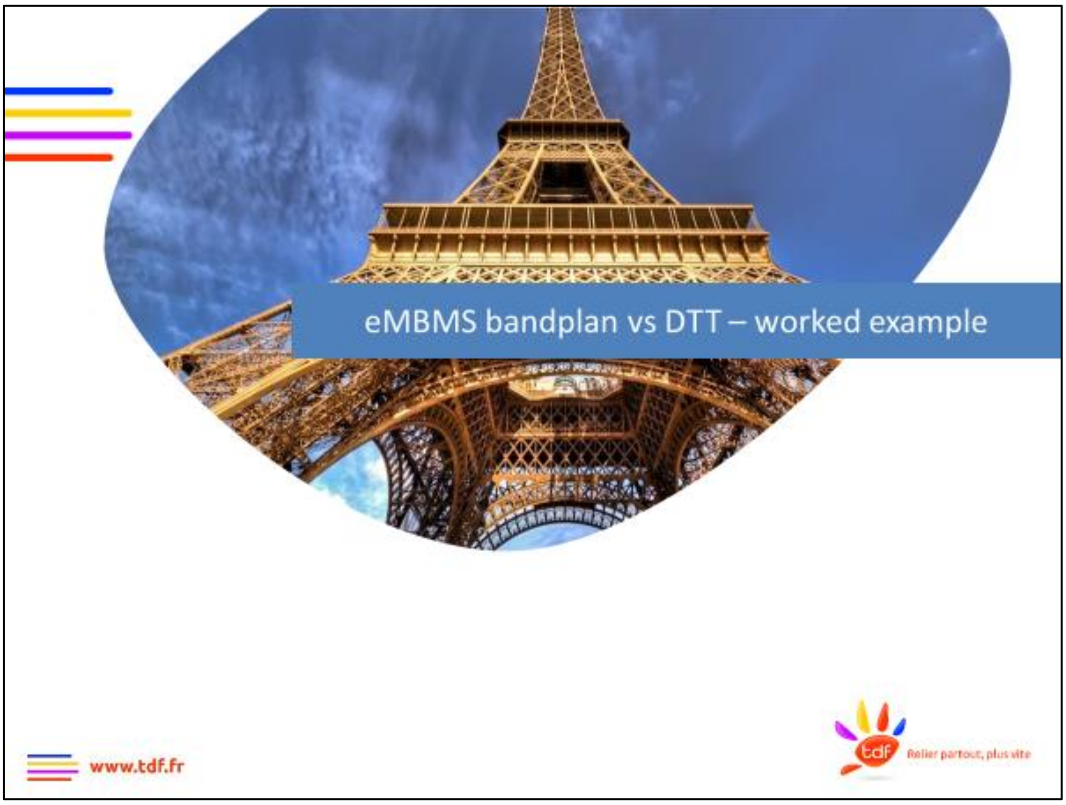
DVB-T active bandwidth (MHz)	7.61
LTE 10 MHz active bandwidth (MHz)	9

PR DVB-T vs DVB-T adjacent channel	-37.1

Note: for both parts of Table B1: The power reduction is calculated using as reference the protection ratio for DVB-T interfered with by DVB-T (37.1 dB, from Table A1). This explains the 1 dB reduction instead of 0 dB for the situations with no overlap, as the protection ratio for DVB-T interfered with by LTE is -36.1 dB (from Table A2).

Annex C: Example of the calculation of power reduction in a real case

The following are pages taken from a TDF PowerPoint presentation from April 2020.



