Harmonised spectrum for 4th generation mobile communication networks in Europe: Band-plans and technical conditions

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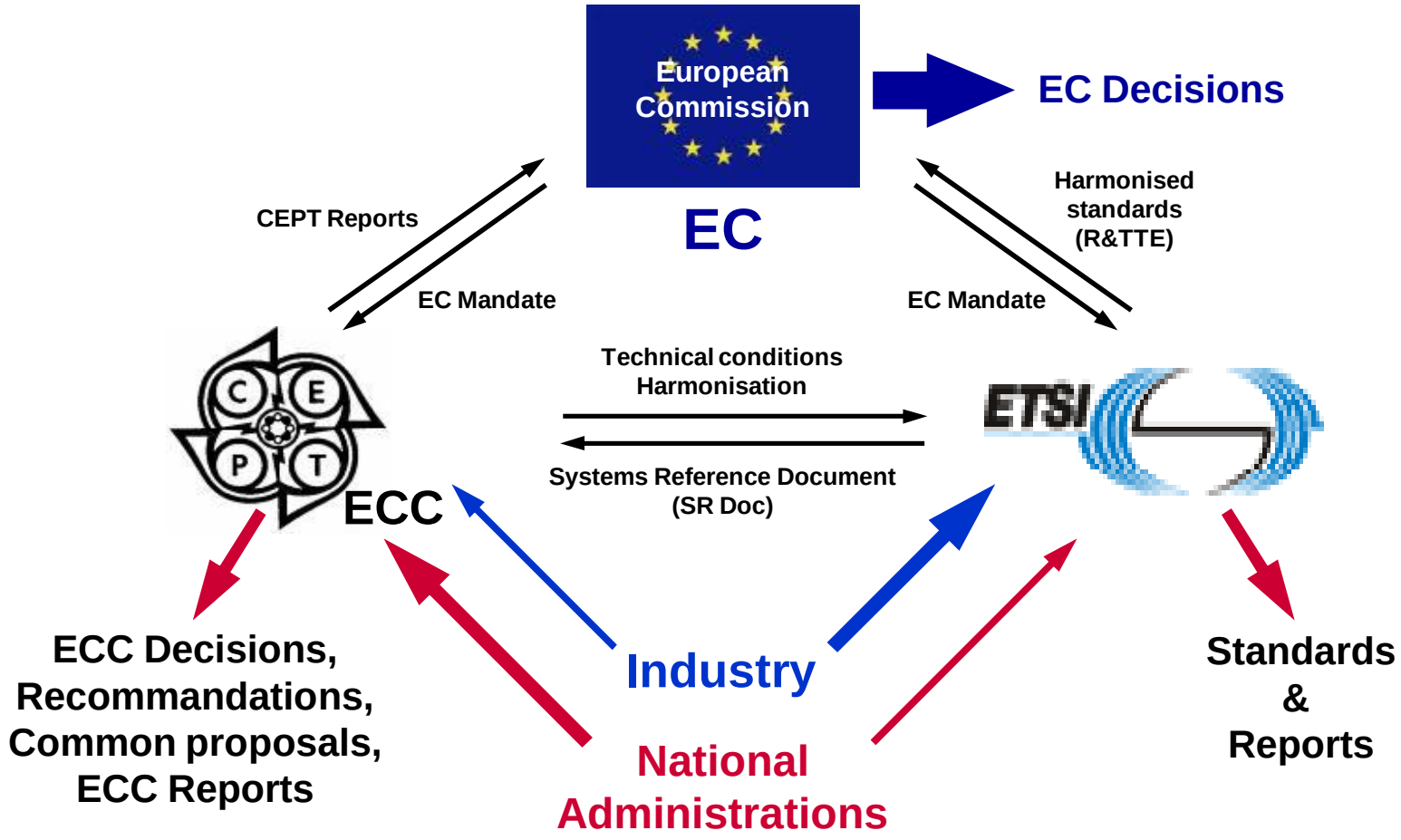
Outline

- Introduction
- The 2.6 GHz band
- The 800 MHz band (Digital Dividend)
- Legacy mobile communications spectrum
- Conclusions

New spectrum for mobile communications

- Mobile communication networks today use frequencies at 900 MHz, 1800 MHz and 2.1 GHz for 2G and 3G technologies.
- Over the past two years the Conference of European Post & Telecommunications Administrations (CEPT) has specified band-plans and technical conditions for two new bands for use by mobile communications networks.
- These new bands consist of:
  - 190 MHz at 2.6 GHz.
  - 72 MHz at 800 MHz (so-called Digital Dividend).
- In this presentation we describe details of the technical conditions defined by CEPT for the 2.6 GHz and 800 MHz bands, and also briefly describe CEPT activities for the liberalisation of the 900 MHz, 1800 MHz, and 2.100 GHz bands.

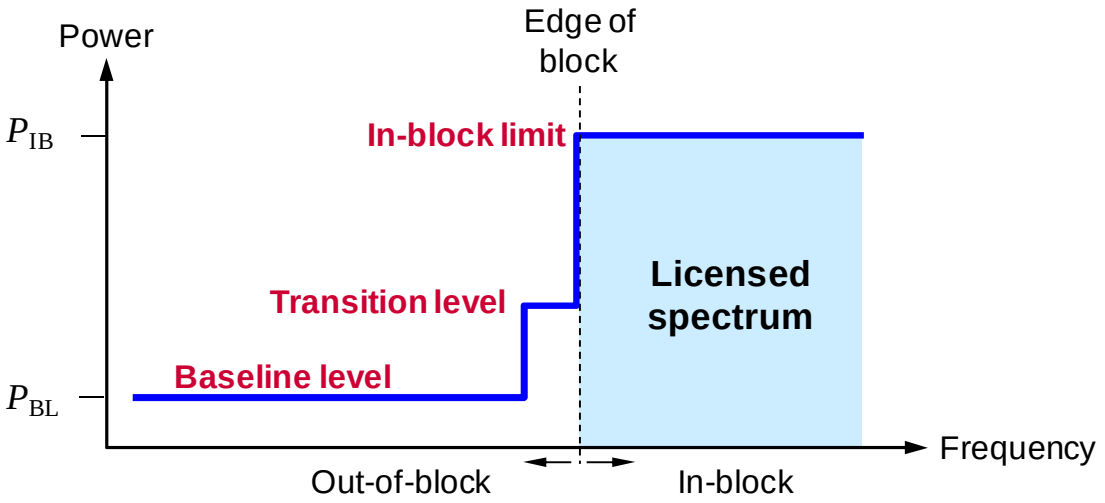
European spectrum harmonisation process



Websites:
www.ero.dk (CEPT)
www.etsi.org (ETSI)
http://ec.europa.eu/information_society/policy/ecomm/radio_spectrum/ (EC)

Technical conditions defined by CEPT: block edge masks

- CEPT defines the technical conditions for the use of a band in the form of block-edge masks (BEMs). These are specified for the purposes of spectrum licensing and the avoidance of interference from between services in adjacent frequencies.
- A BEM is a *regulatory* emission mask that is defined, as a function of frequency, relative to the edge of a block of spectrum that is licensed to an operator.
- A BEM consists of in-block and out-of-block components which specify the permitted radiation levels over frequencies inside and outside the licensed block of spectrum, respectively.



