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Compatibility between TMMB System-L and DTTB systems in the 470-694 MHz band within the GE06 agreement

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REPORT ITU-R BT.2544-0

Compatibility between TMMB System-L and DTTB systems in the 470-694 MHz band within the GE06 agreement

(2024)

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List of abbreviations and acronyms

3GPP	3rd generation partnership project
ACS	Adjacent channel selectivity
CEPT	Conference of European Post and Telecommunications Administrations
C/*I*	Carrier-to-interferer ratio
C/*N*	Carrier-to-noise ratio
COFDM	Coded orthogonal frequency division multiplexing
DAB	Digital audio broadcasting
DTT	Digital terrestrial television
DTTB	Digital terrestrial television broadcasting
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
e.i.r.p.	Equivalent isotropically radiated power
ERP	Equivalent radiated power
FFT	Fast fourier transform
GE06	Geneva Agreement 2006
*GI	Guard interval
HPHT	High-power high-tower
ISDB-Tmm	Integrated services digital broadcasting – Terrestrial multimedia broadcasting for 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	Modulation error ratio
MFN	Multi frequency network
MPMT	Medium-power medium-tower
OFDM	Orthogonal frequency-division multiplexing
PLP	Physical layer pipes
PMCH	Physical multicast channel
PSM	Public service media
QAM	Quadrature amplitude modulation

RB	Resource block
RMS	Root mean squared
SFN	Single frequency network
SINR	Signal-to-interference plus noise ratio
TMMB	Terrestrial multimedia mobile broadcasting
WiB	Wideband reuse-1 based DTT concept

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.

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 2000s, 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, e.g. DVB H, MediaFlo, ISDB Tmm, DVB T2 Lite, have been unsuccessful.

The new technology called LTE-based 5G Terrestrial Broadcast, developed and specified as part of the general mobile communication technology of 3rd generation partnership project (3GPP) and included in ITU-R Recommendations and Reports under the name Terrestrial Multimedia Mobile Broadcasting (TMMB) System-L (abbreviated to “5G Broadcast” in this Report), 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 audiovisual 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 Digital terrestrial television (DTT) in the spectrum range 470-694 MHz.

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 470-694 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. e.i.r.p. reduction, polarisation, antenna adjustments) on 5G Broadcast sites, as needed.

2 5G Broadcast signals with bandwidth of 5 or 8 MHz can be deployed within the GE06 plan with minimal constraints. The 8 MHz option provides the highest efficiency of spectrum usage.

1 Introduction

TMMB System-L corresponds to LTE-based 5G Terrestrial Broadcast System. For the purpose of this Report, the term 5G Broadcast has been used for simplification.

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 (System-L) 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 Digital terrestrial television broadcasting (DTTB) networks designed for fixed reception using rooftop antennas), medium-power medium-tower (MPMT), transmitters (like most digital audio broadcasting (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 coded orthogonal frequency division multiplexing (COFDM), can operate in single frequency network (SFN) mode or in multi frequency network (MFN) mode, much like current DTTB systems based on COFDM.

In Region 1, the provisions of the Geneva 2006 Agreement (GE06) apply to the introduction of 5G Broadcast (System-L) within spectrum currently used for DTTB 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 (System-L) technologies by some countries while neighbouring countries retain DVB systems. Section 2 presents the identified scenarios of introduction of 5G Broadcast.

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

Section 5 provides an analysis of the possible 5G Broadcast band plans. Conclusions are provided in § 6, and further supporting information is provided in Annexes 1 to 4.

2 Scenarios for introducing 5G Broadcast in the 470-694 MHz band

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

Scenario 1 (applicable to Region 1): Use of coordinated GE06 DTTB entries by 5G Broadcast

In this scenario, 5G Broadcast transmissions could make use of existing GE06 allocations under section 5.1.3 of the GE06 Agreement (the so-called envelope concept). In this case they shall neither cause more interference than the original DTTB proposals nor claim more protection. This scenario assumes that some of the existing GE06 allocations in one area are unused by DTTB 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 (applicable to Region 1): Interleaved use in GE06

5G Broadcast transmissions could be introduced into the band alongside and between existing DTTB 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 DTTB transmissions are already used for programme making and special events (PMSE) services (primarily radio microphones for programme production). Further, many administrations use non-coordinated low-power DTTB in the spaces between GE06 allocations (e.g. for local TV).

Scenario 3: Band segmentation

By restricting DTTB 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 DTTB 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 DTTB entries by 5G Broadcast

The outgoing interference from 5G Broadcast into DTTB may not be an issue if the conditions for the use of the DTTB 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 DTTB 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 DTTB 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 DTTB 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 DTTB services. In such a case this service would have to:

– be compatible with existing DTTB services -that is, it will cause no material damage to the coverage of the existing DTTB, and

– be compatible with DTTB services in neighbouring countries.

The impact on existing DTTB will depend on the way DTTB has been planned in each country. For example, a study done by Arqiva, for the Wideband reuse-1 based DTT concept (WiB) DVB study mission, considered introducing an interleaved service in the United Kingdom [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 DTTB services subject to the following measures/conditions:

1) A power reduction of 20 dB relative to the DTTB (Public service broadcasting (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 DTTB on the same site, but cross-polar with the UK relay stations (generally using vertical polarization).

3) To offset interference, the DTTB network would need to be changed from Digital video broadcasting – first generation terrestrial (DVB-T) to Digital video broadcasting – second generation terrestrial (DVB-T2) with use of a more robust system variant, which would then only slightly increase the DTTB capacity compared to DVB-T.

These results apply only to the United Kingdom 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 than that of a HPHT network though not co-siting with the existing DTTB 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 DTTB sites (for example, France), the impact to existing DTTB coverage will be higher than the UK example above, as no polarization discrimination could be considered between the new system and DTTB.

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

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

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 signal-to-interference plus noise ratio (SINR) to cover the same population as DTTB 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 DTTB would be a mixture of the following:

1 Reduction of power on the HPHT sites compared to DTTB or using different antenna patterns or polarization. These changes will depend on the existing DTTB 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 470-694 MHz band for use by 5G Broadcast, such use would need to co-exist with existing DTTB 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 and 2

4.1.1.1 Impact on DTTB

For Scenarios 1 and 2, the protection of DTTB reception requires adequate measures to solve the hole-punching issue[1, 2]. 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 digital video broadcasting - hand held (DVB-H) in the UHF band in Italy.
2) Non-co-located DAB or DTTB transmitters in several countries.
3) The introduction of white space devices in the interleaved spectrum (this is relevant mostly for Scenario 2).

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

– Appropriate site selection, avoiding where possible proximity with existing DTTB receiving antennas. Co-siting between DTTB and the 5G Broadcast is the preferred option.
– Appropriate design of the transmit power and antenna patterns to minimize impact on DTTB 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 DTTB 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 DTTB active receiving installation. In the experience of DVB-H in Italy, on average, one to two DTTB receiving installations per DVB-H site required filtering (using one or two notch filters). In the experience of introducing LTE800 in France, on average four to five DTTB 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

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

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

DTTB 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 DTTB, 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 DTTB 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 DTTB 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 DTTB

For the protection of existing DTTB 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 DTTB.

– In some cases, appropriate filtering of the DTTB 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 DTTB 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 DTTB 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 DTTB 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 5G Broadcast receiver adjacent channel selectivity

Knowledge of the 5G Broadcast receiver adjacent channel selectivity (ACS), i.e. its ability to reject signals of services operating in adjacent channels, is required to assess service areas of 5G Broadcast transmitters.

The ACS value from 3GPP is as follows:

Adjacent channel selectivity for LTE based 5G terrestrial broadcast

Rx parameter	Units	PMCH bandwidth		
		6 MHz	7 MHz	8 MHz
ACS	dB	29.0	30.5	31.5

5 5G Broadcast band plans assessment

This section shows an evaluation of several band plans considered in studies on 5G Broadcast introduction in the 470-694 MHz band.

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

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

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

Section 5.4 provides conclusions and recommended further studies.

Detailed and supporting material are provided in the Annexes:

– Annex 1: Measurement of adjacent and overlapping channels protection ratios.

– Annex 2: Detailed calculation results.

