Electronic Communications Committee (ECC)
within the European Conference of Postal and Telecommunications Administrations (CEPT)

MEASUREMENTS ON THE PERFORMANCE OF DVB-T RECEIVERS IN THE PRESENCE OF INTERFERENCE FROM THE MOBILE SERVICE (ESPECIALLY FROM UMTS)

Ljubljana, September 2009
Revised Marseille, June 2010

0 EXECUTIVE SUMMARY

Justification

This Report summarises the CEPT activity relating to measurements on the performance of DVB-T receivers in terms of measured carrier-to-interference protection ratios and overloading thresholds in the presence of interference from the mobile service, especially that from UMTS. It is aimed to assist administrations seeking to protect their broadcasting services in the band 470-790 MHz from interference generated by UMTS services in the band 790-862 MHz.

Findings

In general, protection ratios show a decrease in values (from -31 to -67 dB for the base station interference and from -5 to -55 dB for the user equipment interference) as the frequency offset increases. However, the protection ratio in the image channel is similar to the one in the third adjacent channel. The overloading threshold shows only small variations with frequency offset.

At equal frequency offsets the impact of user equipment interference into DVB-T receiver is considerably higher than the one from the base station, the effect being linked to the use of transmit power control. In particular, the latter increases the required protection ratio by 12-26 dB and decreases the overloading threshold detected by 7-11 dB depending on the frequency offset.

Further information

It is expected that LTE will be more widely deployed than WCDMA mobile service (UMTS) in the band 790-862 MHz. Therefore, measurements on LTE interference into DVB-T reception were also carried out in order to assess the impact of this on the broadcasting service.

The results of the measurements are set out in a subsequent ECC Report 148 [1].

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LIST OF ABBREVIATIONS

ACLR	Adjacent Channel Leakage Ratio
AWGN	Additive White Gaussian Noise
BS	Base station
BEM	Block Edge Mask
BER	Bit error ratio
CEPT	European Conference of Postal and Telecommunications Administrations
COFDM	Coded Orthogonal Frequency Division Multiplexing
DVB-T	Digital Video Broadcasting – Terrestrial
ECC	Electronic Communications Committee
FDD	Frequency Division Duplex
GE06	The Geneva 2006 Agreement and Plan
GSM	Global System for Mobile communications
IMT	International Mobile Telecommunications
ITU-R	International Telecommunication Union - Radiocommunication Sector
LTE	Long Term Evolution
PF	Picture failures
RRC-06	Regional Radiocommunication Conference, Geneva 2006
TPC	Transmit Power Control
UE	User equipment
UMTS	Universal Mobile Telecommunications System
WCDMA	Wideband Code Division Multiple Access
WRC-07	World Radiocommunication Conference 2007

Measurements on the performance of DVB-T receivers in the presence of interference from the mobile service (especially from UMTS)

1 INTRODUCTION

WRC-07 co-allocated the band 790-862 MHz (channels 61-69) to the mobile service (except aeronautical mobile) on a primary basis from 17 June 2015 in Region 1 with an identification of the band for IMT. In some European countries this allocation is valid before 2015 subject to technical coordination with other countries contracting to the GE06 Agreement.

This report summarises the CEPT activity relating to measurements on the performance of DVB-T receivers in the presence of interference from the mobile service, especially that from UMTS.

The measurements described in this report were used to develop the channelling arrangements for the mobile services in the band 790-862 MHz and the block edge mask applicable to the 790 MHz boundary (see CEPT Reports 30 [2] and 31 [3] for more details).

2 USEFUL DEFINITIONS

2.1 Radio frequency signal-to-interference ratio (C/I)

It is the ratio, generally expressed in dB, of the power of the wanted signal to the total power of interfering signals and noise, evaluated at the receiver input (see Rec. ITU-R V.573-5 [4]).

Usually, C/I is expressed as a function of the frequency offset between the wanted and interfering signals over a wide frequency range. In this document, C/I expressed in this way is referred to as “C/I curve”. C/I curves show the ability of a receiver to discriminate against interfering signals on frequencies differing from that of the wanted signal.

2.2 Radio frequency protection ratio (PR)

It is the minimum value of the signal-to-interference ratio required to obtain a specified reception quality under specified conditions at the receiver input (note that this differs from the definition in Rec. ITU-R V.573-5 [4]). In this report, the “specified reception quality” and the “specified conditions” have been defined separately by each entity that has undertaken measurements.

Usually, PR is specified as a function of the frequency offset between the wanted and interfering signals over a wide frequency range. In this document, PR specified in this way is referred to as “PR curve”. PR curves show the ability of a receiver to discriminate against interfering signals on frequencies differing from that of the wanted signal.

2.3 Receiver Blocking

Receiver blocking is the effect of a strong out-of-band interfering signal on the receiver’s ability to detect a low-level wanted signal. Receiver blocking response (or performance level) is defined as the maximum interfering signal level expressed in dBm reducing the specified receiver sensitivity by a certain number of dB's (usually 3 dB). Consequently, the receiver blocking response is normally evaluated at a wanted signal level which is 3 dB above the receiver sensitivity and at frequencies differing from that of the wanted signal.

2.4 Receiver (front-end) overloading threshold

Overloading threshold (O_{th}) is the maximum interfering signal level expressed in dBm, where close to that level the receiver loses its ability to discriminate against interfering signals at frequencies differing from that of the wanted signal.

In some cases the interfering signal may so strongly overload the receiver front-end that the receiver becomes blind and thus unable to receive anything at all. In most cases, receiver overloading happens beyond the first adjacent channels. Under overloading conditions ($I>O_{th}$), the receiver is interfered with by the interfering signal whatever the wanted signal level.

3 CRITERIA TO BE USED WHEN ASSESSING INTERFERENCE

DVB-T systems use coded orthogonal frequency division multiplexing (COFDM) which spreads the information over a large number of orthogonal carriers. Forward error correction is then applied to improve the bit error ratio (BER). In many digital systems the data to be transmitted undergoes two types of FEC coding; Reed Solomon and convolutional coding (Viterbi). At the receiver end, the pseudo-random sequence added at the transmitter by the convolutional encoder is decoded by the Viterbi decoder, followed by Reed Solomon decoding for parity checking.