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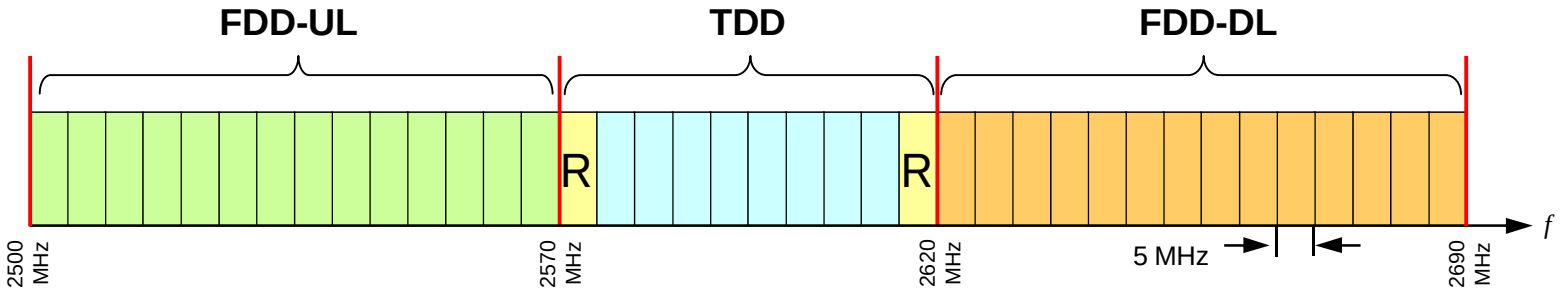
EC mandate on the 2.6 GHz band

- In 2006, the EC issued a mandate to CEPT to develop least restrictive technical conditions for the use of a number of frequency bands (including the 2.6 GHz band) addressed in the context of WAPECS.
- This included the 2.6 GHz band, consisting of 190 MHz of spectrum spanning 2500 – 2690 MHz.
- In 2007, CEPT SE42 published Report 19 in response to the EC mandate, specifying technical conditions in the form of block edge masks (BEMs) for base stations (BSs) and terminal stations (TSs) operating in the 2.6 GHz band.
- In response to comments raised during the public consultation of CEPT Report 19, CEPT SE42 performed further studies on the required TS BEMs, and the impact of TS-to-TS interference in the 2.6 GHz band. These further studies resulted in the publication of ECC Report 131.
- In what follows, we summarise the results of the above studies performed by CEPT/ECC, in which Ofcom took a leading role.

Harmonised channelling arrangement (1)

- ECC Decision (05)05 and EC Decision 2008/477/EC describe a channelling arrangement which allows use of spectrum for both FDD and TDD systems.

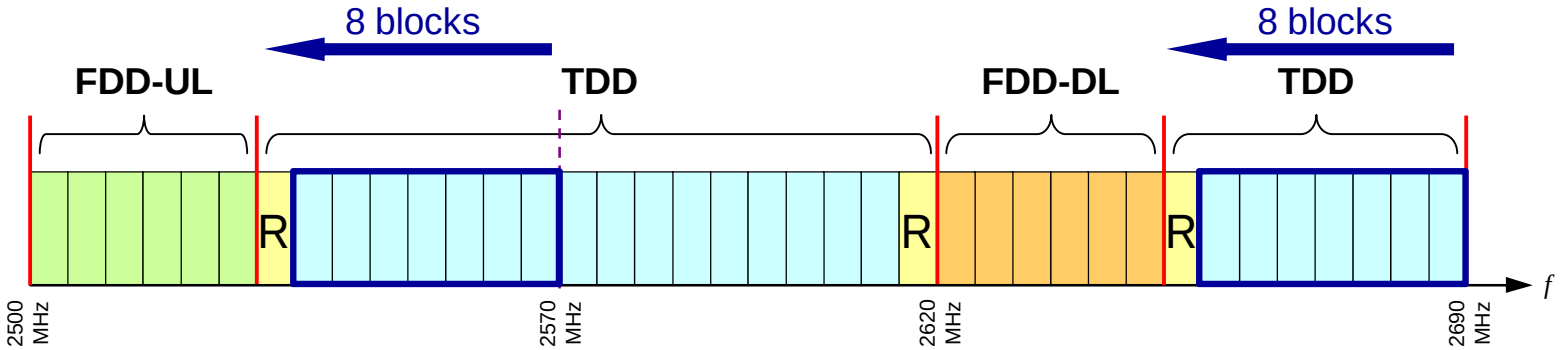


Victim: FDD base station (BS)	Victim: TDD BS/TS	Victim: FDD terminal station (TS)
BS → FDD BS	BS → TDD TS **BS → TDD BS**	BS → FDD TS
TS → FDD BS	TS → TDD BS **TS → TDD TS**	**TS → FDD TS**

- Based on CEPT Report 19, a 5 MHz *restricted* block is required at a) boundaries between FDD & TDD networks, and b) boundaries between TDD networks.
- These restricted blocks can be used with no guarantees of freedom from interference (and may additionally be associated with a reduced BS EIRP limit and antenna height).
- Restricted blocks are marked with “R” in the above figure.

Harmonised channelling arrangement (2)

- EC Decision 2008/477/EC also defines a flexible channelling arrangement where the proportions of FDD and TDD spectrum can be decided at a national level; e.g.:



Victim: FDD BS	Victim: TDD BS/TS	Victim: FDD TS	Victim: TDD BS/TS
BS → FDD BS	BS → TDD TS **BS → TDD BS**	BS → FDD TS	BS → TDD TS **BS → TDD BS**
TS → FDD BS	TS → TDD BS **TS → TDD TS**	**TS → FDD TS**	TS → TDD BS **TS → TDD TS**

- Additional TDD spectrum can be made available, subject to a fixed FDD duplex spacing of 120 MHz.

Interference at FDD/TDD boundaries

- Four types of inter-system adjacent-channel interference exist here:

  a) base station to terminal station (BS-TS) interference;
  b) terminal station to base station (TS-BS) interference;
  c) base station to base station (BS-BS) interference; and
  d) terminal station to terminal station (TS-TS) interference.

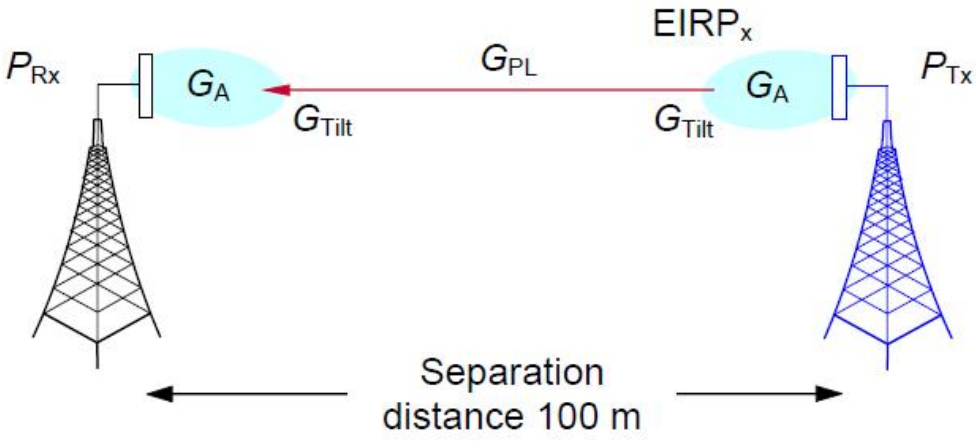
- (a) and (b) are the same as those which occur at frequency boundaries which separate "similar" cellular systems. Provisions for mitigation of (a) and (b) are available in the technology standards.

- (c) and (d), are specific to scenarios where transmissions in adjacent frequencies are subject to uplink and downlink phases which are not synchronised in time.

  This is characteristic at frequency boundaries which separate FDD and TDD networks, or at those which separate uncoordinated TDD networks.