– Annex 3: 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 470-694 MHz band for DTTB and country B replacing some of its existing or planned DTTB 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 Fig. 1 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 equivalent radiated power (ERP) to serve the cell with a DTTB 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 Fig. 1) 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. It is also considered 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, 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 Fig. 2 and in blue in for the blue cell in Fig. 3. 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 DTTB (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 DTTB channel in the neighbouring cell) and the old protection ratio (between the initially planned DTTB channel in the analysed cell and the concerned DTTB channel in the neighbouring cell). The protection ratios for the adjacent and overlapping channels are determined by measurements. (See Annex 1.) (See Annex 3 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 1

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

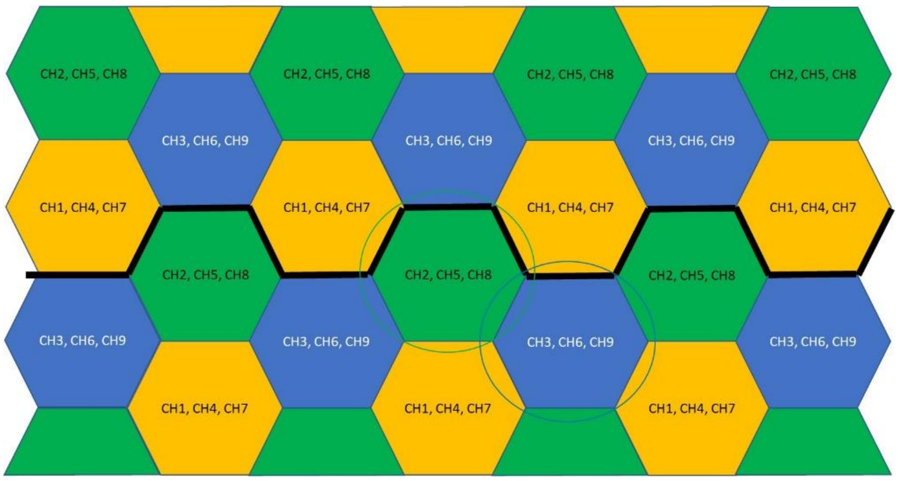


FIGURE 2

Retained channels in each considered band plan, for the Green circled border cell in Fig. 1

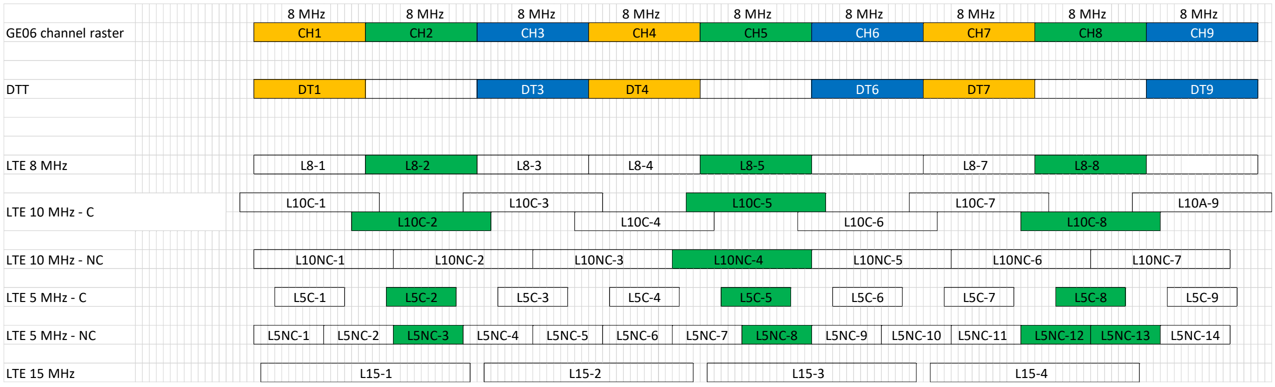
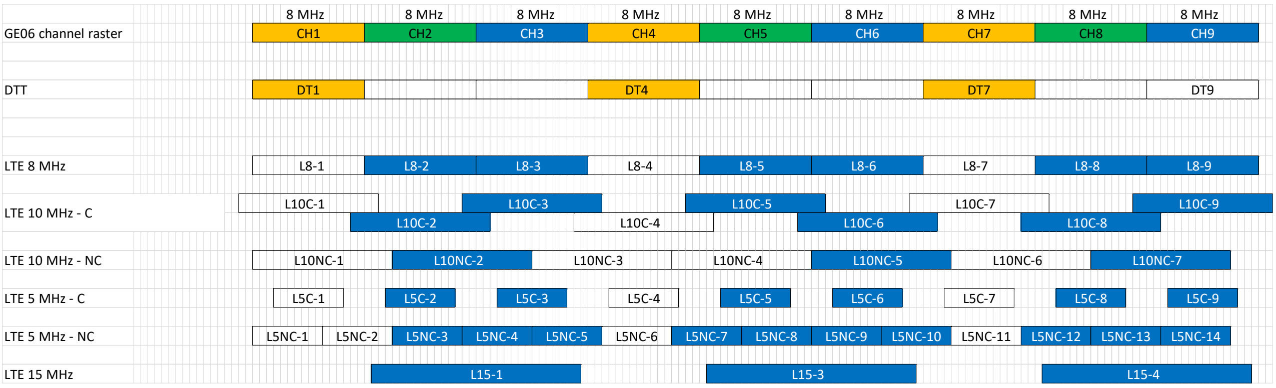


FIGURE 3

Retained channels in each considered band plan, for the Blue circled border cell in Fig. 1



5.1.2 Summary of the quantitative evaluation

Tables 1 and 2 show the available total bandwidth and the required power reduction relative to the planned DTTB channel(s), for each band plan options and for the two analysed cells.

TABLE 1

Summary of the evaluation of 5G band plans for the green circled border cell in Fig. 1

Green border cell	Potential available total bandwidth and power reduction relative to planned DTTB	
	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 available 8 MHz channels	0	

TABLE 2

Summary evaluation results of 5G band plans for the blue circled border cell in Fig. 1

Blue border cell	Potential available bandwidth and power reduction relative to planned DTTB	
	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 2 for explanation).

2) Using centred 5 MHz 5G Broadcast channels with only 1 dB power reduction offers capacity 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 DTTB 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 DTTB channels in the neighbouring cross border cells.

The detailed calculation and results are provided in Annex 2.

5.2 The GE06 envelope concept (applicable to Region 1)

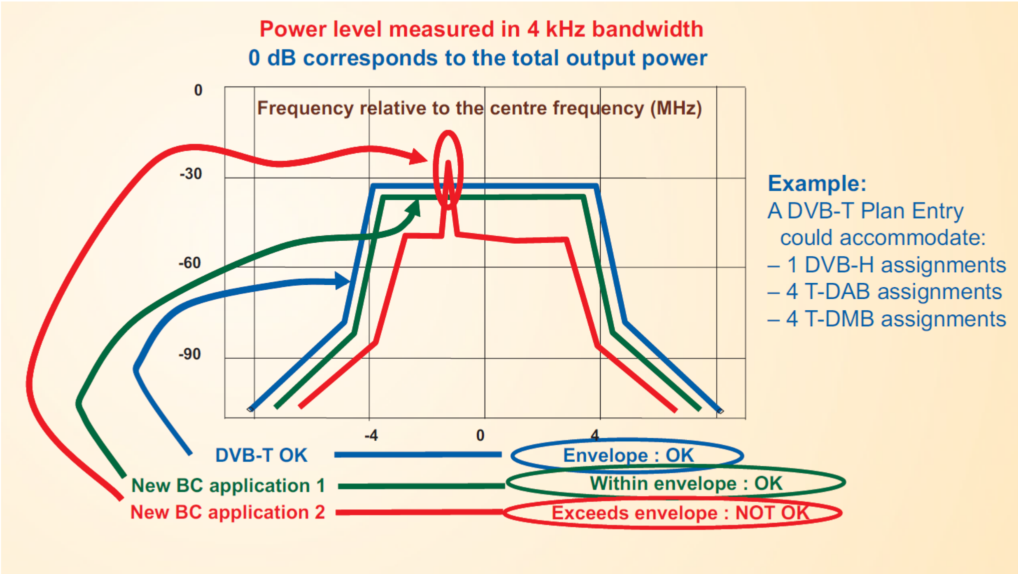
The ‘envelope concept’ has been introduced in the GE06 agreement to allow the use of a digital plan entry by another broadcasting technology than DVB-T or even by a technology for other services. The envelope concept is described in the agreement as follows (Article 5, clause 5.1.3 of the GE06 Final Acts [4]):

"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 4 illustrates this concept (extract from EBU Tech Review 308 – Overview of the Second Session (RRC-06) – October 2006 [5]).