The error protection employed by such digital systems usually results in an abrupt “cliffedge” effect in the presence of interference when compared to analogue systems. The different criteria to be used when assessing interference to digital systems include:

- Post Viterbi BER=$2x10^{-4}$
- A measure of the number of un-correctable Transport Stream errors in a defined period (sometimes also normalized to ‘Error Seconds’).
- “Picture Failure”. Number of observed (or detected) picture artefacts in a defined period.
- “Subjective failure point”

The reference BER, defined as BER = 2×10^{-4} after Viterbi decoding, corresponds to the quasi error free (QEF) criterion in the DVB-T standard, which states “less than one uncorrelated error event per hour”. However, there is often no direct way of identifying BER or transport stream errors for commercial receivers. In this case picture failure (PF) is the only means of assessing the interference effects.

4 MEASUREMENTS

4.1 Broadcasting service parameters

The DVB-T parameters shown in Table 1 were used as the wanted signal source.

DVB-T signal parameters					
Modulation	**Centre frequency (MHz)**	**Number of carriers**	**Channel raster (MHz)**	**Coding rate**	**Guard interval**
COFDM-64-QAM	786	8k mode	8	2/3	1/32
Average receiver sensitivity measured (dBm)			**Wanted signal levels used (dBm)**		
-81			-75, -70, -60, -50, -40 and -30		

Table 1

4.2 Mobile service parameters

Interfering UMTS signal parameters are given in Table 2. The restriction of 488 frames (7320 bits) put on the Transmit Power Control (TPC) pattern length was necessary to keep the time needed to generate UMTS frames reasonable. The finite TPC profile was periodically repeated to simulate TPC profile of infinite duration.

UMTS (3GPP version 6)		
Access technique	**Modulation**	**Modulation filter**
CDMA/FDD	QPSK single carrier	Root raised cosine α=0;22
Channel raster	**Chip rate**	**Data rate DL DPCH / UL DPDCH&DPCCH**
5 MHz	3,84 Mbps	30 ksps / 60&15 ksps[1]
Mode DL/UL	**Scrambling mode**	**UL TPC pattern length/step**
DPCH / DPDCH&DPCCH	Long	7320 bits (488 frames)/1 dB
Generated UMTS BS signal ACLR[3] (dB/5MHz); TPC off	**Generated UMTS UE signal ACLR[2,3] (dB/5MHz); TPC on**	
50 (f_c=792.5 MHz) 48 (f_c=812.5 MHz) 49 (f_c=858 MHz)	35 (worst case, f_c=817.5) ∞ (best case f_c=817.5)	
[1] No impact was observed on the measurements results at lower and higher data rates [2] high variation of ACLR due to the TPC profile used in the measurements [3] Measured with a rectangular filter of 5 MHz bandwidth. This definition of ACLR is different from the ACLR definition used in the 3GPP specifications (see 3GPP TS 25.101 [5] and 25.104 [6]) and thus the values shown above cannot be directly compared with the ACLR requirements given in the 3GPP specifications.		

Table 2

It should be noted that the generated UMTS interfering signal out-of-band power was lower than specified in 3GPP requirements for UMTS base stations (BS) and user equipment (UE) (see Figures 1 and 2). However ECC/SE42 has defined a block edge mask (BEM) which will need to be respected by ECN base stations emitting into the frequency range below 790 MHz. ACLR values calculated from this BEM would be more stringent than the values used for the measurement in this report. Improvement in ACLR values result in a slightly improved PR in the 1st adjacent channel due to reduction of out-of-band emission of the interfering transmitter.

The preferred band plan is defined for a FDD mobile system. In most cases the UE contains a duplex filter to prevent interference into its own receiver. Usage of such a filter will at the same time further reduce the required protection ratio in the 1st adjacent channel due to reduction of out-of-band emission of the interfering transmitter.