Objective

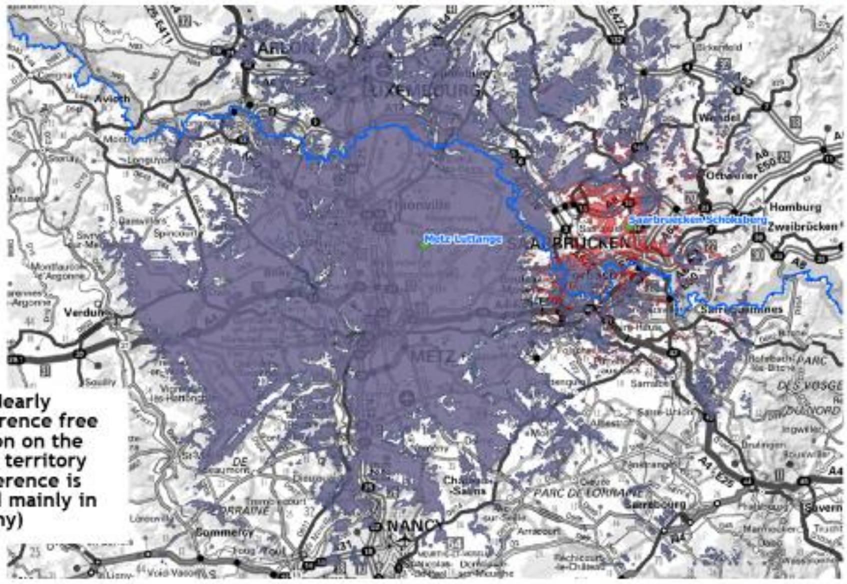
Assess the situation of :

- Country A maintaining its existing DTT transmisions
- Country B transitionning to feMBMS from an existing DTT situation
- Adjacent channel situation in adjacent areas
- Use of a 10 MHz feMBMS channel centered on the existing 8 MHz DTT channel

Worked example : coordinated situation between France (Metz/Forbach C36) and Germany (Saarland and beyond C37)

08/04/2020 eMBMS bandplan vs DTT - worked example 1

DTT vs DTT - existing situation (red = interference)



Nota: Nearly interference free situation on the French territory (interference is located mainly in Germany)

08/04/2020 eMBMS bandplan vs DTT - worked example 3

Detailed situation

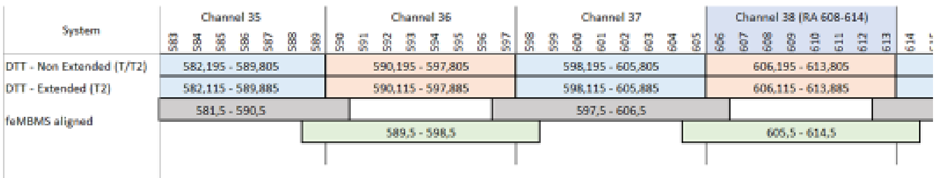
Retain only one site from each side :

- Metz-Luttange 50 kW ERP - omni-directionnal antenna @ 230m - H polarized
- Saarbrucken Shocksberg 50 kW ERP - omni-directionnal antenna @ 283m - V polarized
- ~45 km distance between the two transmitters