FIGURE 4

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 [4] "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 [4] section 3.6.2 (Fig. 3-3 and Table 3-11, reproduced below under Fig. 5 and Table 3). 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 5

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

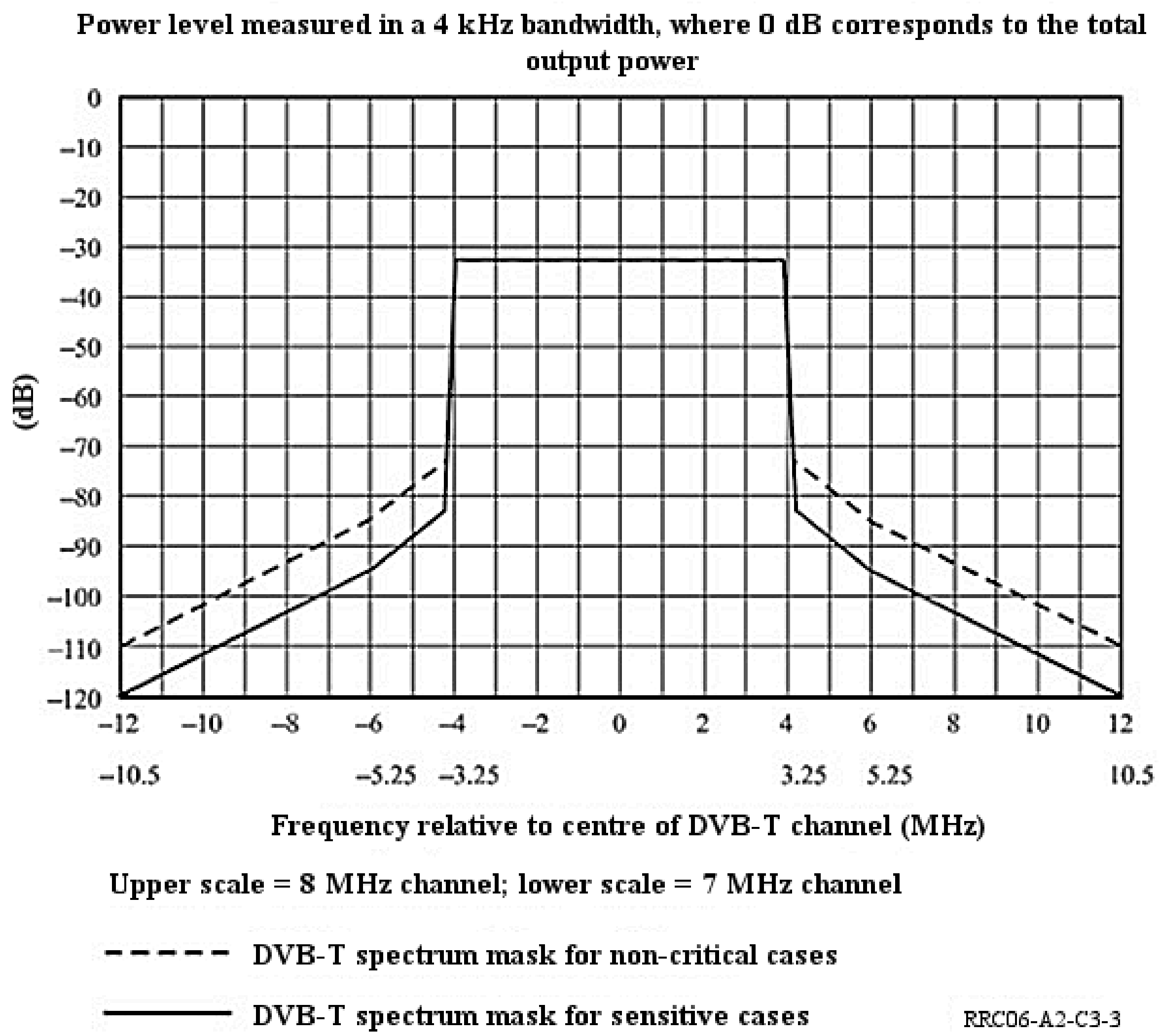


TABLE 3

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

TABLE 3 (*end*)

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)
−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 DTTB 8 MHz channel (see line LTE 10 MHz – C in Fig. 3)

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 DTTB 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 DTTB and 5G Broadcast.

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

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

The first and fourth 10 MHz 5G Broadcast block will overlap the upper adjacent DTTB channel (the second DTTB 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 DTTB service of the 10 MHz 5G Broadcast block will be significantly higher than that caused by an 8 MHz DTTB channel (see § 5.1).

The second 10 MHz 5G Broadcast block overlaps the second and third frequency DTTB 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 DTTB 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 MHz 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.

8 MHz has been added as a standardized bandwidth in 3GPP in 2023 (see ETSI TS 103 720 V1.2.1 (2023-06) (https://www.etsi.org/deliver/etsi_ts/103700_103799/103720/01.02.01_60/ts_103720v010201p.pdf) section 5.5.4, last indent on page 30).

The use of the 10 MHz bandwidth in the 470-694 MHz band is subject to several major constraints:

– power reduction to protect DTTB 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 DTTB.

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 DTTB 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 DTTB services:

Scenario 1: Use of coordinated GE06 DTTB 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 DTTB entries by 5G Broadcast) –applicable in Region 1 – seems to be the most practical for early introduction of 5G Broadcast in the 470-694 MHz band. The compatibility between 5G Broadcast and DTTB in this scenario, including at border areas between neighbouring countries, is manageable with the same mitigation measures and solutions currently applied to DTTB networks.

2 5G Broadcast signals with bandwidth of 5 MHz or 8 MHz can be deployed within the GE06 plan in Region 1 with minimal constraints. An 8 MHz option provides the highest efficiency of spectrum usage.

7 References

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

[2] Report ITU-R BT.2301, 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] 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.

[5] EBU Technical Review 308, GE06 – Overview of the Second Session (RRC-06), October 2006.

Other references

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.

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.

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.

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

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

Annex 1

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 DTTB (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 orthogonal frequency-division multiplexing (OFDM) service (DTTB or LTE) overlapping a wanted DTTB service (DVB-T and 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 DTTB 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 § 2.

1 DVB-T as wanted system

TABLE A1-1

DVB-T 64-QAM ¾ 8K interfered with by DTTB

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)				
Frequency (MHz)	**Measured**	**Corrected**	**Protection ratio (dB)**	**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		

TABLE A1-1 (*end*)

Frequency (MHz)	Measured	Corrected	Protection ratio (dB)	Overlap (MHz)	
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 A1-1