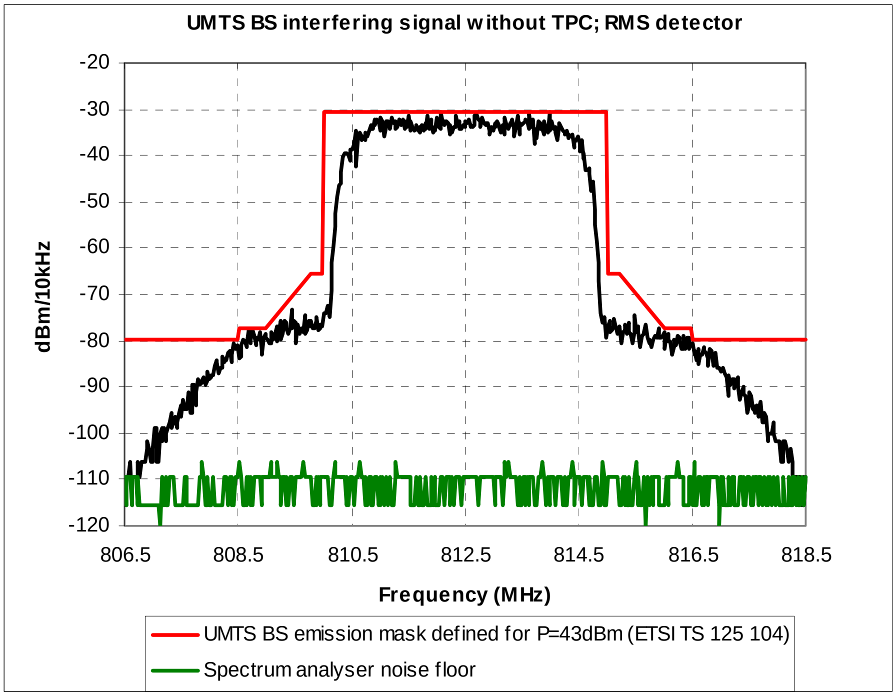

Figure 1

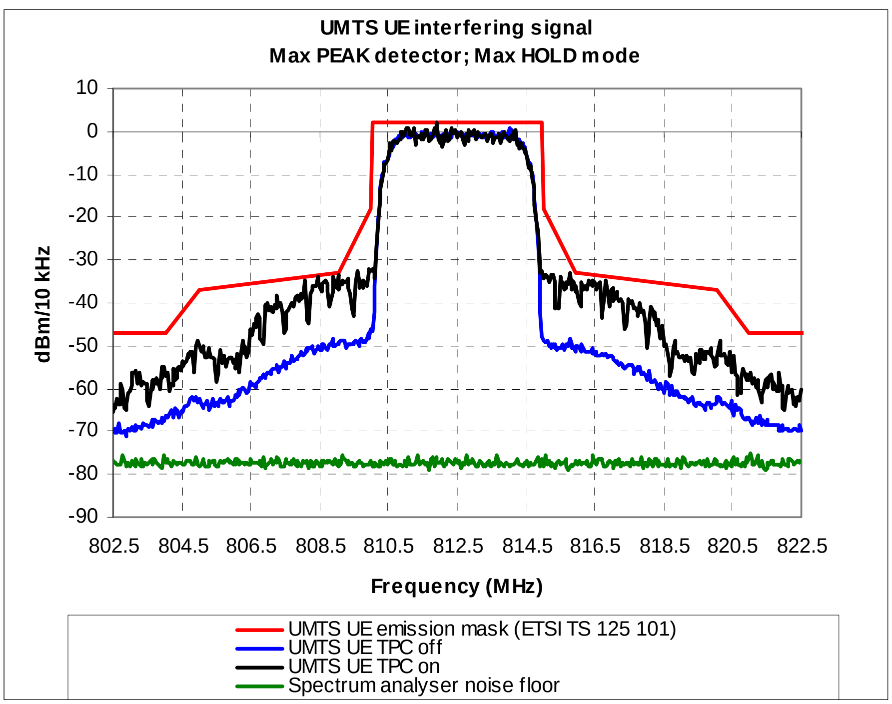

Figure 2

4.3 Test procedure

Ten different DVB-T receivers (set-top boxes available on the market in 2008, can type tuners), which are considered to be typical DVB-T receivers, were tested against UMTS interference in a Gaussian channel environment.

In addition, measurements have been conducted in the United Kingdom to characterise the performance of USB TV devices in the presence of DVB-T interference. The results have been compared to the RF performance of a typical set-top box DVB-T receiver. The results of the measurements are given in Annex A to this report and can be used to extrapolate the impact of UMTS interferer on overall performance of the USB TV devices. The relatively poor performance as the channel offset is increased of the USB stick tuners for computer viewing should be noted as a cause for concern. These are miniaturised units and appear to have compromises in their design, when compared with the RF selectivity of tuners tested in digital set-top boxes and current digital TV sets.

The DVB-T receiver signal-to-interference ratios (C/I) were measured, in the presence of a UMTS interfering signal, at six different wanted signal levels: -75, -70, -60, -50, -40 and-30 dBm. The objective was to evaluate the receiver PR and O_{th}. Setting the wanted signal at relatively high levels permitted feeding into the receiver under test stronger interfering signals than those fed into it at lower wanted signal levels. In principle, C/I measured at C_{ref} are 3 dB higher than those measured at higher wanted signal levels. Actually, when the measurements are conducted at a wanted signal level close to the receiver noise floor, the impact of the receiver noise on the measurement results is not negligible. Consequently, at wanted signal level close to receiver sensitivity, noise should be taken into account, e.g. at sensitivity + 3dB, 3 dB should be added to the PR.

4.3.1 Measurements under static conditions

Receiver sensitivity as well as protection ratio were determined to ensure the absence of picture failure during a minimum observation time of 30 s. The wanted and interfering signal levels were measured at the receiver input as the rms power in an additive white Gaussian noise (AWGN) channel. Measurement results were noted as C/I.

4.3.2 Measurements under dynamic conditions

Transmit Power Control (TPC) is one of the most important features of cellular mobile communication systems like GSM, UMTS and LTE. In particular, in UMTS, for an optimal reception in the uplink, all UE signals should reach the base station receiver with the same signal power. Actually, if the UE transmitted at a fixed power level, the cells would be dominated by users closest to BS and distant users could not be distinguished by BS (Near-Far problem). TPC is also a very effective method to compensate the UE/BS signal amplitude variations, which are mainly due to fading, in the uplink (UE⇨BS) as well as in the downlink (BS⇨UE). Furthermore, TPC is an efficient method of reducing UE power consumption.

In principle, the transmitted UMTS signal subjected to TPC is received with a quasi-constant amplitude by the UMTS receiver as shown in Figure 3, ensuring a given SIR or BER/BLER at the receiver. This is particularly true for mobile speeds lower than 50 km/h.

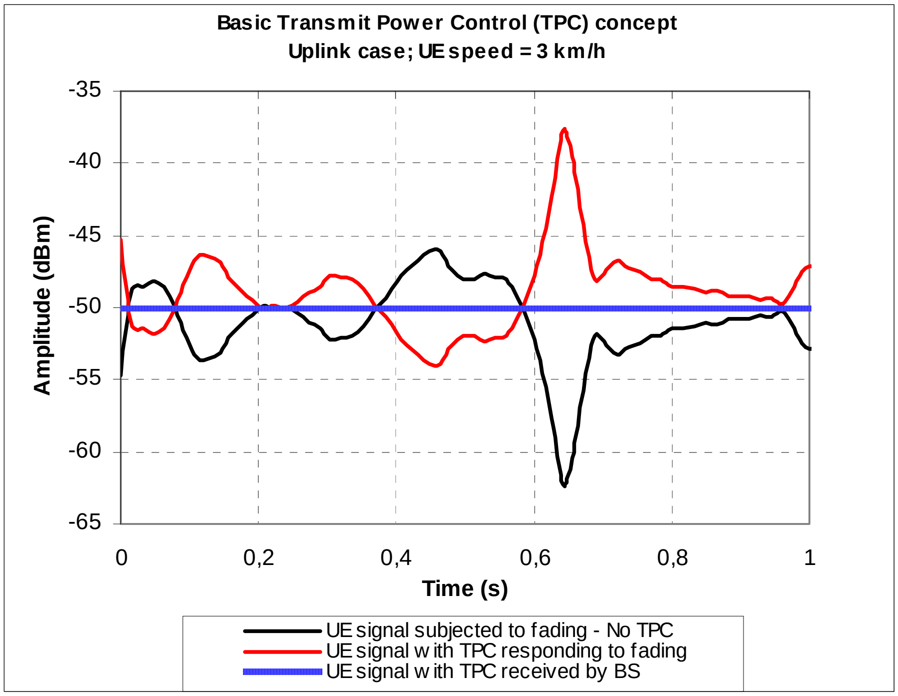

Figure 3

However, via a different transmission path, the same UMTS signal can be received with a time-varying amplitude by a victim receiver (e.g. by a DVB-T receiver). The range of the amplitude variation may reach several tens of dB depending on the UMTS UE speed and the environment.