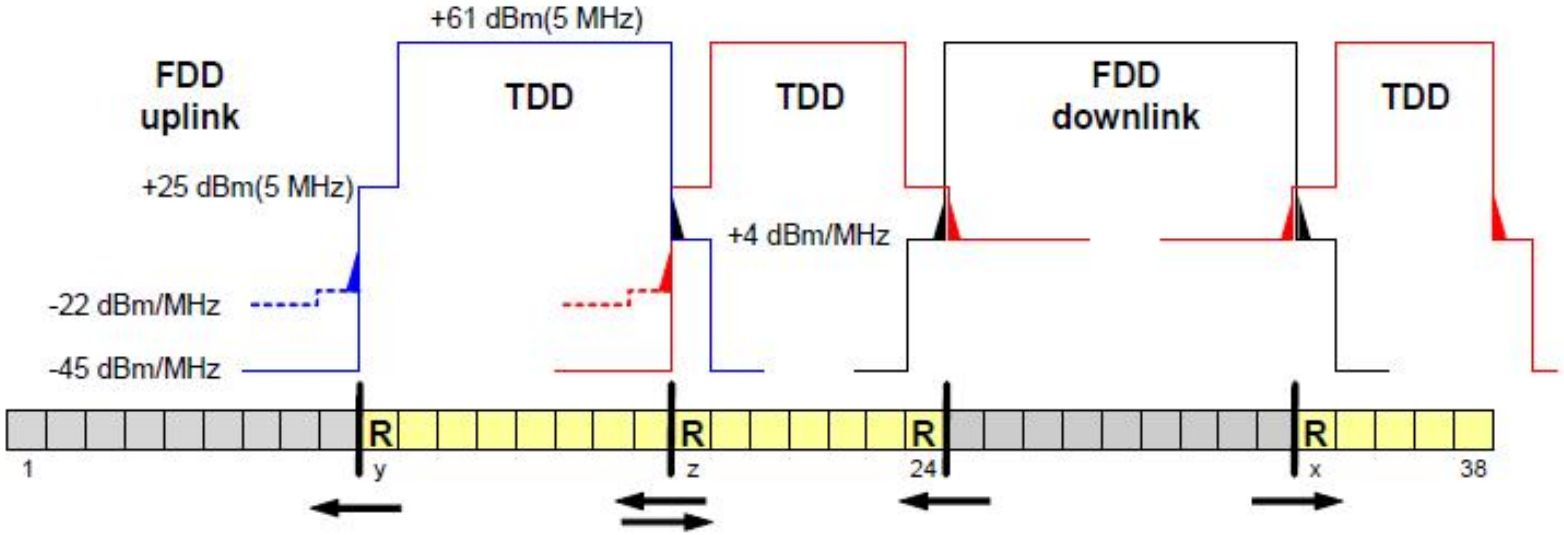
BS-to-BS interference

- BS technical conditions should not require detailed coordination arrangements between licensees if the relevant BSs have a spatial separation that is greater than a reasonable *coordination distance*.
- A requirement for large coordination distances can result in excessive coordination overheads and inefficiencies in network deployment. Accordingly, CEPT SE42 assumed a line-of-sight geometry with a BS-to-BS separation of 100 metres.
- The BS BEM out-of-block baseline limit was then specified such that a victim BS would be desensitised by only 1 dB in such a geometry.
- Minimum coupling loss (MCL) analysis indicates a required BS BEM baseline limit of -45 dBm/MHz.



EIRPx = 61 dBm/(5 MHz) , G_{Tilt} = -3 dB, G_{PL} = -81 dB, G_A = 17 dBi, P_N = -102 dBm/(5 MHz) is receiver noise floor (nominal bandwidth of 5 MHz and noise figure of 5 dB).

BS block edge masks



In-block limits

- 61 dBm/(5 MHz) for standard blocks.
- 25 dBm/(5 MHz) for restricted blocks (subject to limits on antenna placement).

Out-of-block baseline limits

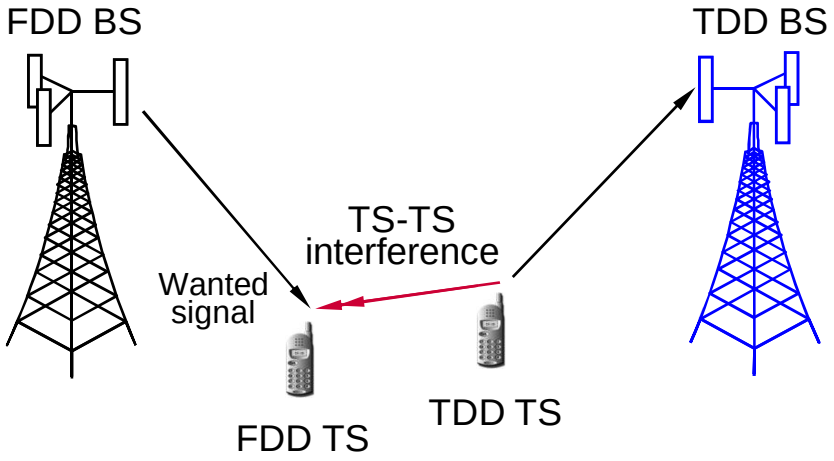
- Baseline limit of -45 dBm/MHz for mitigation of BS-to-BS interference into standard blocks.
- Baseline limit is relaxed (dashed curves) for low-power BSs in restricted blocks (in line with 3GPP TS 25.104 specifications for local-area BSs, given an antenna gain of 3 dBi.

Transition limits

- Transition limit of +4 dBm/MHz for mitigation of BS-to-BS interference into restricted blocks (in line with 3GPP TS 25.104 specifications for wide-area base stations, given an antenna gain of 17 dBi).
- Same value of +4 dBm/MHz is used as BS out-of-block limit where there is no BS-to-BS interference.

TS-to-TS interference

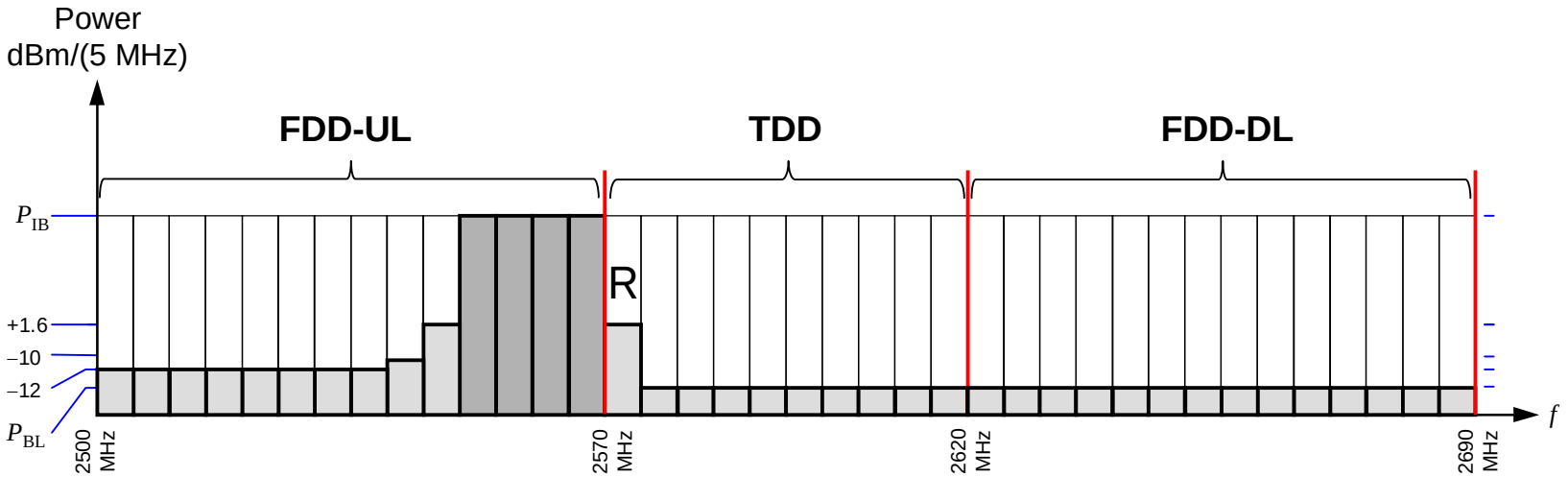
- MCL analysis effectively captures the relationship between victim desensitisation and interferer-victim separation. This is appropriate for assessing BS-to-BS interference.
- TS-to-TS interference is transient in nature. Therefore, MCL analysis can not account for the *likelihood* of harmful TS-to-TS interference. Consequently, the required baseline limits indicated by a MCL analysis are over-stringent. A statistical analysis is required.
- Consequently, CEPT SE42 undertook a Monte Carlo analysis of TS-to-TS interference in a hot-spot geometries, and accounting for probability of collisions between packets. The TS BEM baseline limit was then derived subject to the requirement that the victim receiver is desensitised by 3 dB with a probability of only 5%.
- The Monte Carlo analysis indicates a required TS BEM baseline limit of -15.5 dBm/(5 MHz) [1].