DVB-T 64-QAM 3/4 8K interfered with by DTTB

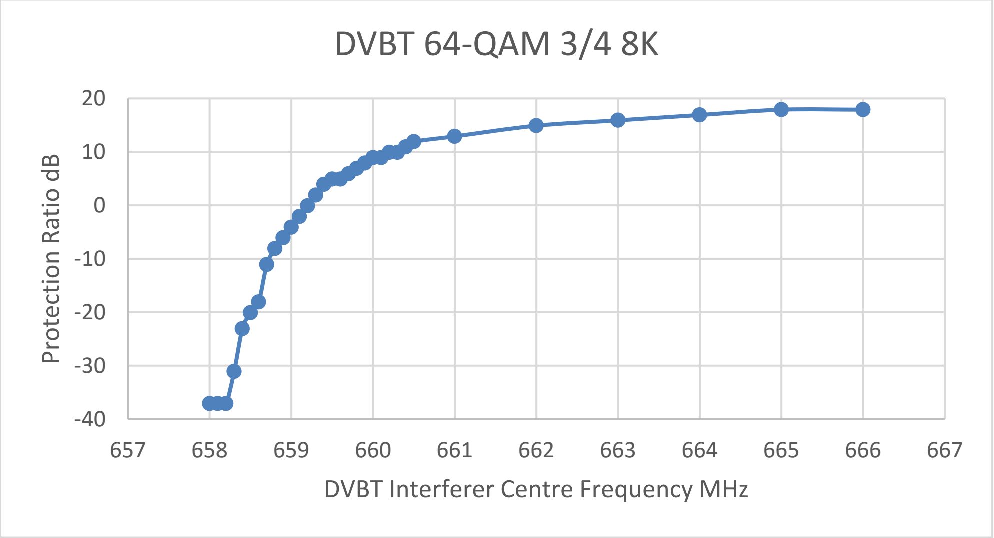


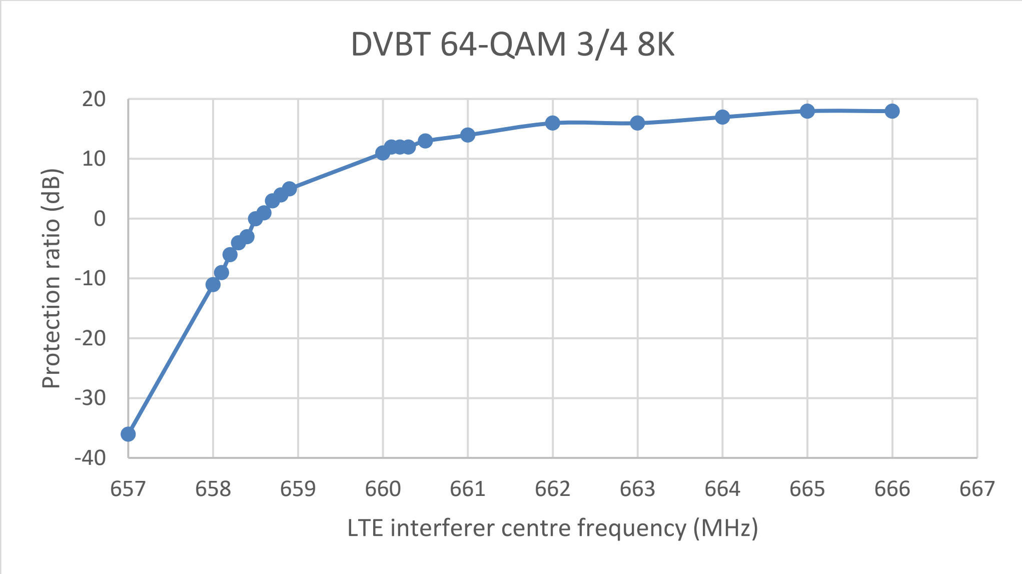
TABLE A1-2

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)			
Frequency (MHz)	**Measured**	**Corrected**	**Protection ratio (dB)**	**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 A1-2

DVB-T 64-QAM 3/4 8K interfered with by LTE 10 MHz



2 DVB-T2 as wanted system

2.1 Measurements done by Arqiva

TABLE A1-3

DVB-T2 256-QAM 2/3 32K interfered with by DTTB

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)			
Frequency (MHz)	**Measured**	**Corrected**	**Protection ratio (dB)**	**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	

TABLE A1-3 (*end*)

Frequency (MHz)	Measured	Corrected	Protection ratio (dB)	Overlap (MHz)	
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 A1-3

DVB-T2 256-QAM 2/3 32K interfered with by DTTB

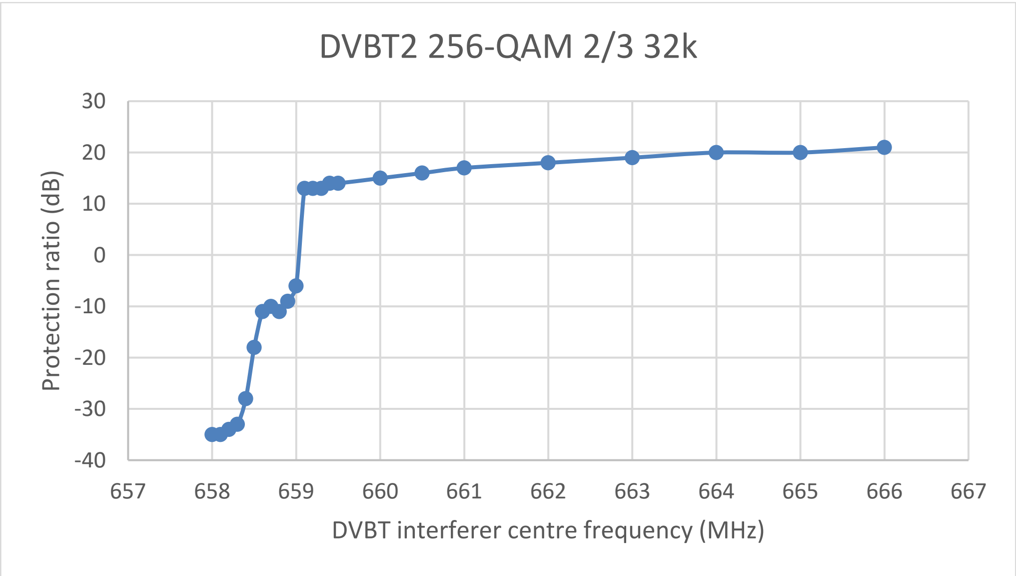


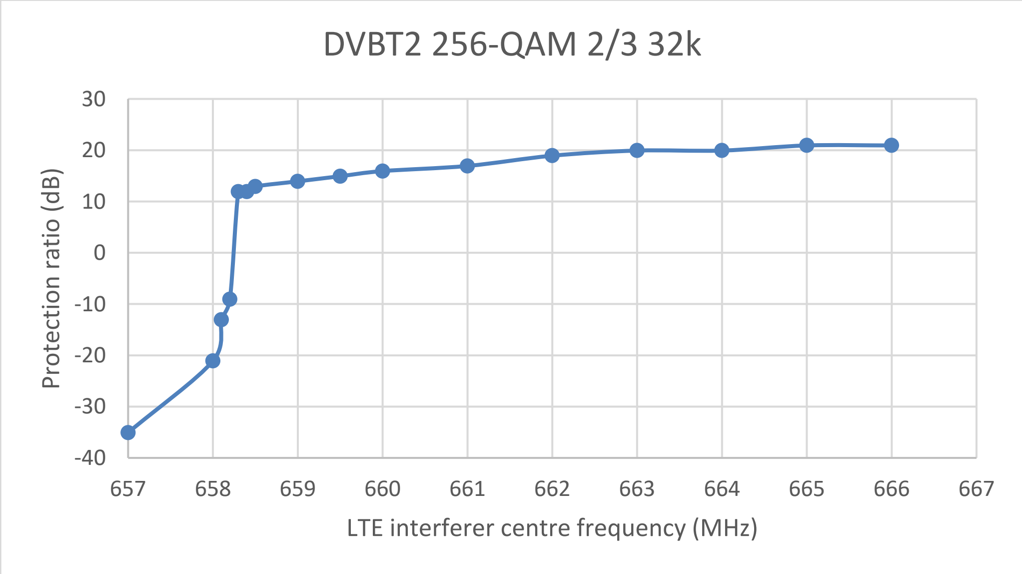
TABLE A1-4

DVB-T2 256-QAM 2/3 32K interfered with by 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)				
Frequency (MHz)	**Measured**	**Corrected**	**Protection ratio (dB)**	**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 A1-4

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



2.2 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 DTTB 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, this signal cannot be received with an LTE receiver.

Short description

SFU is generating a DVB-T2 signal with the (main) parameters in Table A1-5.

TABLE A1-5

Main DVB-T2 parameters

Parameter	Value	Note
Centre frequency	666 MHz	UHF CH 45
Bandwidth	8 MHz	
Nldpc	64 800	
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 Channel Power (CP) function of the receiver. See Figs A1-5 and A1-6.