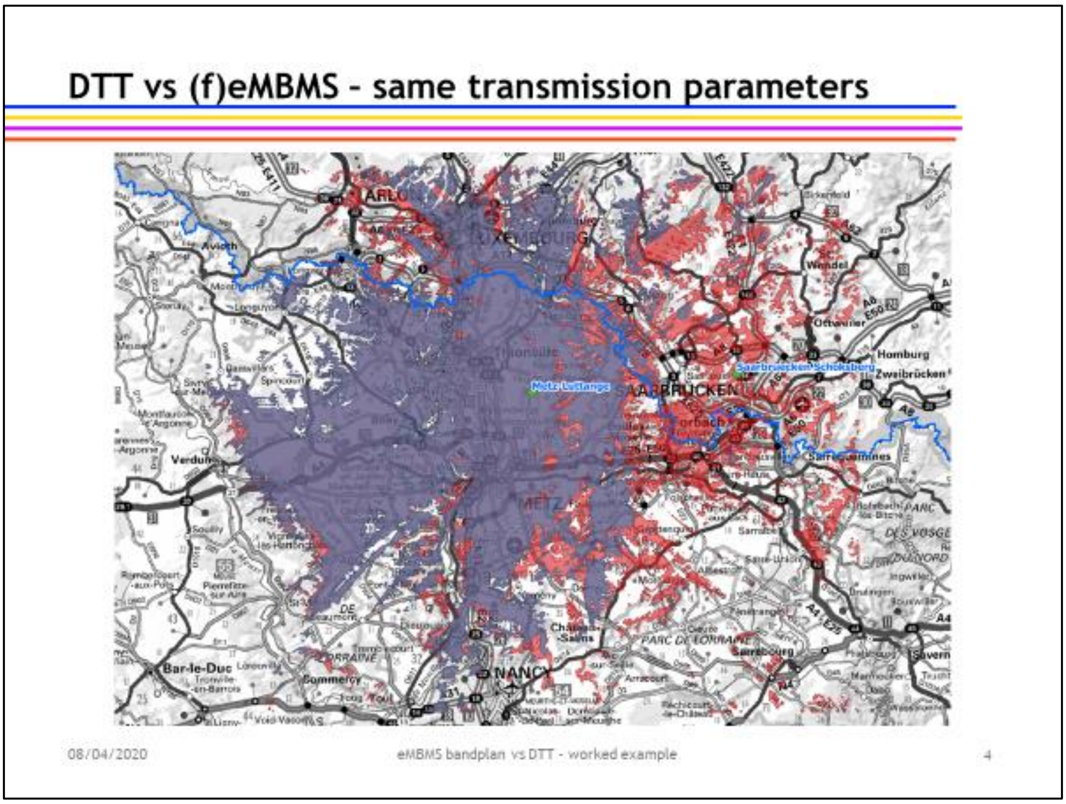
France sticks to DVB-T(2), Germany transitions to (f)eMBMS, using an overlaping (f)eMBMS bandplan

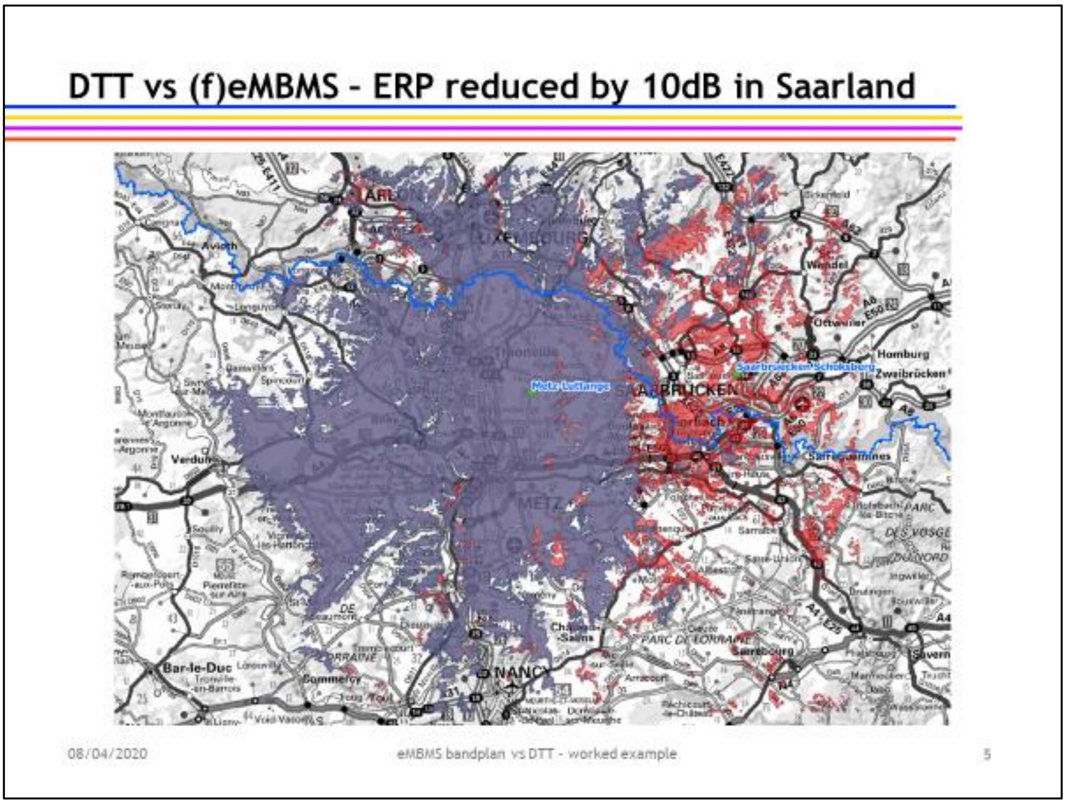
Assessment of the impact on the French side