[1] Where probability of collision between victim and interferer packets is not be taken into account, a BS BEM baseline of -35 dBm/(5 MHz) can be justified.

TS block edge masks (1)

TS BEM for an FDD operator with a FDD/TDD frequency boundary.
Note that there are two transition levels on the left side, and only one transition level on the right side of the licensed spectrum.



In-block limits

- P_{IB} = 31 dBm/(5 MHz).

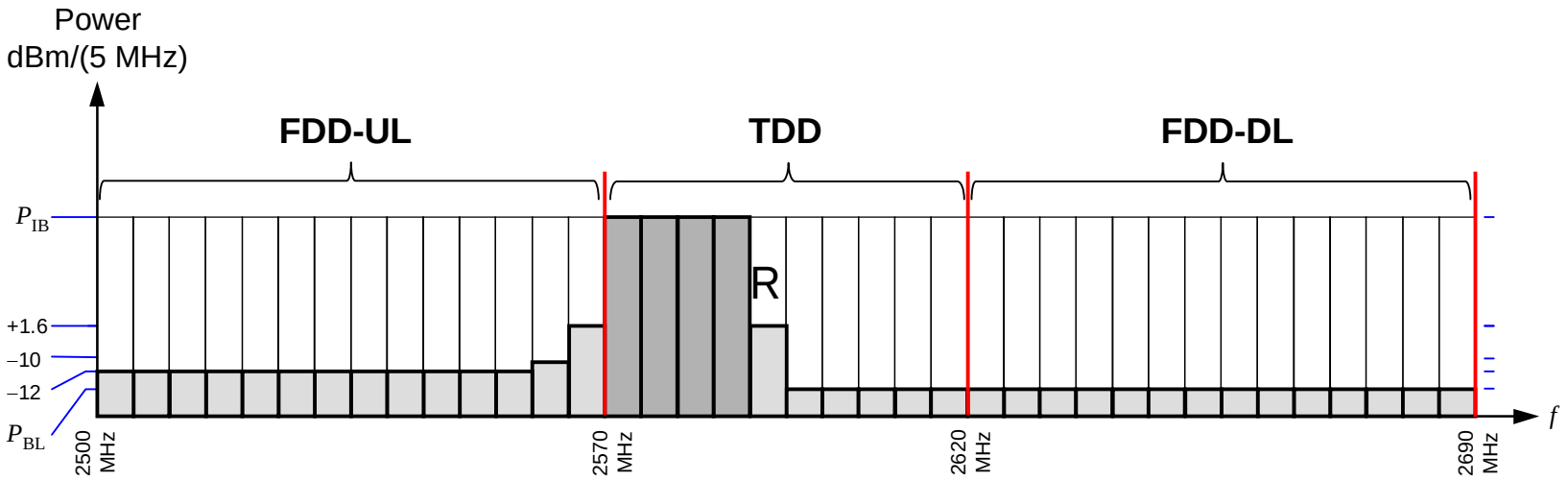
Out-of-block baseline limit

- Baseline limit of P_{BL} = -15.5 dBm/(5 MHz) for mitigation of TS-to-TS interference into standard blocks.

Transition limits

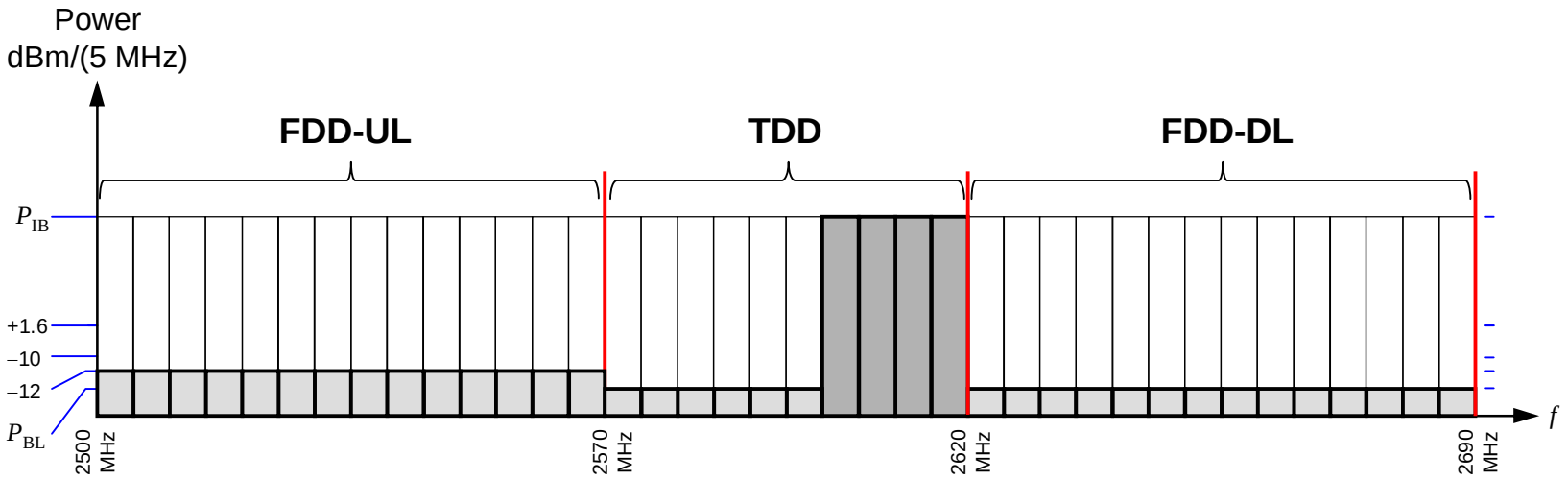
- Transition limits (light gray) are in line with 3GPP TS 25.101 specifications.
  These are considered appropriate for mitigation of TS-to-TS interference into restricted blocks,
  or where TS-to-TS interference does not occur.