FIGURE A1-5

Channel power (useful signal)

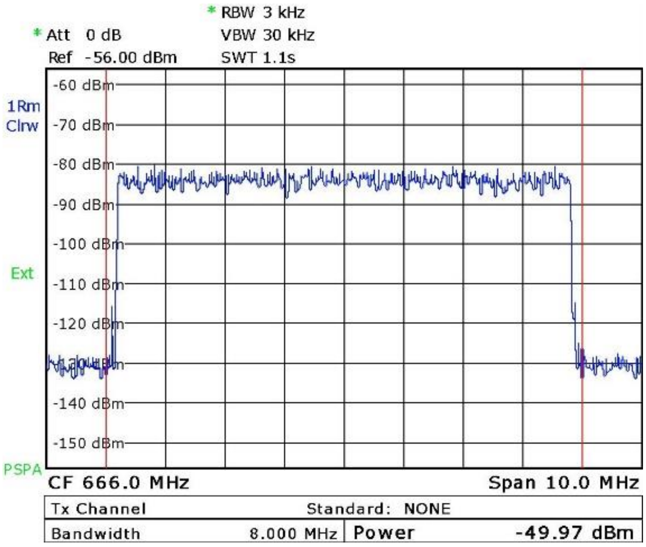


FIGURE A1-6

Received parameters

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)**		

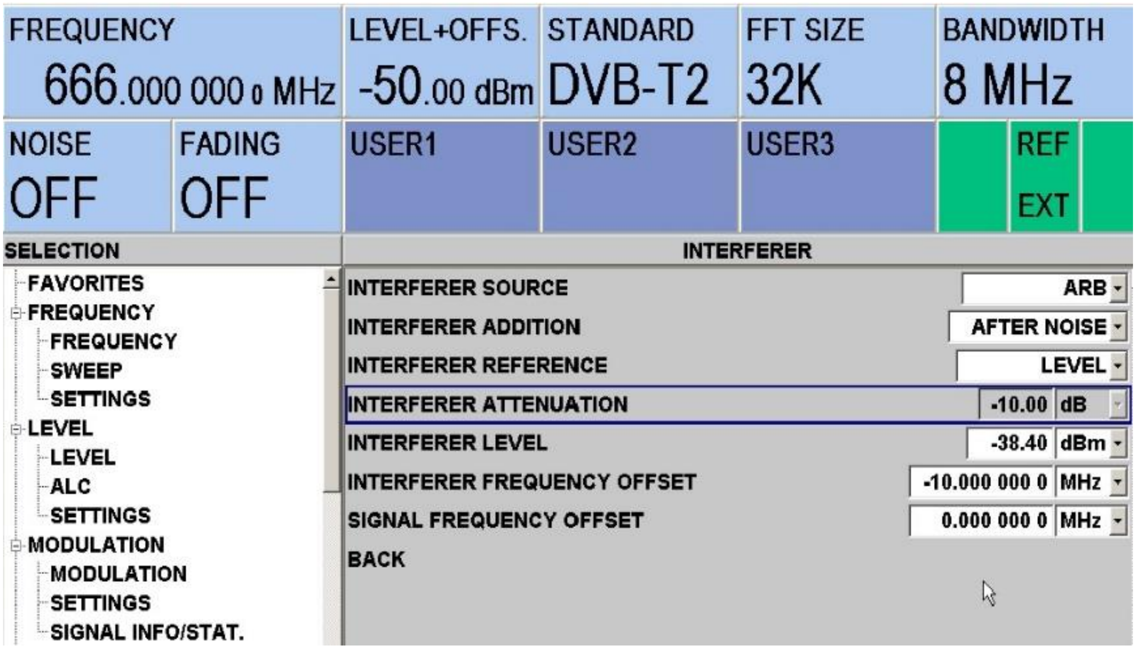
Lvl –49 dBm | BER 0.0E-9 | MER 40.2 dB DEMOD PLP:1

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

As a starting point, the frequency offset of the LTE to the DTTB 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 DTTB 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 Fig. A1-7.

FIGURE A1-7

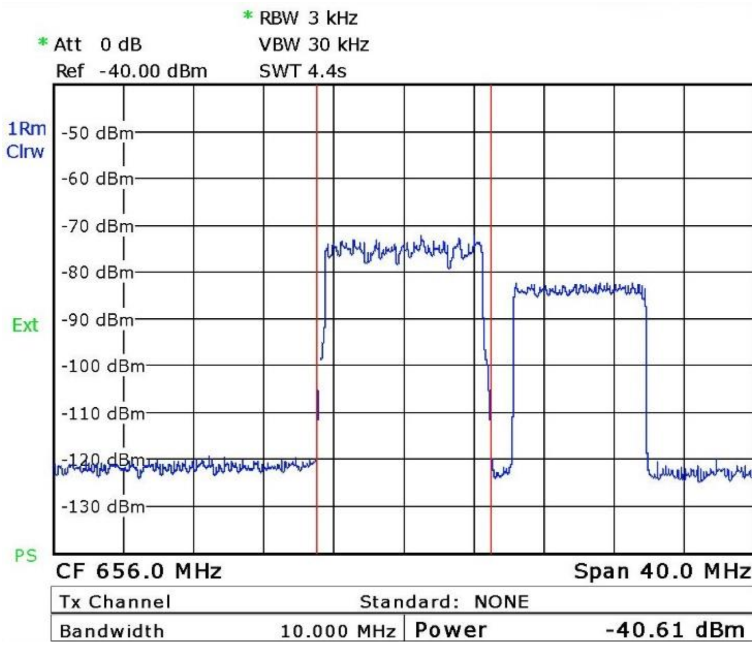
Setting the ARB generator



The level of the LTE signal is checked with the CP function of the receiver. See Fig. A1-8.

FIGURE A1-8

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[3].

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 DTTB parameters are registered.

Some results

Figure A1-9 shows the value of the protection ratio (PR) 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.

[3] 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.

FIGURE A1-9

Protection ratio (PR) values, function of the LTE Centre frequency

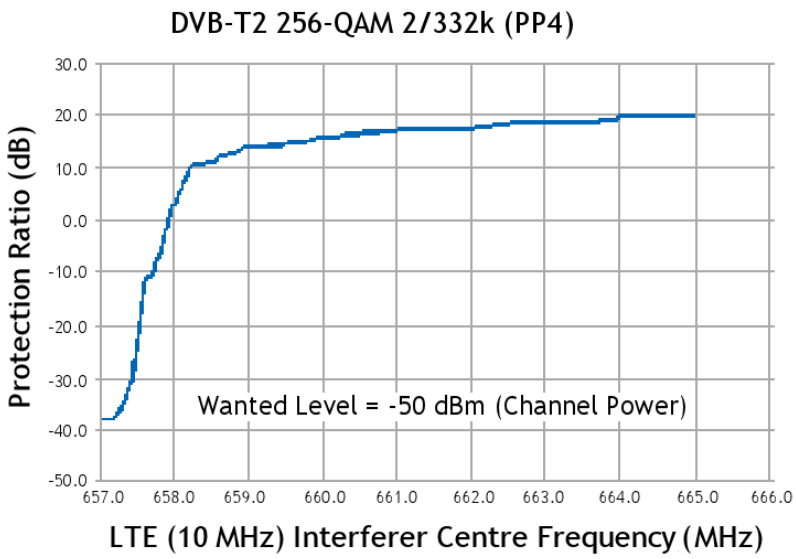


Table A1-6 is a (partial) summary of the results. Note that the value of MER PLP (root mean squared (RMS) value, dB) is a function of the percentage of overlapping; an example is shown in Fig. A1-10.

TABLE A1-6

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

FIGURE A1-10

MER (rms) example 1

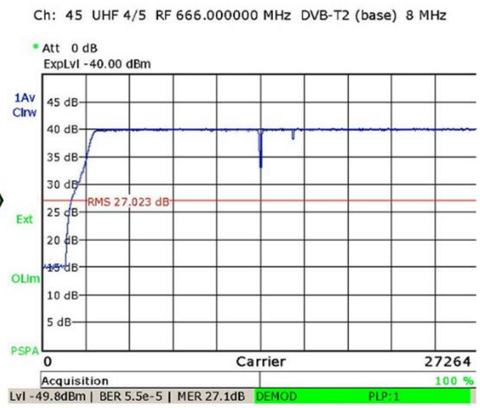


TABLE A1-6 (*end*)

Δ*f* (MHz)	Results of measurements					*f*	Δ*f* (MHz)	Protection ratio (dB) yellow interp. Val.
	Iter. Numb.	BER before LDPC	BER before BCH	MER PLP (dB)	MER L1 (dB)			
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

Table A1-7 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 Fig. A1-11.