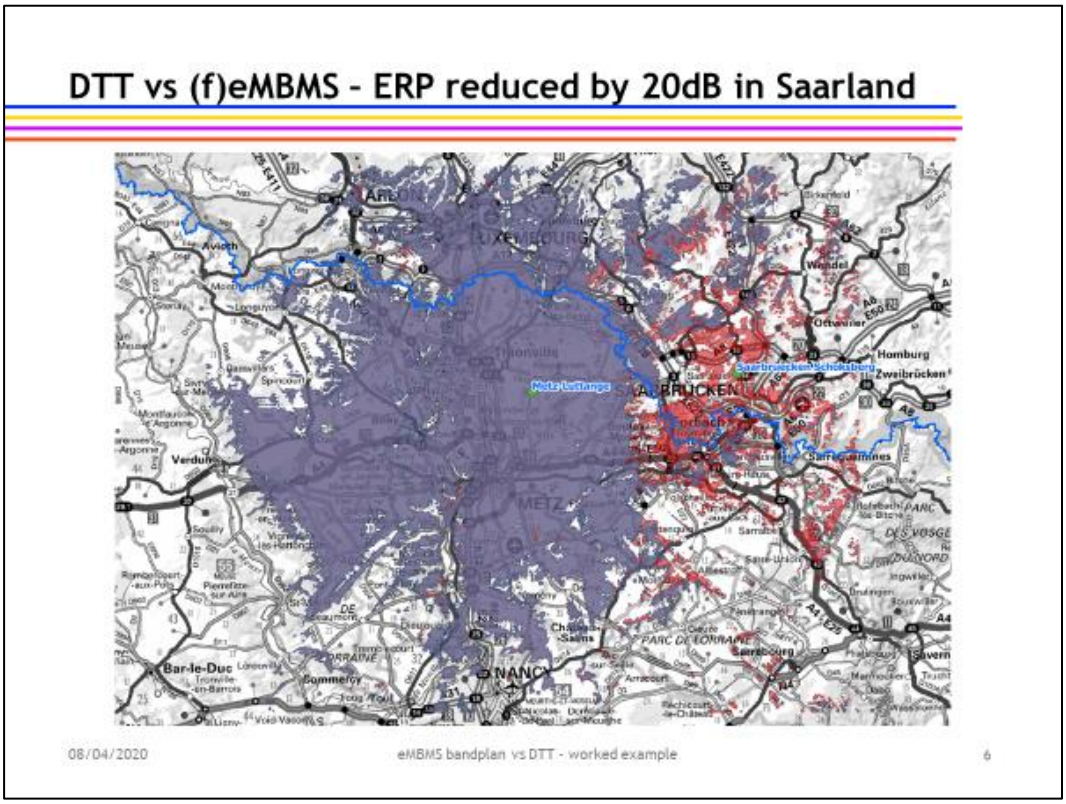
- Fixed reception / ITU-R 419 receiving antenna @ 10m
- Co-channel DTT protection ratio : 21 dB
- Adjacent channel DTT protection ratio : -30 dB (ITU-R BT.1368-4)
- Overlapping (f)eMBMS channel protection ratio : 8 dB (overlap (f)eMBMS / DVB-T2 extended = 0,385 MHz / 7,77 MHz, overlap (f)eMBMS / DVB-T/T2 non extended = 0,305 MHz / 7,61 MHz)