In the UMTS downlink, UMTS BS is continuously requested to vary its output power by several UMTS UE communicating with it through statistically independent time-varying transmission paths. Accordingly, UMTS BS increases or decreases the amplitude of the baseband signal intended for each UMTS UE concerned. Then, all the baseband signals are added, including the pilot signal (CPICH) which is not subjected to TPC, to build up the complex envelope of the UMTS BS signal. Note that generally 5-15 % of the total BS power is devoted to CPICH (about 10% in the case of urban/suburban deployment).The addition of all these independently varying signals has an averaging effect and thus minimises the amplitude variation of the UMTS signal fed into the BS power amplifier. Therefore, one may logically expect that UMTS BS output power variation due to TPC in the downlink is less significant than the UMTS UE output power variation due to TPC in the uplink.

For the aforementioned reason, in this measurement campaign, DVB-T PR and O_{th} in the presence of a UMTS BS interfering signal were measured only under static conditions (TPC off). For DVB-T PR and O_{th} measurements in the presence of a UMTS UE interfering signal, the latter was subjected to a 3 km/h TPC profile with a dynamic range of 20 dB that is shown in Figure 4. This profile was derived by measuring the fading profile on a spectrum analyser for Case 1 defined in ETSI specifications TS 125 101 [5] and TS 125 104 [6].

The objective of the measurements conducted under dynamic conditions was to evaluate the impact of the time varying UMTS interfering signal on the DVB-T receivers. It can be also noted that in a measurement conducted in the UK on a specific receiver, protection ratios were approximately independent of mobile terminal speed.

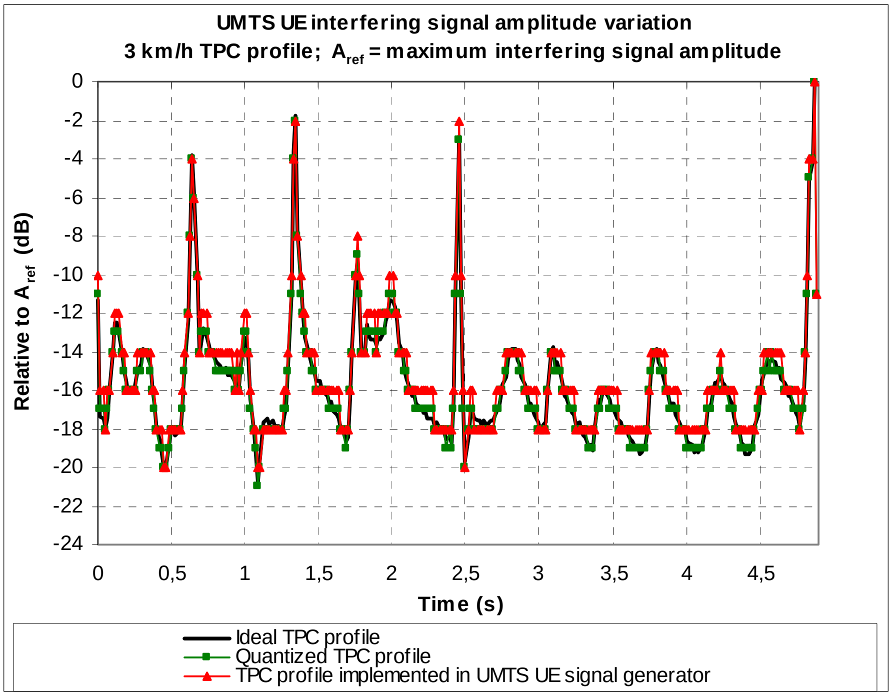

Figure 4

Figure 5 shows the waveform measured at the UMTS generator output. This waveform is quite similar to the TPC profile implemented in the generator. The profile was kept unchanged during the measurements; different UMTS interfering signal levels were obtained by means of a variable RF attenuator.

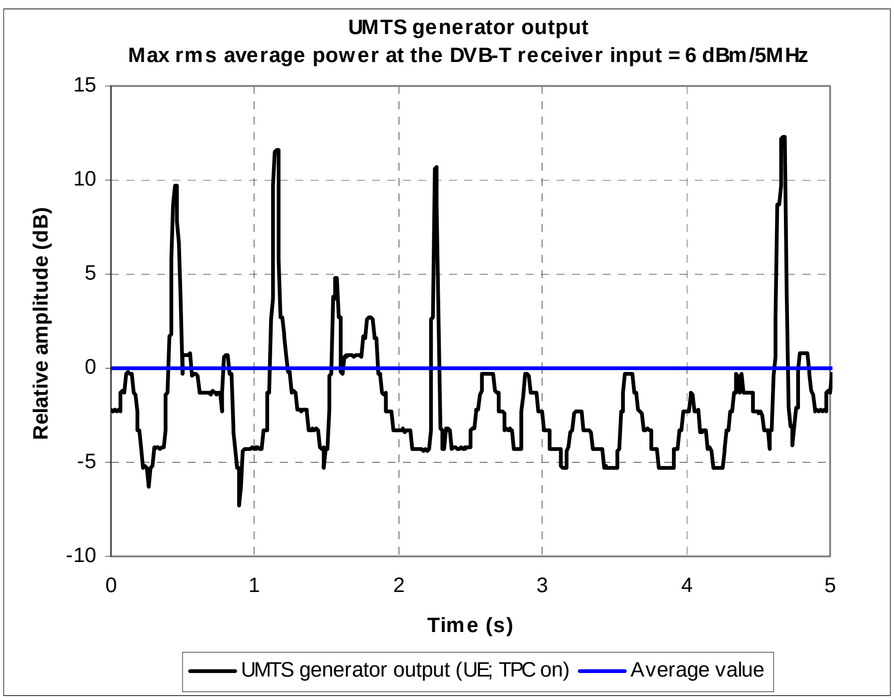

Figure 5

Under dynamic measurement conditions PR and O_{th} were determined to ensure the absence of picture failure during a minimum observation time of 30 s. The interfering signal level was measured as the rms average power in an additive white Gaussian noise (AWGN) channel. Measurement results were noted as C/I.