TABLE A1-7

Summary of the results (first part)

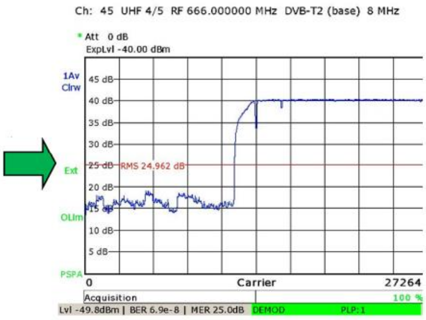
Δ*f* (MHz)	Results of measurements					*f*	Δ*f* (MHz)	Protection ratio (dB) yellow interp. Val.
	Iter. Numb.	BER Before LDPC	BER Before BCH	MER PLP (dB)	MER L1 (dB)			
5.9						660.1	5.9	15.8
5.8						660.2	5.8	16.0
5.7						660.3	5.7	16.2
5.6						660.4	5.6	16.4
5.5				26.0		660.5	5.5	16.6
5.4						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

TABLE A1-7 (*end*)

	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.**
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 A1-11

MER (rms) example 2



Annex 2

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

TABLE A2-1

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	3 × 8	0	−36.1	1.0
L10C-2, L10C-5, L10C-8	3 × 10	0.305	−11.0	26.1
L10NC-4	10	1.305	5.5	42.6
L5C-2, L5C-5, L5C-8	3 × 5	0	−36.1	1.0
L5NC-3, L5NC-8	2 × 5	0	−36.1	1.0
L5NC-12, L5NC-13	2 × 5	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	6 × 8	0	−36.1	1.0
L10C-2, L10C-3, L10C-5, L10C-6, L10C-8, L10C-9	6 × 10	0.305	−11.0	26.1
L10NC-2, L10NC-7	2 × 10	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	6 × 5	0	−36.1	1.0
L5NC-3, L5NC-4, L5NC-8, L5NC-9, L5NC-13, L5NC-14	6 × 5	0	−36.1	1.0
L5NC-5, L5NC-12	2 × 5	0.555	−5.1	32.0
L5NC-7, L5NC-10	2 × 5	1.555	6.9	44.0
L15	3 × 15	0	−36.1	1.0

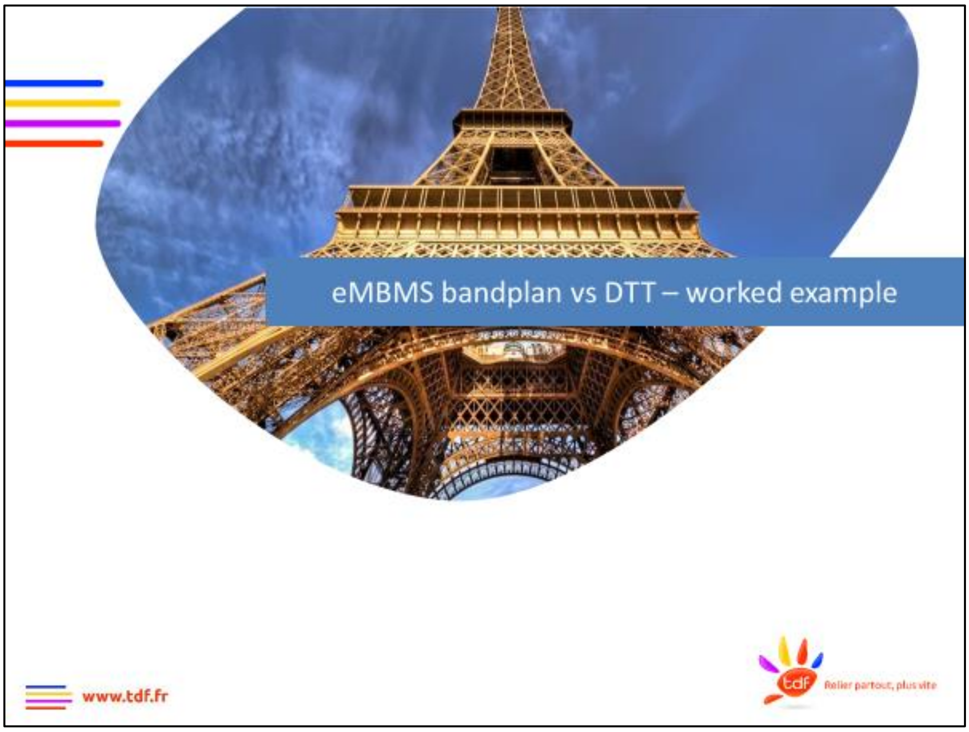
DVB-T active bandwidth (MHz)	7.61
LTE 10 MHz active bandwidth (MHz)	9

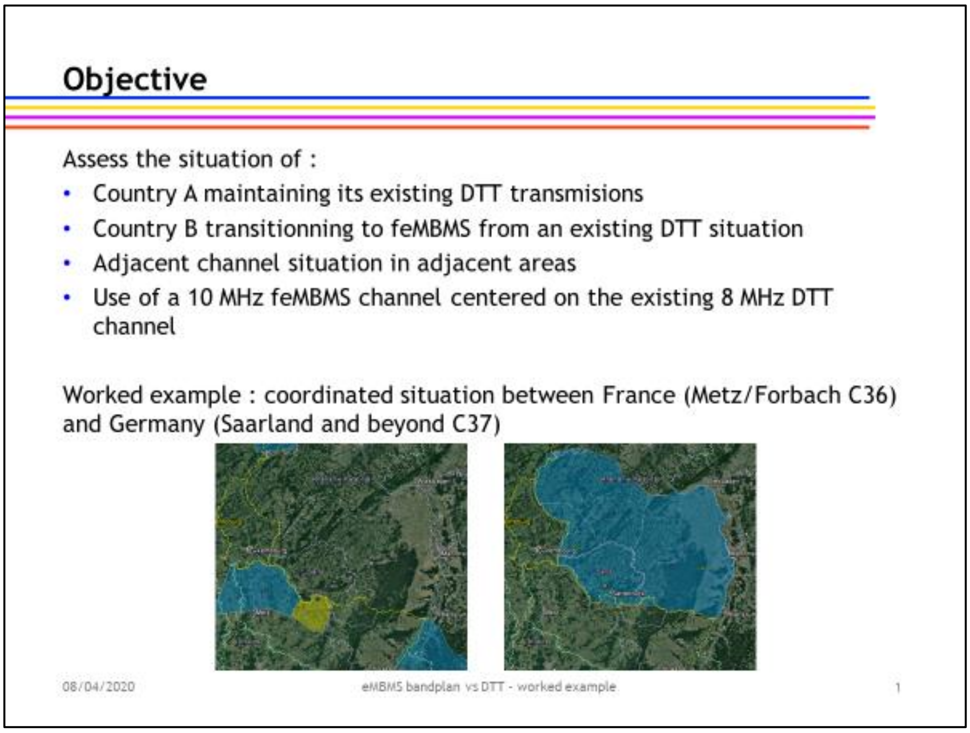
PR DVB-T vs DVB-T adjacent channel	−37.1

Note to Table A2-1: The power reduction is calculated using as reference the protection ratio for DVB-T interfered with by DVB-T (37.1 dB, from Table A1-1). 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 A1-2).

Annex 3

Example of the calculation of power reduction in a real case





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

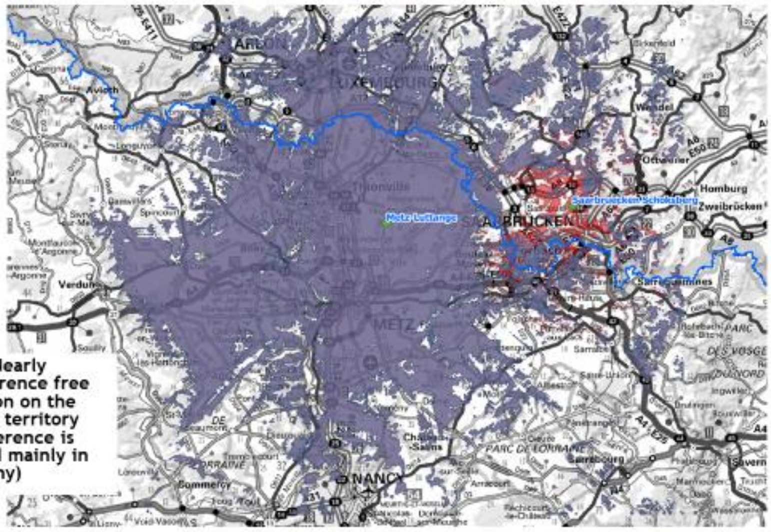
Assessment of the impact on the French side

- 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)

System	Channel 35	Channel 36	Channel 37	Channel 38 (RA 608-614)
	583 584 585 586 587 588 589	590 591 592 593 594 595 596 597	598 599 600 601 602 603 604 605	606 607 608 609 610 611 612 613
DTT - Non Extended (T/T2)	582,195 - 589,805	590,195 - 597,805	598,195 - 605,805	606,195 - 613,805
DTT - Extended (T2)	582,115 - 589,885	590,115 - 597,885	598,115 - 605,885	606,115 - 613,885
feMBMS aligned	581,5 - 590,5		597,5 - 606,5	
		589,5 - 598,5		605,5 - 614,5