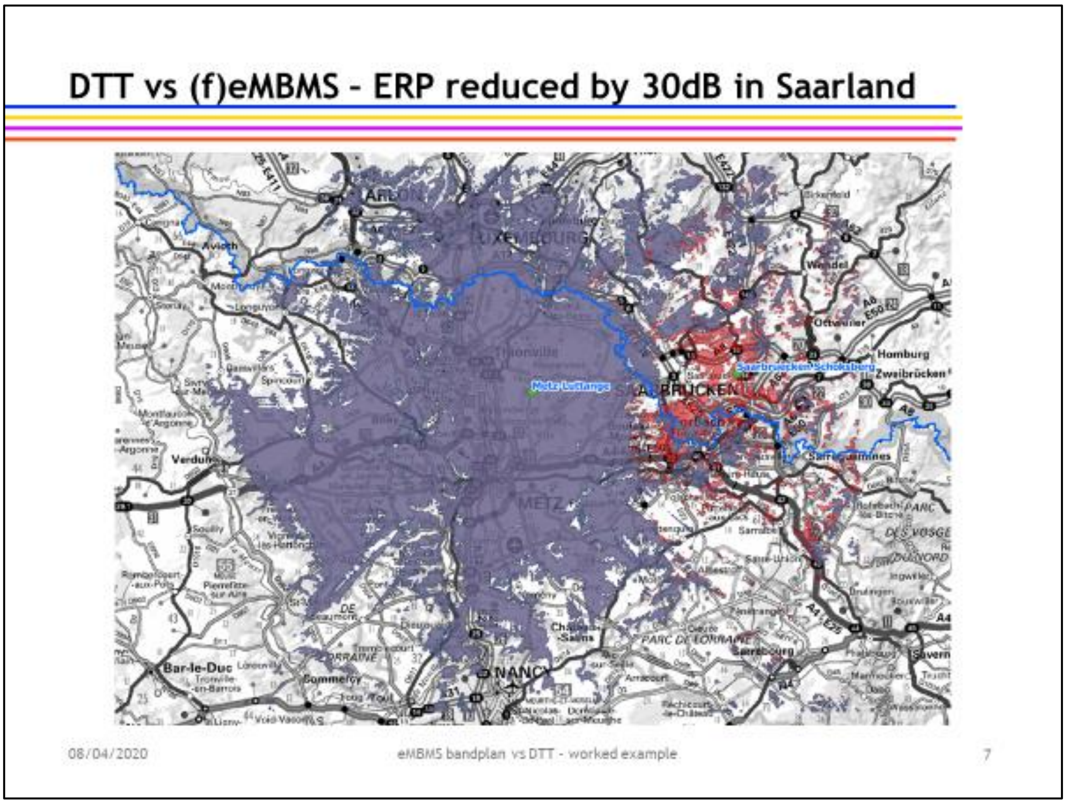


08/04/2020 eMBMS bandplan vs DTT - worked example 2

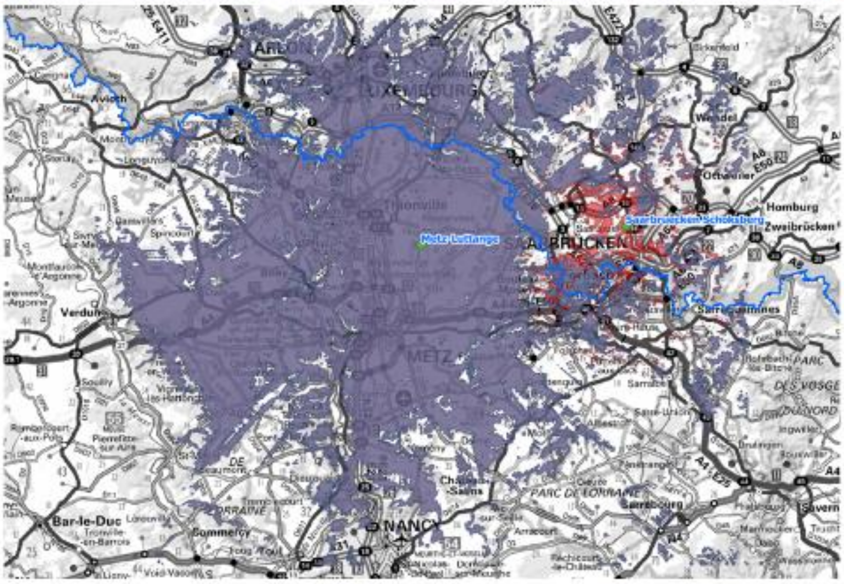

DTT vs (f)eMBMS - same transmission parameters
ARLON
LUXEMBOURG
Metz Luttange
SAARBRUCKEN
Saarbruecken Schoksberg
Homburg
Zweibrücken
Verdun
METZ
NANCY
Bar-le-Duc
08/04/2020
eMBMS bandplan vs DTT - worked example
4