TS block edge masks (2)



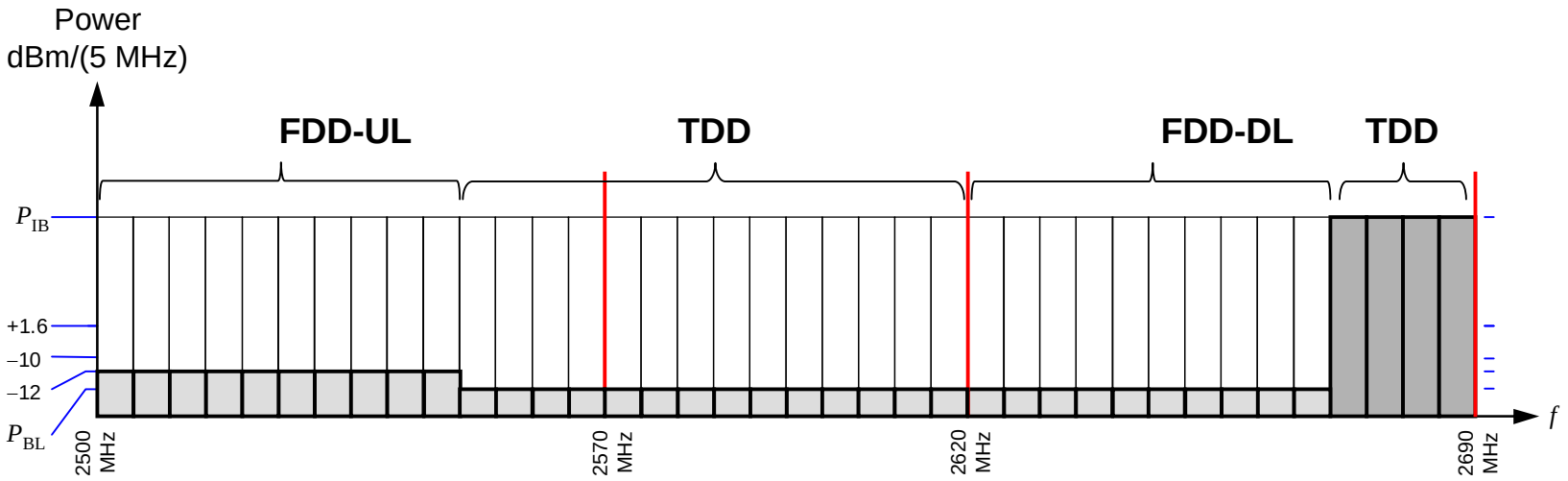
TS BEM for a TDD operator with a FDD-UL/TDD lower frequency boundary.
Note that there are two transition levels on the left side, and only one transition level on the right side of the licensed spectrum.

TS block edge masks (3)



TS BEM for a TDD operator with a FDD-DL/TDD upper frequency boundary.
Note that there are no transition levels either side of the licensed spectrum.

TS block edge masks (4)



TS BEM for a TDD operator with a FDD-DL/TDD lower frequency boundary.
Note that there are no transition levels on either side of the licensed spectrum.

Current status of the 2.6 GHz band in Europe

- The 2.6 GHz band has already been auctioned in a number of countries, including Norway and Sweden. Many others in the pipeline.
- Having published a Statement on the subject in April 2008, Ofcom had planned to auction the 2.6 GHz spectrum in the UK during the 2nd half of 2008.
- This was delayed due to legal action by T-Mobile and O2 against the auctioning of the 2.6 GHz band, broadly on the grounds of uncertainty regarding 2G liberalisation in the 900 MHz and 1800 MHz bands.
- The legal proceeding have since been overtaken by the UK government's Digital Britain report of June 2009, which has proposed
  - an early separate auction of the TDD 2.6 GHz spectrum; and
  - co-ordinating the upcoming FDD suitable auctions at 2.6 GHz and 800 MHz to allow existing and new operators to build spectrum holdings in an integrated, strategic fashion.

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The Digital Dividend

- The switchover from analogue television to digital terrestrial television (DTT), to be completed in Europe by the end of 2012, will free up a large amount of radio spectrum.
- This so-called *Digital Dividend* will provide a unique opportunity to meet the demand for spectrum by mobile/fixed communication networks (MFCNs) and other uses, while allowing broadcasters to significantly expand their services through the use of digital audio/video compression technologies.
- The availability of TV channels 61 to 69 (the 800 MHz Digital Dividend) throughout Europe for mobile/fixed communication networks (MFCNs) can result in considerable economies of scale for equipment manufacturers.
- In order to benefit from the above economies of scale, the UK has decided to re-align its 800 MHz Digital Dividend with that of other European administrations; i.e., via clearing channels 61 to 69.
- Ofcom has also been playing a leading role in the CEPT in specifying appropriate technical conditions for the use of the Digital Dividend.

EC mandate on the 800 MHz band

- In April 2008, the European Commission (EC) issued a mandate to CEPT to define technical conditions for use of the 790-862 MHz Digital Dividend spectrum by mobile/fixed communication networks (MFCNs).

- Specifically, the mandate consisted of two key tasks:

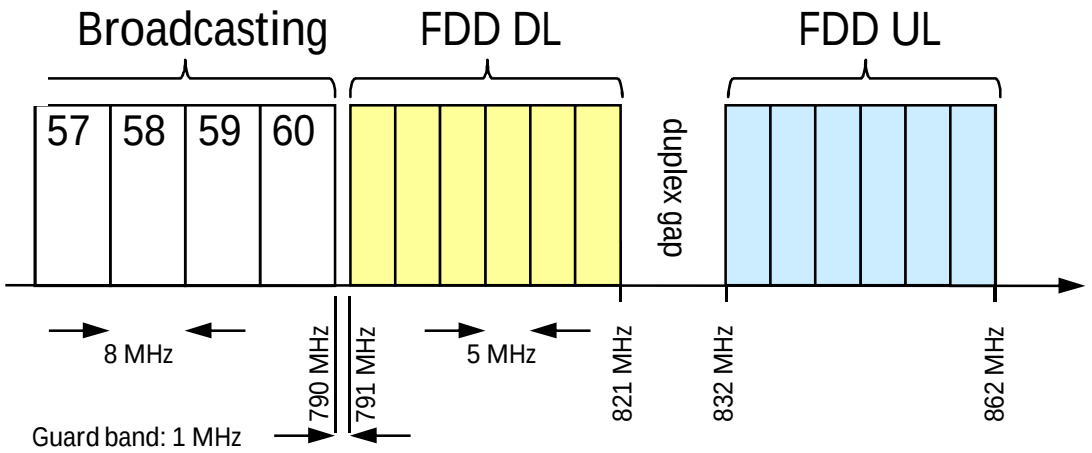
  - Development of the most appropriate channelling arrangements for MFCNs. These should be sufficiently precise for the development of EU-wide equipment, but at the same time allow Member States to adapt these to national circumstances and market demand.

  - Identification of common and minimal (least restrictive) technical conditions for the operation of MFCNs.

- The above tasks were completed in September 2009 by CEPT PT1 and CEPT SE42, respectively (subject to final approval in October 2009).