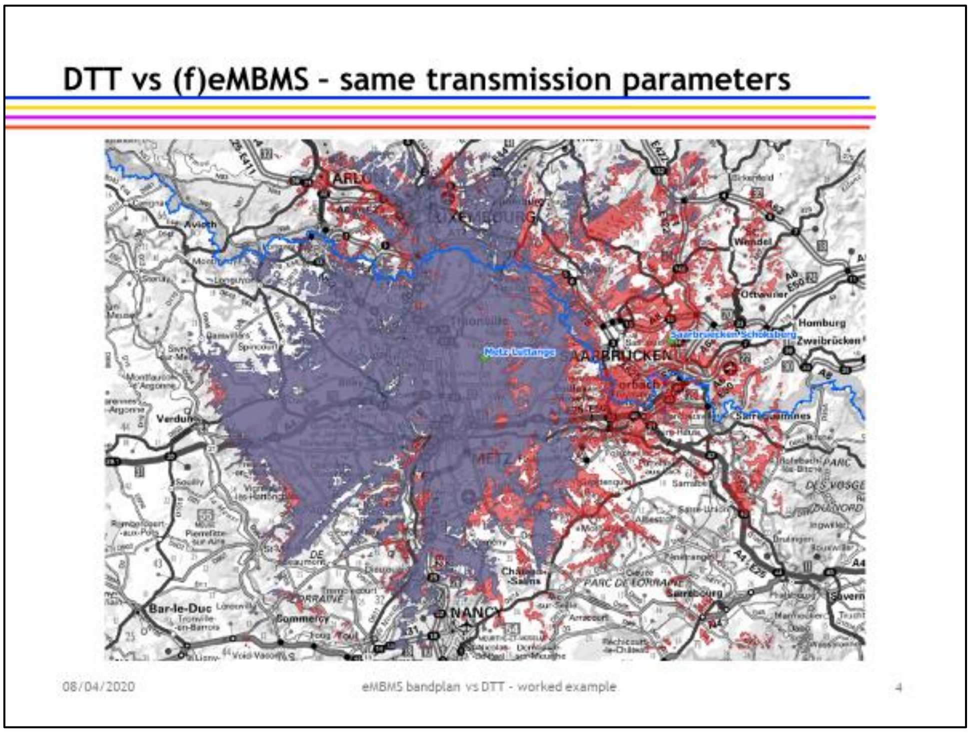
08/04/2020 eMBMS bandplan vs DTT - worked example 2

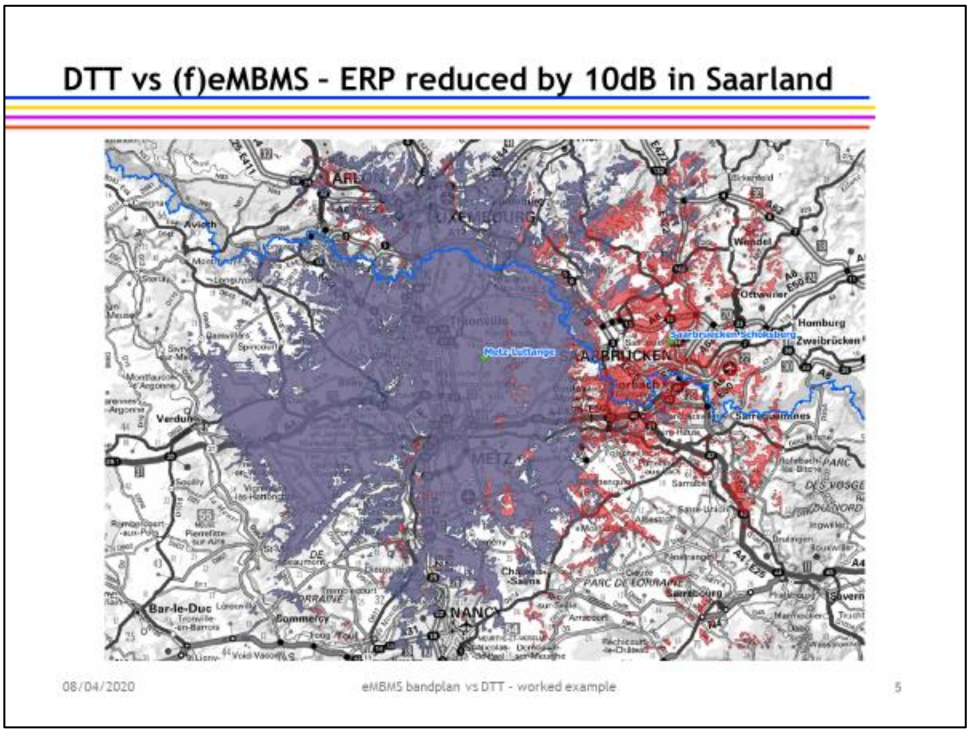
DTT vs DTT - existing situation (red = interference)