DTT vs (f)eMBMS - ERP reduced by 10dB in Saarland
ARLON
LUXEMBOURG
Metz Luttange
SAARBRUCKEN
Saarbruecken Schoksberg
Homburg
Zweibrücken
Verdun
METZ
NANCY
Bar-le-Duc
08/04/2020
eMBMS bandplan vs DTT - worked example
5


DTT vs (f)eMBMS - ERP reduced by 20dB in Saarland
Metz-Luttange
Saarbrücken-Schoksberg
ARLON
LUXEMBOURG
Thionville
METZ
NANCY
Verdun
Bar-le-Duc
Commercy
Homburg
Zweibrücken
Sarreguemines
Sarrebourg
08/04/2020
eMBMS bandplan vs DTT - worked example
6


DTT vs (f)eMBMS - ERP reduced by 30dB in Saarland
Metz-Luttange
Saarbrücken-Schoksberg
ARLON
LUXEMBOURG
Thionville
METZ
NANCY
Verdun
Bar-le-Duc
Commercy
Homburg
Zweibrücken
Sarreguemines
Sarrebourg
08/04/2020
eMBMS bandplan vs DTT - worked example
7

DTT vs (f)eMBMS - ERP reduced by 38dB in Saarland



08/04/2020 eMBMS bandplan vs DTT - worked example 8

Conclusion

To restore the same situation (on the French territory, i.e. nearly interference free on the area of interest) as the existing one (DTT vs DTT), the (f)eMBMS conversion of the German position needs a reduction of 38 dB in the ERP.

i.e. power reduction = new protection ratio - old protection ratio
38 dB = 8 dB - (-30 dB)

This is due to the close location of the two transmitters: farther transmitters will have less interference zone overlap, and may need a lower power reduction; other factors such as polarization (co / cross / circular) will have an impact as well.

On the (f)eMBMS converted area, the ERP is considerably lowered, resulting in a huge reduction of the available C/N / throughput; taking into account the (overlapping) adjacent channel interference from DTT, the effectively available throughput might be further reduced.

08/04/2020 eMBMS bandplan vs DTT - worked example 9

Annex D: Identifying contiguous DTT channels at the border between Germany and France

In the context of possible band plans identification for 5G Broadcast in the sub-700 MHz band, one option being considered is the accommodation of 15 MHz LTE channels within 2x8 MHz DTT channels. For the countries considering the implementation of such a band plan, this requires the identification of contiguous DTT channels that are usable in the field, i.e., currently in use or planned for use by the concerned country and coordinated with its neighbours.

To illustrate the issue independently from any decision of the considered countries to use such a band plan, this document tries and identifies possible contiguous DTT channels at the border between Germany and France, based on the existing coordination arrangements, considering other neighbouring countries (Luxembourg, Switzerland, The Netherlands, …). It is based on publicly available information, namely:

- WEDDIP (Western European Digital Dividend Implementation Platform) agreement, April 29th 2016
  https://www.anfr.fr/fileadmin/mediatheque/documents/coordination/Accords_par_pays/WEDDIP_statement_700_MHz_band_release.pdf
- Agreement between the administrations of Germany and France concerning frequency co-ordination of Digital Terrestrial Television in the band 470-694 MHz
  https://www.anfr.fr/fileadmin/mediatheque/documents/coordination/Accords_par_pays/171219_D_F_UHF_Agreement_v1-7_final_signed.pdf

The WEDDIP agreement covers a large geographical area including Ireland, The Netherlands, the United Kingdom, Belgium, Luxembourg, Germany and France. To try and have a first result the area of interest was restricted to the area highlighted in red in Figure D1.