4.4 Results of field measurements

A field study has been undertaken jointly by the EBU and Free TV Australia in August 2008 making use of the existing UMTS (WCDMA) network in Australia in the 850 MHz band[1]. The study aimed to carry out real tests of compatibility between DVB-T[2] reception on one side and UMTS base station and mobile terminal transmissions on the other side. The results of the study were made available to ITU-R in the context of JTG 5-6 activities.

Although the Australian DVB-T system is based on 7 MHz raster, the measurements results are broadly comparable to those carried out in Europe and presented in section 5 to this report. The significant finding was that there was definite interference between a UE and a close proximity receiving DVB-T antenna, when the UE is in close frequency proximity to the DVB-T receive channel. The interference occurred within an order of a few meters separation. This finding confirms that the decision to reverse the duplex direction in CEPT is correct.

5 PROTECTION RATIOS

The protection ratios presented in this section have been measured for DVB-T 8 MHz bandwidth system variant 64-QAM 2/3 for static reception conditions (Gaussian channel). Protection ratios for different DVB-T system variants relative to 64-QAM 2/3 DVB-T signal and for different reception conditions can be obtained using correction factors given in Table A.4.4-15 of the RRC-06 Final Acts. These correction factors are repeated in Table 3 and are to be added to the protection ratios for a DVB-T 64-QAM 2/3 Gaussian channel:

DVB-T system variant	Gaussian channel	Fixed reception	Portable outdoor reception	Portable indoor reception	Mobile reception
QPSK 1/2	−13.5	−12.5	−10.3	−10.3	−7.3
QPSK 2/3	−11.6	−10.5	−8.2	−8.2	−5.2
QPSK 3/4	−10.5	−9.3	−6.9	−6.9	−3.9
QPSK 5/6	−9.4	−8.1	−5.6	−5.6	−2.6
QPSK 7/8	−8.5	−7.1	−4.5	−4.5	−1.5
16-QAM 1/2	−7.8	−6.8	−3.6	−3.6	−1.6
16-QAM 2/3	−5.4	−4.3	−2.0	−2.0	1.0
16-QAM 3/4	−3.9	−2.7	−0.3	−0.3	2.7
16-QAM 5/6	−2.8	−1.5	1.0	1.0	4.0
16-QAM 7/8	−2.3	−0.9	1.7	1.7	4.7
64-QAM 1/2	−2.2	−1.2	1.0	1.0	4.0
64-QAM 2/3	0.0	1.1	3.4	3.4	6.4
64-QAM 3/4	1.6	2.8	5.2	5.2	8.2
64-QAM 5/6	3.0	4.3	6.8	6.8	9.8
64-QAM 7/8	3.9	5.3	7.9	7.9	10.9
Note: Recent measurements of IMT BS interference into DVB-T reception for Gaussian and time-variant Rayleigh channels indicate that the correction factors of Table 3 for mobile reception are more appropriate also for portable reception than those given in Table 3 for portable reception. It is therefore recommended to use the correction factors for mobile reception for both portable and mobile reception. Details can be found in Annex B.					

Table 3: Correction factors for protection ratios (dB) for different system variants relative to 64-QAM 2/3 DVB-T signal and for different reception conditions interfered with by other primary services

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[1] The report can be downloaded from ftp://sydney:video@ftp.ebu.ch

[2] DVB-T system variant considered: 64 QAM 2/3

The overloading thresholds are assumed to be independent from the reception conditions.

The protection ratio for a frequency offset of plus 72 MHz corresponds to the spurious response at the image frequency.

Using statistical analysis the 10th, 50th, and 90th percentile of all measured protection ratios and the 10th, 50th, and 90th percentile of all measured overloading thresholds for UMTS interference into DVB-T were calculated. They are listed in Table 4 and Table 5 for the interfering signal defined as the average and as maximum rms power, respectively. The frequency offset is measured between the central frequencies of wanted and interfering signals.

DVB-T PR and O_{th} for 64-QAM 2/3 DVB-T signal (UMTS BS TPC off)						
f_i-f_w (MHz)	**PR (dB)**			**O_{th} (dBm)**		
	10th	**50th**	**90th**	**10th**	**50th**	**90th**
0	16	18	19	NR	NR	NR
6.5	-36	-31	-26	-15	-9	-3
7.5	-38	-33	-28	-14	-8	-2
8.5	-40	-35	-30	-13	-7	-1
11.5	-46	-41	-35	-9	-4	2
16.5	-55	-41	-28	-9	-2	4
21.5	-61	-45	-29	-12	-4	3
26.5	-64	-51	-38	-14	-5	5
31.5	-71	-57	-44	-15	-6	3
36.5	-73	-45	-17	-14	-6	2
41.5	-75	-66	-56	-13	-5	3
46.5	-72	-63	-54	-12	-4	4
51.5	-76	-66	-56	-12	-4	5
56.5	-76	-67	-57	-12	-3	6
72	-53	-48	-42	-12	-1	9

NR: O_{th} is not reached. That is at this frequency offset PR is the predominant criterion. Consequently, DVB-T receiver is interfered with by the interfering signal due to insufficient C/I (<PR) before reaching its O_{th}

Note 1: PR is applicable unless the sum of all interfering signals is above the corresponding O_{th}. If the interfering signal level is above the corresponding O_{th}, the receiver is interfered with by the interfering signal whatever the PR is.