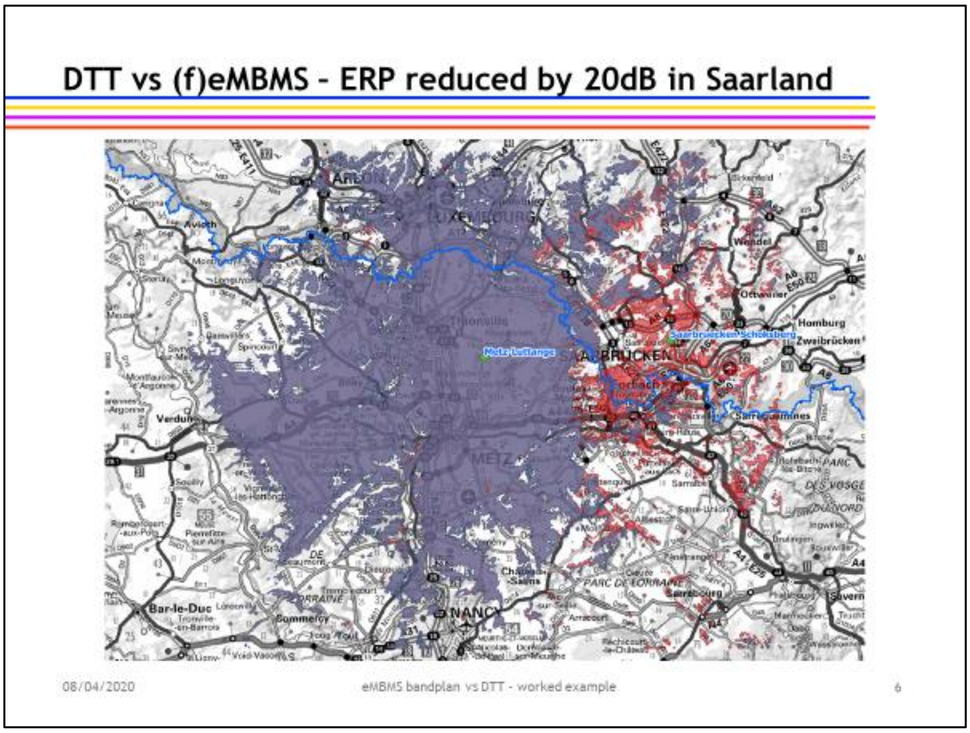


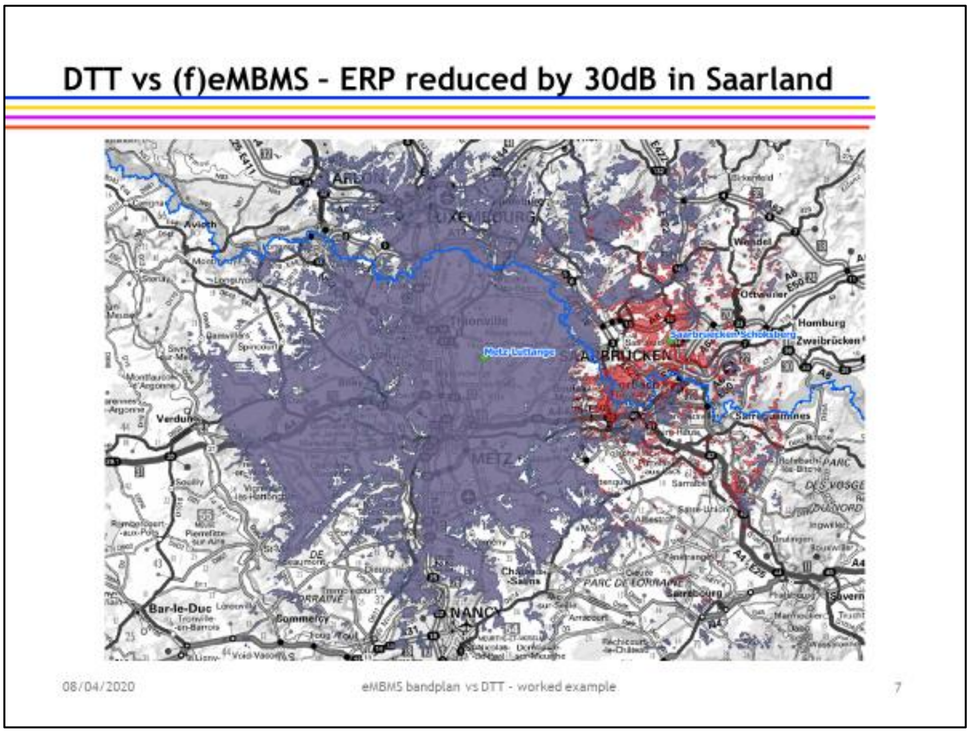
Nota: Nearly interference free situation on the French territory (interference is located mainly in Germany)

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

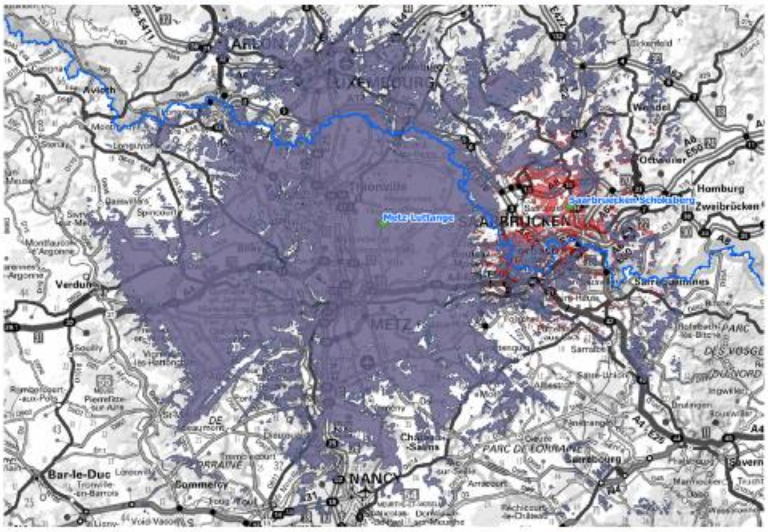

DTT vs (f)eMBMS – same transmission parameters
08/04/2020
eMBMS bandplan vs DTT - worked example
4


DTT vs (f)eMBMS – ERP reduced by 10dB in Saarland
08/04/2020
eMBMS bandplan vs DTT - worked example
5


DTT vs (f)eMBMS – ERP reduced by 20dB in Saarland
08/04/2020
eMBMS bandplan vs DTT - worked example
6


DTT vs (f)eMBMS – ERP reduced by 30dB in Saarland
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 4

Identifying contiguous DTTB channels at the border between Germany and France

In the context of possible band plans identification for 5G Broadcast in the 470-694 MHz band, one option being considered is the accommodation of 15 MHz LTE channels within 2 × 8 MHz DTTB channels. For the countries considering the implementation of such a band plan, this requires the identification of contiguous DTTB 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 DTTB 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, 29 April 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 Fig. A4-1.

FIGURE A4-1

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

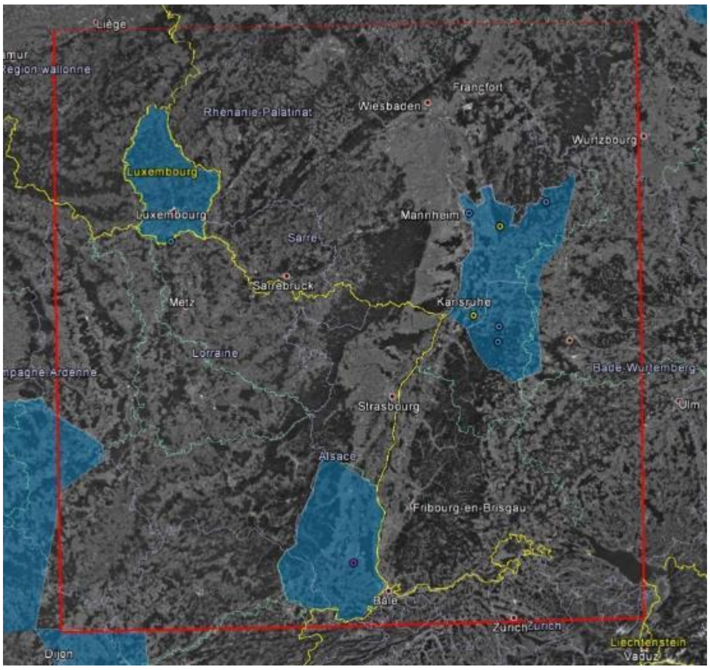


Table A4-1 presents the possible contiguous channel arrangements that were identified based on the above information, using the following approach: All contiguous channel pairs are considered as viable at this stage, meaning the 15 MHz LTE signal would have to use an 8 MHz raster starting at the boundary between channel 21 and 22 (478 MHz) and ending at the boundary between channel 47 and 48 (686 MHz).

TABLE A4-1

Evaluation of the number of areas that can effectively host a 2 × 8 MHz channels configurations, in the area of interest shown in Fig. A4-1

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	

TABLE A4-1 (*end*)

Channel pairs	France		Germany	
	Planned areas	Effective areas	Planned areas	Effective areas
47-48	4	1 (Alsace-Nord)	4	
Total	77	7[4]	85	8[5]
		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 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 2 × 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 A4-2 (composite view of all the areas where a contiguous channel pair is available) shows where such contiguous channels are available in Germany. While Table A4-1 highlights the

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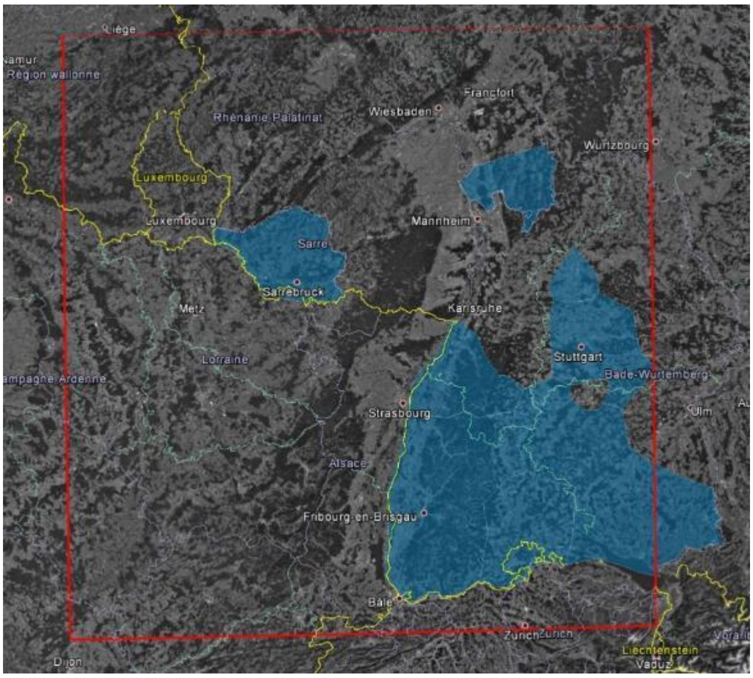
4 Some contiguous channel pairs might not be usable if they are used in the same area; this is not the case for France as the relevant contiguous channel pairs (33-34 / 34-35 and 46-47 / 47-48) are used in different areas.

5 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 are 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.

frequency limitation associated to the identification of effectively usable areas, this map shows the geographical limitation of such availability.

FIGURE A4-2

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 DTTB channels for a possible use by a 15 MHz LTE channel for 5G broadcast remains very limited both by frequency and geography constraints.