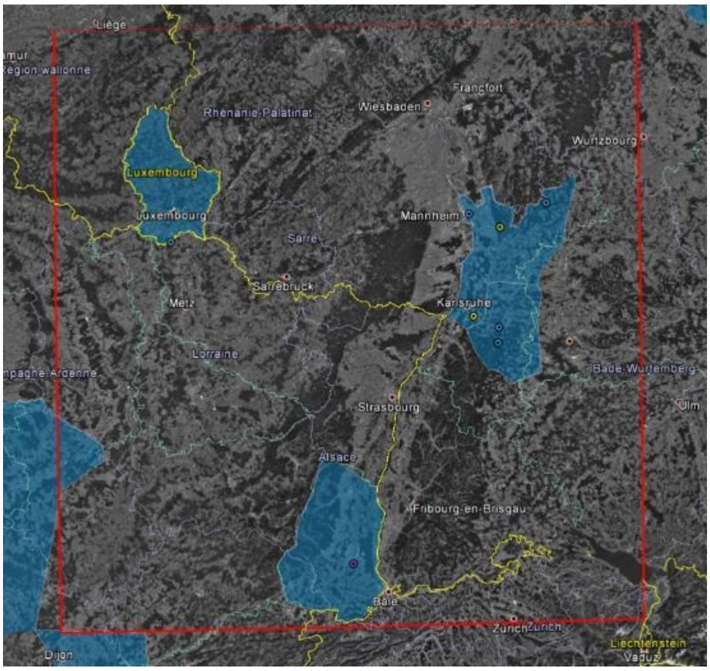


Figure D1: Area of interest - in red for the current analysis (background: channel map for channel 21)

Table D1 presents the possible contiguous channel arrangements that were identified based on the above information, using the following approach: All contiguous channel pairs are considered as viable at this stage, meaning the 15 MHz LTE signal would have to use an 8 MHz raster starting at the boundary between channel 21 and 22 (478 MHz) and ending at the boundary between channel 47 and 48 (686 MHz).

Table D1: evaluation of the number of areas that can effectively host a 2x 8 MHz channels configurations, in the area of interest shown in Figure D1

Channel pairs	France		Germany	
	Planned areas	Effective areas	Planned areas	Effective areas
21-22	2		2	
22-23	3	1 (Moselle-Est)	3	
23-24	3		3	1 (Heilbronn)
24-25	3		3	
25-26	4	1 (Moselle-Est + Alsace Nord)	4	1 (Stuttgart)
26-27	3		3	
27-28	2		4	
28-29	3		4	1 (Freiburg)
29-30	3		2	
30-31	3		3	
31-32	3		3	1 (Stuttgart)
32-33	2		4	
33-34	2	1 (Meurthe-et-Moselle)	4	
34-35	2	1 (Meuse-Sud)	2	
35-36	3		3	1 (Baden-Baden)
36-37	3		4	1 (Bodensee + Tuebingen)
37-38	1	RA protection	2	RA protection
38-39	2	RA protection	1	RA protection
39-40	3		2	
40-41	2		2	
41-42	2		3	1 (Rhein-Main-Sür)
42-43	4		4	
43-44	5	1 (Franche-Comté-Nord)	3	
44-45	4		4	1 (Saarland)
45-46	3		5	1 (Saarland)
46-47	3	1 (Haute-Marne)	4	
47-48	4	1 (Alsace-Nord)	4	
Total	77	7[12]	85	8[13]
		9.1%		9.4%

- **Planned areas**: number of areas (allotments) in one country that are using / allocated either one of the two channels of the designated pair or both. This is used to show the total number of allotments over the considered area of interest for each country.The "Planned areas" information corresponds to the number of contiguous areas in a designated country that are planned to use the lower channel and/or the higher channel of the channel pair for that country; these areas are

[12] Some contiguous channel pairs might not be usable if they are used in the same area; this is not the case for France as the relevant contiguous channel pairs (33-34 / 34-35 and 46-47 / 47-48) are used in different areas.