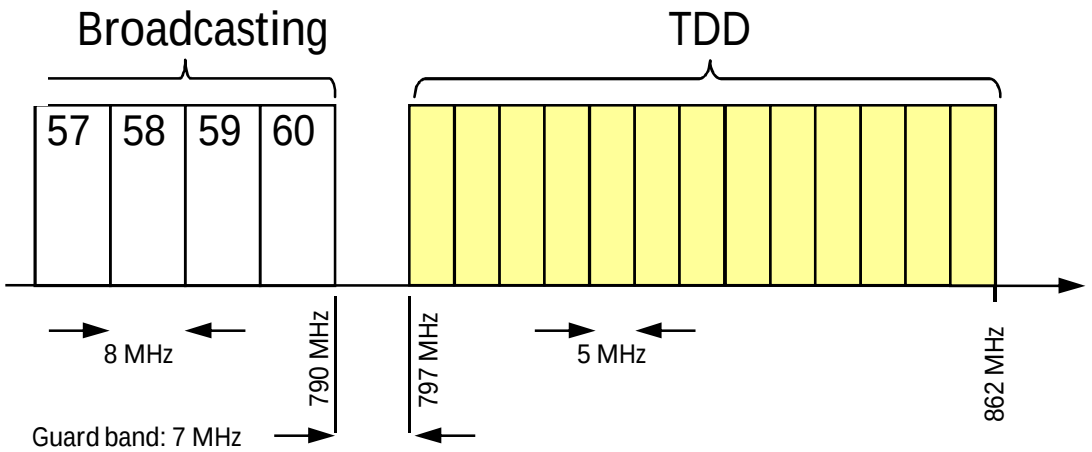
Channelling arrangement: FDD

- In response to the EC mandate, CEPT PT1 has proposed a European *preferred* frequency arrangement for MFCNs.
- This consists of a *reverse* frequency division duplex (FDD) channeling arrangement of 2×30 MHz, based on a block size of 5 MHz, and with a duplex gap of 11 MHz.
- The FDD downlink starts at 791 MHz and the FDD uplink starts at 832 MHz. This implies a 1 MHz guard band between MFCN and DTT services.

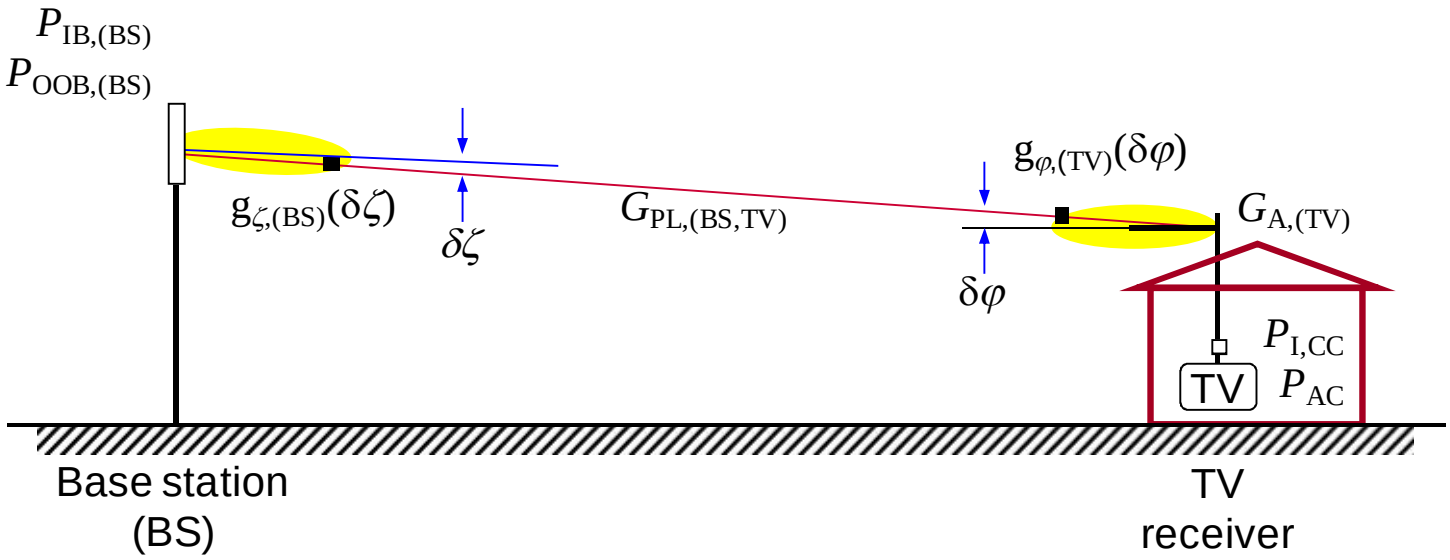


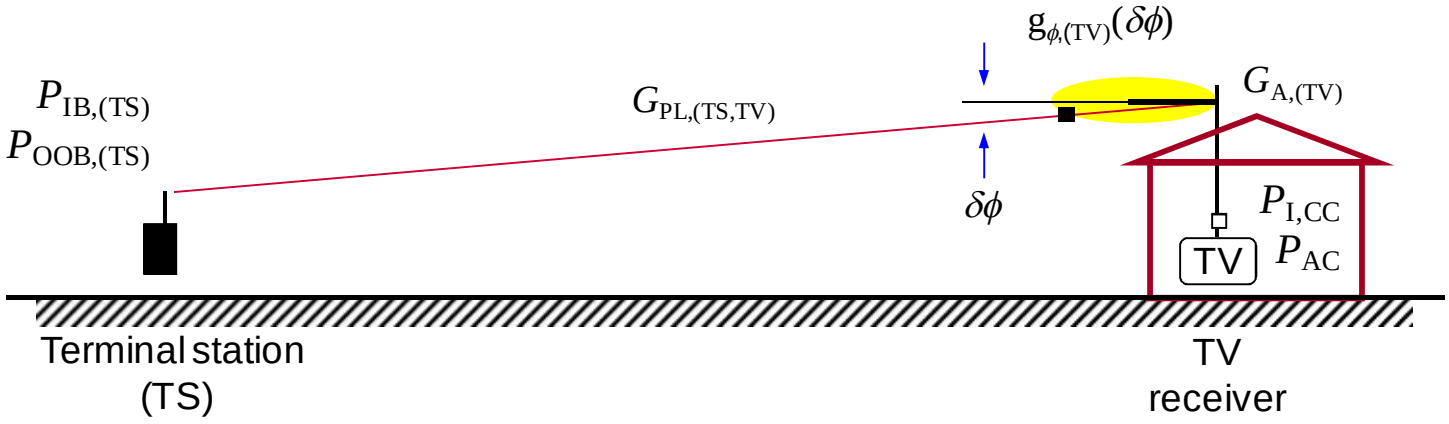
Channelling arrangement: TDD

- CEPT PT1 has also provided guidance on alternative channeling arrangements where the full band 790-862 MHz is not available.
- This includes a time-division duplex (TDD) channeling arrangement with a 7 MHz guard band from 790 to 797 MHz, as well as the possibility to mix both TDD and FDD (and DTT) arrangements.
- TDD-only channeling arrangement:



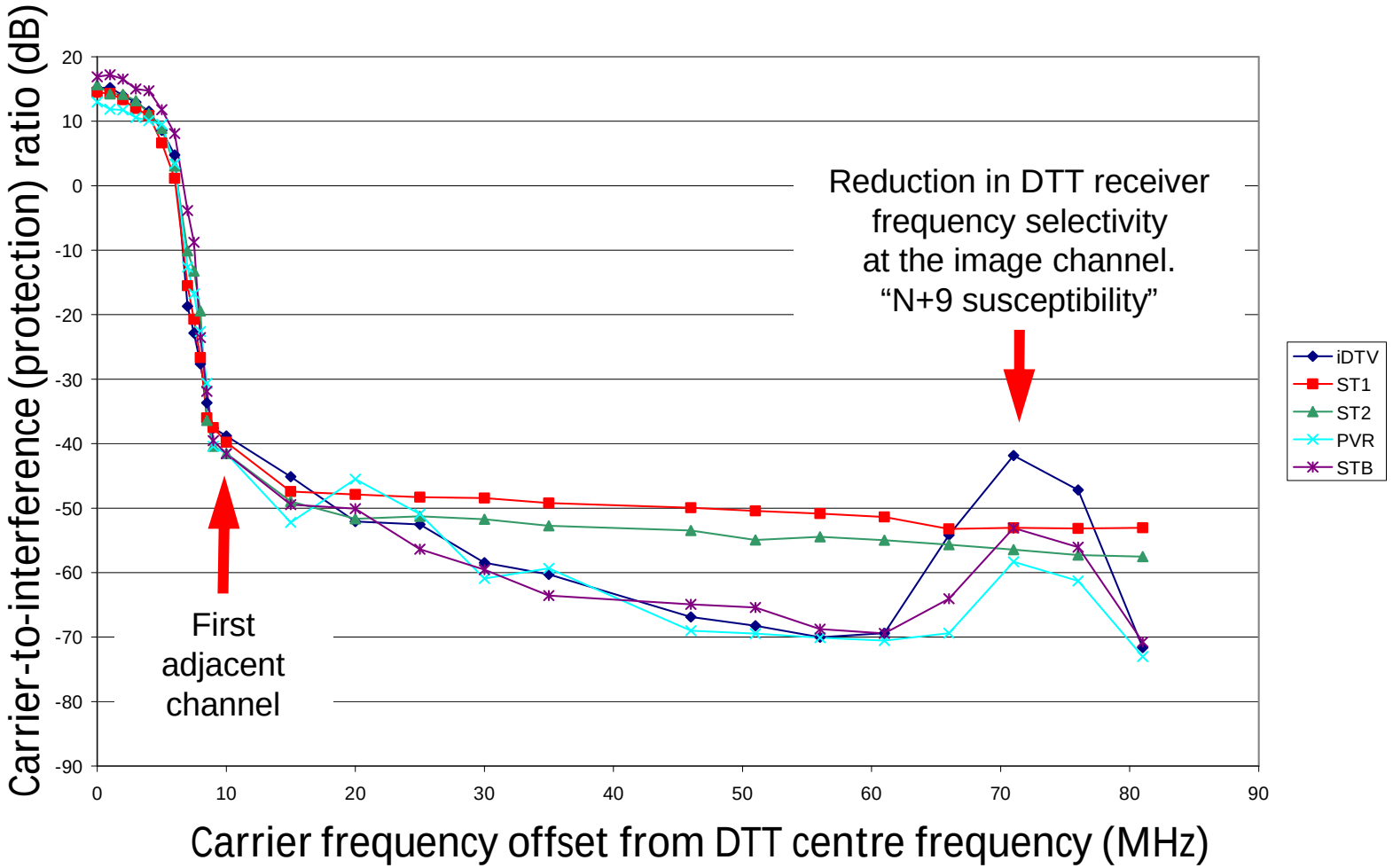
MFCN to DTT interference geometries





Protection ratios (C/I) for 5 DTT receivers

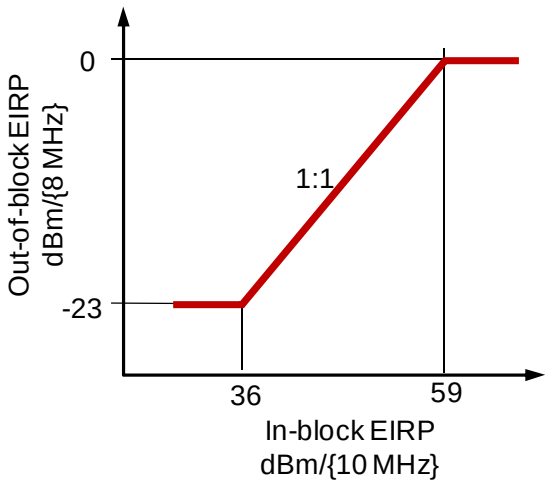
Interferer: LTE base station compliant with SE42 BEM (ACLR = 59 dB)
DTT signal level: -70 dBm, 64QAM – rate 2/3.

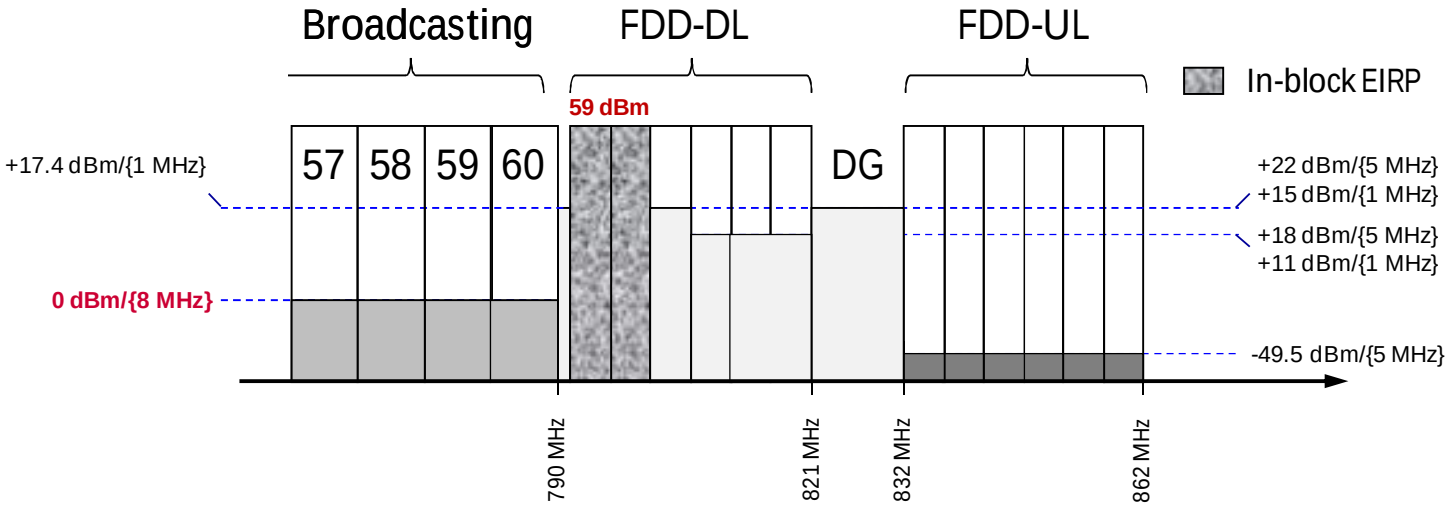


Technical conditions for MFCN base stations

- The MFCN BS in-block and out-of-block emission limits are defined such that the level of interference to DTT services is lower-bounded by the limited adjacent channel selectivity of DTT receivers (typically around 53 dB).