Note 2: At wanted signal level close to receiver sensitivity, noise should be taken into account, e.g. at sensitivity + 3db, 3 dB should be added to the PR.

Note 3: PR for different system variants and various reception conditions can be obtained using the correction factors in Table 3. The overloading threshold is independent of system variant and reception conditions.

Note 4: Treatment of overloading threshold in calculations when assessing interference from UMTS into DVB-T is presented in Annex C.

Note 5: The values for **f_i-f_w** = 7.5 MHz and 8.5 MHz are derived by linear interpolation**.**

Note 6: The 90th percentile for the protection ratio value corresponds to the protection of 90% of receivers measured, with respect to the given frequency offset and parameter; whereas the 90th percentile for the overloading threshold value corresponds to overloading of 10% of receivers measured (i.e. the 10th percentile for the overloading threshold should be used to protect 90% of receivers measured).

Table 4: DVB-T PR and O_{th} values in the presence of a UMTS BS interfering signal without TPC in a Gaussian channel environment at the 10th, 50th and 90th percentile

DVB-T PR and O_{th} for 64-QAM 2/3 DVB-T signal (UMTS UE TPC on)												
	PR and O_{th} relative to the interfering signal rms average power						PR and O_{th} relative to the interfering signal maximum rms power					
f_i-f_w (MHz)	PR (dB)			O_{th} (dBm)			PR (dB)			O_{th} (dBm)		
	10th	50th	90th	10th	50th	90th	10th	50th	90th	10th	50th	90th
0	30	30	31	NR	NR	NR	18	18	19	NR	NR	NR
6.5	-7	-5	-3	NR	NR	NR	-19	-17	-15	NR	NR	NR
11.5	-29	-22	-14	-21	-14	-8	-41	-34	-26	-9	-2	4
16.5	-37	-25	-14	-18	-13	-8	-49	-37	-26	-6	-1	4
21.5	-39	-28	-16	-18	-12	-6	-51	-40	-28	-6	0	6
26.5	-43	-33	-24	-19	-12	-6	-55	-45	-36	-7	0	6
31.5	-56	-42	-28	-21	-13	-5	-68	-54	-40	-9	-1	7
36.5	-60	-32	-4	-27	-17	-8	-72	-44	-16	-15	-5	4
41.5	-64	-53	-42	-21	-13	-5	-76	-65	-54	-9	-1	7
46.5	-60	-51	-42	-21	-13	-6	-72	-63	-54	-9	-1	6
51.5	-64	-54	-44	-21	-13	-5	-76	-66	-56	-9	-1	7
56.5	-65	-55	-45	-21	-13	-4	-77	-67	-57	-9	-1	8
72	-41	-36	-30	-22	-12	-2	-53	-48	-42	-10	0	10

NR: O_{th} is not reached. That is at this frequency offset PR is the predominant criterion. Consequently, DVB-T receiver is interfered with by the interfering signal due to insufficient C/I (<PR) before reaching its O_{th}.

Note 1: PR is applicable unless the sum of all interfering signals is above the corresponding O_{th}. If the interfering signal level is above the corresponding O_{th}, the receiver is interfered with by the interfering signal whatever the PR is.

Note 2: At wanted signal level close to receiver sensitivity, noise should be taken into account, e.g. at sensitivity + 3dB, 3 dB should be added to the PR.

Note 3: PR for different system variants and various reception conditions can be obtained using the correction factors in Table 3. The overloading threshold is independent of system variant and reception conditions.

Note 4: DVB-T PR and O_{th} relative to the interfering signal maximum rms power is applicable to MCL calculation when the interfering UMTS UE signal power is kept fixed to its maximum value.

Note 5: Treatment of overloading threshold in calculations when assessing interference from UMTS into DVB-T is presented in Annex C.

Note 6: The 90^{th} percentile for the protection ratio value corresponds to the protection of 90% of receivers measured, with respect to the frequency offset, whereas the 90^{th} percentile for the overloading threshold value corresponds to overloading of 10% of receivers measured (i.e. the 10^{th} percentile for the overloading threshold should be used to protect 90% of receivers measured).

Table 5: DVB-T PR and O_{th} values in the presence of a UMTS UE interfering signal with TPC in a Gaussian channel environment at the 10^{th}, 50^{th} and 90^{th} percentile. The results are provided for the interfering signal level measured as the rms average and the rms maximum power

5.1 Effect of UE Transmit Power Control (TPC)

Measurement results show that the needed protection ratio to maintain DVB-T receiver performance increases compared to a UMTS interfering signal without TPC when the interfering signal is subjected to TPC .

In UMTS, TPC is applied to the complex envelope of the modulated signal; that is to s'(t)=I(t)+jQ(t). Then, the modulated signal subjected to TPC is fed into the UMTS transmitter power amplifier. As explained in previous sections above, TPC is a very effective method to compensate for the UMTS UE/BS signal amplitude variations mainly due to fading in the uplink/downlink. However, it also has an important drawback. Actually, the UMTS UE signal subjected to TPC has a variable envelope with a fairly high dynamic range at the input of the UE power amplifier. Consequently, the non-linearity effects of the amplifier cause the "spectral re-growth" of the UMTS UE signal subjected to TPC compared to a UMTS signal without TPC. This phenomenon is shown in Figure 2. This seems to be the main reason why UMTS UE TPC has a negative impact on the DVB-T receiver performance.

The impact of a UMTS signal subjected to TPC on a DVB-T receiver cannot be linked to a single parameter (i.e. max peak value of the UMTS signal). It seems that it rather depends on the overall TPC profile or more precisely on the magnitude of the amplitude variations around the average value (dynamic range of the TPC) and the relative number of occurrences (or frequency) of the high amplitude variations.

6 CONCLUSION

This report presents the results of CEPT studies to assess the performance of DVB-T receiver in terms of measured carrier-to-interference protection ratios and overloading thresholds in the presence of interfering UMTS signal with (for interference from the user equipment) and without (for interference from the base station) transmit power control.