[13] For Germany, the contiguous channel pairs 35-36 / 36-37 can both be used because different areas are concerned. On the contrary, only one of the two pairs 44-45 / 45-46 can be used as they are both available for Saarland only. The total effective usable pairs is thus affected by this choice. In other words: the total is not simply the addition of the number of effective areas (this would give 9 for Germany and not 8 as indicated here), as if two overlapping channel pairs are available in the same area (allotment), only one of these pairs can effectively be used. This is the case for Germany, where 44-45 and 45-46 are used over Saarland. If one accommodates a 15 MHz LTE channel over 44-45 in Saarland, then a 15 MHz LTE channel cannot be used over 45-46 in Saarland, and vice-versa.

not necessarily the common (i.e., overlapping, even partially) across the two considered channels due to the frequency planning constraints.

- **Allotments** / transmitter coverages that are geographically contiguous in a given country count as one area for the country / channel / channel pair being considered.
- **Effective areas**: number of areas (allotments) in one country that are using / allocated both channels of the designated pair. The “Effective areas” information corresponds to the number of contiguous areas that are planned to use both channels of the channel pair. Even partial geographical overlaps between areas (as area shapes may vary from one channel to another) are counted as effective.
- In addition to the potential varying shapes of an area between two consecutive channels, peculiar additional channel limitations (different transmitter characteristics: ERP, antenna diagram, … , different set of transmitters between the two channels, … due to frequency coordination constraints) are not considered in the identification of Effective areas.
- Protection of Radio Astronomy on channel 38 prevented the implementation of any DTT coordinated position on either side of the border for France and Germany and prevents the use of channel pairs 37-38 and 38-39.

Considering the indications above, the evaluation of the number of effectively usable areas to host a 2x 8 MHz channels configuration is an upper bound of what will be feasible in reality. Still, compared to the number of planned areas, it remains at a very low ratio of the overall planned situation, with less than 10% for both countries.

Figure D2 (composite view of all the areas where a contiguous channel pair is available) shows where such contiguous channels are available in Germany. While Table D1 highlights the frequency limitation associated to the identification of effectively usable areas, this map shows the geographical limitation of such availability.

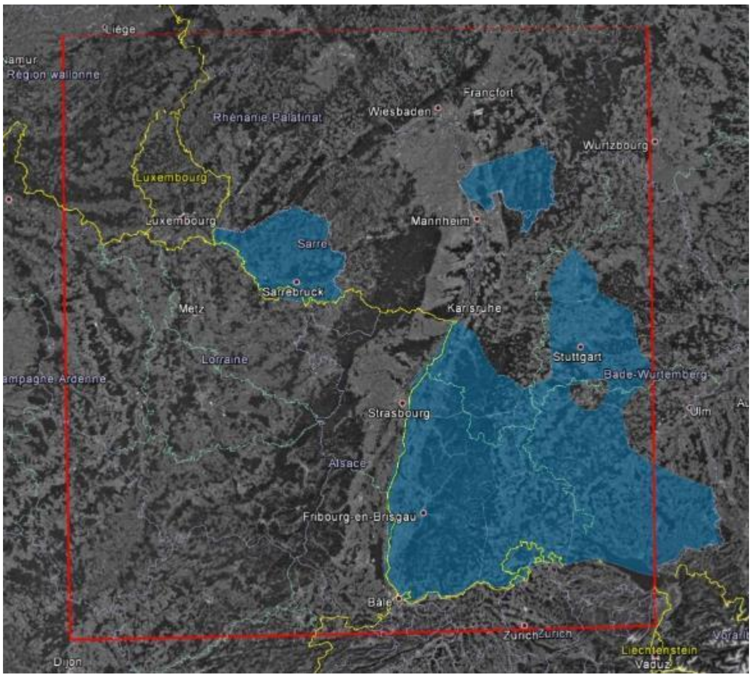


Figure D2: Geographical availability of contiguous DTT channels for Germany (blue), in the area under study (red)

In the state of the current coordinated frequency plan, involving numerous countries and their associated needs and constraints, the availability of pairs of contiguous DTT channels for a possible use by a 15 MHz LTE channel for 5G broadcast remains very limited both by frequency and geography constraints.