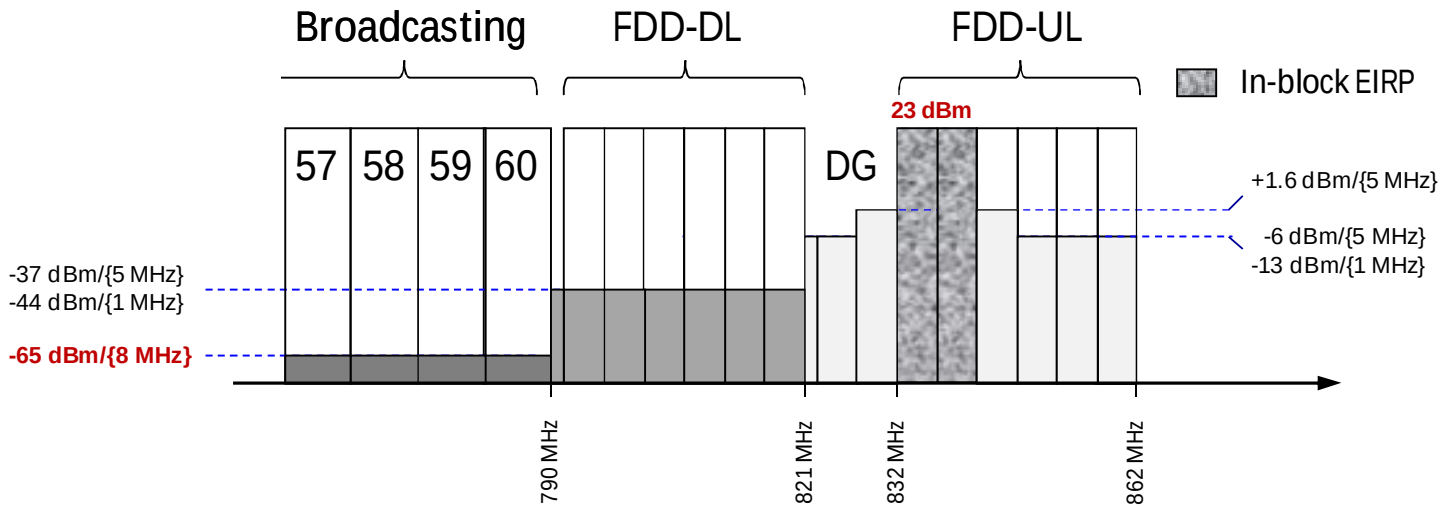
- BEM example for a 59 dBm EIRP:





Technical conditions for MFCN terminal stations

- The MFCN TS in-block EIRP limit of 23 dBm.
- The MFCN TS out-of-block EIRP limit of -65 dBm/{8 MHz}.
- Implications:
  - A DTT receiver with a fixed roof-top antenna would be desensitised by 1 dB due to interference from a MFCN TS in a worst-case geometry (i.e., ~ 22 m separation) assuming a 6 dB body loss and given a DTT receiver selectivity of around 72 dB
    (implies that additional Rx filtering would typically not be required).



Potential for interference to DTT services

- It should be understood that the BEMs derived by CEPT do not always provide the required level of protection for DTT services.
- Additional mitigation techniques would need to be applied at a regional basis in order to resolve any remaining cases of interference.
- In considering mitigation measures in the UK, the following should be noted:
  - The multi-frequency DTT network in the UK means that many households will not use the upper DTT channels (such as channel 59 and 60) which are most susceptible to adjacent-channel interference from MFCN base stations.
  - The DTT receiver N+9 image channel susceptibility means that DTT channels 52 and above could be affected by interference from MFCN BSs or TSs.

Mitigation measures

- **Guard bands**

  A sufficiently large guard band helps but would be spectrally inefficient.
  In any case, CEPT has proposed a harmonised guard band of only 1 MHz between MFCN and DTT.

- **Co-siting of MFCN base stations with DTT transmitters**

  This is generally not possible (there will be many more MFCN BSs than DTT transmitters). But careful siting of MFCN BSs could reduce the potential for interference.

- **Filtering at MFCN base station transmitters**

  This has limited impact since DTT receiver frequency selectivity (rather than MFCN BS emission spectral leakage) is the bottle-neck.

Mitigation measures

- **Grouped aerials**

  The natural roll-off of aerial gains in the lower groups (A and B) in combination with the frequency offset between DTT and MFCN channels should overcome almost all interference issues for users of DTT channels in the lower parts of the spectrum (except those viewers with wideband aerials – currently about 10% of UK households).

- **MFCN BS polarisation**

  A 16 dB discrimination against interference could be achieved if MFCN BSs radiate with a polarisation that is orthogonal to that used by the DTT service.

  Mobile network operators may choose this as the default mode of transmission.

Mitigation measures

- **Filtering in the DTT receiver aerial down-lead**

  This would be of limited benefit to viewers of DTT channel 60 receiving interference from MFCN BSs operating in the adjacent channel 61.

  However, filtering can be effective where greater frequency separations are involved between the MFCNs and DTT channels. This would also mitigate interference due to the N+9 image channel susceptibility.

- **On-channel DTT repeaters**

  The use of low-power DTT on-channel repeaters (OCR) at the location (or in the vicinity) of MFCN BSs can effectively repair any local damage to DTT reception.

  OCRs may not be able to operate in all locations (e.g., where the DTT signal is too weak to repeat). Consequently, OCRs are unlikely to be effective everywhere, but have the potential to be an extremely powerful mitigation technique.

Current status of the 800 MHz band in Europe

- CEPT is due to approve the technical conditions for the use of the 790-860 MHz band in October 2009. An EC Decision is expected in December 2009.
- Sweden, Finland, and Norway initially announced their digital dividends in 2008. Subsequently, France and Switzerland announced their digital dividends towards the end of 2008. Many other administrations followed or remain likely to follow.
- Having played the pivotal role in making the case for a Digital Dividend in Europe, the UK decided to re-align its original 800 MHz Digital Dividend spectrum with that of other European administrations; i.e., via clearing TV channels 61-69 (760-860 MHz).
- The UK government's Digital Britain report of June 2009 has proposed a co-ordination of the upcoming FDD suitable auctions at 2.6 GHz and 800 MHz.

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EC mandates on the 900 MHz, 1800 MHz and 2.1 GHz bands

- Recently, the EC issued two new mandates to CEPT.
- The first relates to the 900 MHz and 1800 MHz bands currently used for GSM.
  - The mandate asks CEPT to look at the technical conditions necessary to allow other technologies to operate alongside GSM (e.g. UMTS, LTE and WiMAX).
  - This work has been assigned to CEPT PT1.
  - A direct consequence of early compatibility work carried out by Ofcom has been a change in 3GPP to the spectrum masks of LTE base stations operating in these bands to improve adjacent band sharing conditions.
- The second relates to the 2.1 GHz band currently used for UMTS.
  - The mandate asks CEPT to develop common and minimal (least restrictive) technical conditions for the band to allow the introduction of new technologies (e.g. LTE and WiMAX).
  - The mandate specifically asks CEPT to develop BEMs for the band by translating the work already carried out at 2.6 GHz.
  - This work has been assigned to CEPT SE42.
- For both mandates, CEPT is expected to report back by July 2010.

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Conclusions

- Two new bands will soon be available for use by 4G mobile communications systems:
  - 2.6 GHz band (190 MHz of spectrum), and
  - 800 MHz band (72 MHz of spectrum).

2.6 GHz band

- CEPT finalized the band-plans and technical conditions for the 2500-2690 MHz band back in 2008.
- The technical conditions are in the form of block edge masks and are derived with the aim of mitigating the impact of base-to-base and terminal-to-terminal interference at frequency boundaries between FDD and TDD networks (or between uncoordinated TDD networks).

Conclusions

800 MHz band (Digital Dividend)

- CEPT has only recently finalized the band-plans and technical conditions for the Digital Dividend (subject to final approval in October 2009).
- The technical conditions are in the form of block edge masks and are derived with the aim of mitigating the impact of interference from mobile networks to DTT reception.
- The block edge masks defined by CEPT are not always sufficient for providing the appropriate levels of protection to DTT services in channels 60 and below. Additional mitigation measures will need to be applied at a national level.

  Examples of such mitigation measures include use of appropriate polarisation, filtering at the DTT receiver, and the installation of on-channel DTT repeaters.

Thank you!

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