The measurements described in this report were used to develop the channelling arrangements for the mobile services in the band 790-862 MHz and the block edge mask applicable to the 790 MHz boundary (see CEPT reports 30 & 31 for details). Improvement in interfering transmitter ACLR values result in a slightly improved (decreased in this case) PR for the broadcasting service interfered with by UMTS signals in the 1st adjacent channel due to reduction of out-of-band emission of the interfering transmitter.

Ten different DVB-T receivers (set-top boxes available on the market in 2008, can type tuners), which are considered to be typical DVB-T receivers, have been tested against UMTS interference in a Gaussian channel environment. Interference in co-channel, first adjacent channel and beyond has been considered. Values for the measured protection ratios and overloading thresholds have been statistically calculated at the 10th, 50th and 90th percentile for all the receivers tested.

In general, protection ratios show a decrease in values (from -31 to -67 dB for the base station interference and from -5 to -55 dB for the user equipment interference) as the frequency offset increases. However, the protection ratio in the image channel is similar to the one in the third adjacent channel. The overloading threshold shows only small variations with frequency offset.

At equal frequency offsets the impact of user equipment interference into DVB-T receiver is considerably higher than the one from the base station, the effect being linked to the use of transmit power control. In particular, the latter increases the required protection ratio by 12-26 dB and decreases the overloading threshold detected by 7-11 dB depending on the frequency offset.

The results may be used by administrations seeking to protect their broadcasting services from interference generated by UMTS services in the band 790-862 MHz.

6.1 Further information

It is expected that LTE will be more widely deployed than WCDMA mobile service (UMTS) in the band 790-862 MHz. Therefore, measurements on LTE interference into DVB-T reception were also carried out in order to assess the impact of this on the broadcasting service.

The results of the measurements are set out in a subsequent ECC Report 148 [1].

7 ANNEX A: PROTECTION RATIO MEASUREMENTS OF DVB-T INTERFERENCE INTO USB DVB-T RECEIVERS

DVB-T USB receivers PR and O_{th} in the presence of a DVB-T interfering signal (f_w=778 MHz)				
f_i-f_w (MHz)	**O_{th} TV6_USB1 (dBm)**	**PR TV6_USB1 (dB)**	**O_{th} TV7_USB2 (dBm)**	**PR TV7_USB2 (dB)**
-88	0	-48	-17	-52
-80	0	-48	-17	-52
-72	0	-48	-18	-50
-64	1	-48	-18	-50
-56	1	-48	-18	-50
-48	1	-48	-18	-51
-40	2	-48	-19	-50
-32	2	-48	-19	-50
-24	2	-48	-19	-49
-16	2	-48	-19	-39
-8	0	-30	-21	-27
0	NR	17	NR	17
8	0	-31	-21	-24
16	4	-47	-20	-41
24	4	-52	-20	-49
32	4	-52	-19	-48
40	5	-51	-19	-49
48	5	-52	-20	-49
56	5	-52	-19	-49
64	5	-52	-20	-49
72	5	-52	-20	-49
80	5	-52	-20	-48
88	5	-54	-20	-48

NR: O_{th} is not reached. That is at this frequency offset PR is the predominant criterion. Consequently, DVB-T receiver is interfered with by the interfering signal due to insufficient C/I (<PR) before reaching its O_{th}

Note 1: PR is applicable unless the sum of all interfering signals is above the corresponding O_{th}. If the interfering signal level is above the corresponding O_{th}, the receiver is interfered with by the interfering signal whatever the C/I is

Note 2: At wanted signal level close to receiver sensitivity, noise should be taken into account, eg, at sensitivity + 3dB, 3 dB should be added to the PR

Note 3: PR for different system variants and various reception conditions can be obtained using the correction factors in Table 3. The overloading threshold is independent of system variant and reception conditions.

Table A1: DVB-T USB receivers PR and O_{th} in the presence of a DVB-T interfering signal (f_w=778 MHz)

8 ANNEX B: CORRECTION FACTORS FOR PROTECTION RATIOS FOR PORTABLE AND MOBILE DVB-T RECEPTION

Measurements on LTE UE interference into DVB-T reception carried out by the IRT show that for a time-variant Rayleigh channel – which is the relevant radio transmission channel for portable and mobile reception – an increase of the protection ratios of 7 to 9 dB is to be expected as compared to an Gaussian radio transmission channel. This is a well know behaviour, which can also be observed for the C/N values of the different DVB-T variants and for the protection ratios for interference from other co- or adjacent channel DVB-T services.

The measurements were taken for a slowly time-varying Rayleigh channel. They are therefore particularly appropriate for portable outdoor and indoor DVB-T reception. Two typical DVB-T set-top boxes have been investigated for centre frequency offsets between -8 MHz and +72 MHz. Even if the absolute values of the protection ratios differ for some frequency offsets, their relative difference between Gaussian and time-variant Rayleigh channel is approximately constant. This leads to the conclusion that the results of the measurements are generally valid. The bandwidth of the interfering IMT signal was taken to be 5 MHz.

The differences in protection ratios vary between 7 and 9 dB, apart from the 32 MHz frequency offset where an exceptional difference in protection ratios of 15 – 16 dB is found. For the image channel (72 MHz frequency off-set) an extremely high value of 21 dB is observed for receiver 1 which is probably due to a particularly high susceptibility of this receiver to image channel interference in the time-variant Rayleigh channel.

Difference of centre frequency Fi - fw [MHz]		0	8	16	24	32	40	48	56	64	72
Difference [dB] Gaussian – time-variant Rayleigh channel	Rx1	-	9	9	9	16	8	9	8	8	21
	Rx2	7	8	8	8	15	8	8	8	7	7
i: interfering signal, w: wanted signal											

Table B1: Difference of PR values for Gaussian and time-variant Rayleigh channel for LTE BS interference into DVB-T 16QAM 2/3

Table 3 of the main section of this document gives correction factors for protection ratios for portable and mobile DVB-T reception as compared to those for a Gaussian radio transmission channel. These differences vary for the different DVB-T variants between 3.2 and 4.0 dB for portable reception and between 6.2 and 7.0 dB for mobile reception.

A comparison with the measurement results in Table B1 shows that the correction factors of Table 3 for mobile reception are much more appropriate to describe the time-variant Rayleigh channel, i.e., also portable reception, than the figures given in Table 3 for portable reception. Even an increase of 1 to 2 dB would be desirable.

It is therefore recommended – if correction factors are to be taken from Table 3 – to use those for mobile reception also for portable reception.

9 ANNEX C: TREATMENT OF OVERLOADING THRESHOLD

In general, to ensure protection within the small covered area (i.e. at 95 % of the locations) in the absence of receiver overload, the median wanted field strength (E_{Wmed}) must exceed the median interfering field strength (E_{Imed}) as in the following expression:

$$E_{Wmed} \geq E_{Imed} + PR + \mu(95\%) \cdot \sqrt{(\sigma_W^2 + \sigma_I^2)}$$

The last term in the preceding expression is the location correction factor, which takes into account the statistical location variations of both the wanted and interfering signals (i.e. σ_W and σ_I).

The *i*-th nuisance field, N_{Ii}, of any given interferer, I_i, is: $N_{Ii} = E_{Iimed} + PR_i$, where E_{Iimed} is the median interfering field strength of the *i*-th interferer, and PR_i is the relevant protection ratio for the wanted signal with respect to the *i*-th interferer.

Figure D1[3] displays different interference cases that may occur at any given reception point.

For an interfering signal, I_U, which is less than the overloading threshold O_{th}, the maximum interfering signal $I_{U\max}$, for any given wanted signal level, C_W, is:

$$I_{U\max} = C_W - PR.$$

That is, $I_U \leq I_{U\max}$ to avoid interference. See Cases 1 and 2 in Figure D1.

However, when the resulting value of $I_{U\max}$ is larger than O_{th}, the actual maximum interfering field strength is $O_{th} < I_{U\max}$, and therefore $I_U < O_{th}$. See Case 3 in Figure D1.

The overloading threshold may vary with frequency offset. So for a given wanted signal, each 'adjacent channel' ($N \pm m_i$, $m_i \geq 1$) may have its 'own' corresponding protection ratio, PR_i. At least two calculations must be made for each interfering signal:

$$E_{Wmed} \geq N_{Ii} + \mu(95\%) \cdot \sqrt{(\sigma_W^2 + \sigma_{Ii}^2)} \text{ (the usual protection condition)}$$

$$E_{Iimed} < O_{thi} - \mu(95\%) \cdot \sqrt{(\sigma_W^2 + \sigma_{Ii}^2)} \text{ (the overload protection condition)}$$

The second indent implies that the overload condition should not occur with more than a 5 % location probability to avoid degradation in reception coverage.

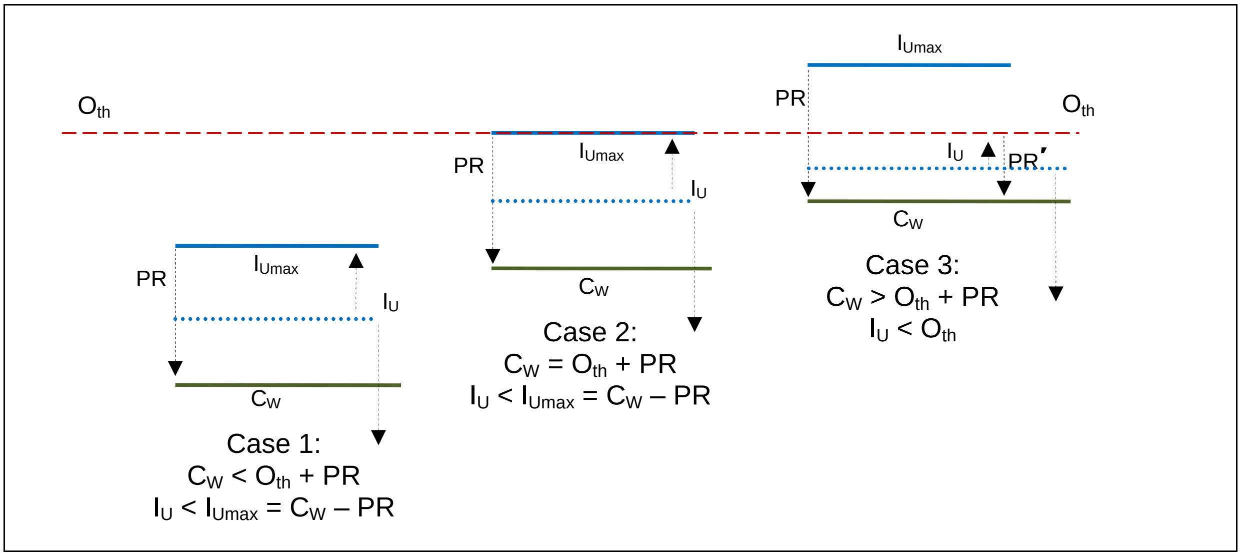

Figure C1: Different interference cases

[3] It is assumed that the relevant protections ratios, PR_i, will refer to 'adjacent channels' ($N \pm m_i$, $m_i \geq 1$), and will thus be negative. Therefore, in Figure D1: $I_{Umax} = C_W - PR$ is indeed greater than C_W, because PR is negative.

10 ANNEX D: LIST OF REFERENCES

[1] ECC Report 148 Measurements on the performance of DVB-T receivers in the presence of interference from the mobile service (especially from LTE)

[2] CEPT Report 30 in response to the EC Mandate on “The identification of common and minimal (least restrictive) technical conditions for 790-862 MHz for the digital dividend in the European Union”

[3] CEPT Report 31 the EC European Commission in response to the Mandate on “Frequency (channelling) arrangements for the 790-862 MHz band” (Task 2 of the 2nd Mandate to CEPT on the digital dividend)

[4] ITU-R Recommendation V.573-5: Radiocommunication vocabulary (www.itu.int)

[5] TS 125 101: Universal Mobile Telecommunications System (UMTS); User Equipment (UE) radio transmission and reception (FDD) (www.etsi.org)

[6] TS 125 104: Universal Mobile Telecommunications System (UMTS); Base Station (BS) radio transmission and reception (FDD) (www.etsi.org)