International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R BT.2033

(01/2013)

Planning criteria, including protection ratios, for second generation of digital terrestrial television broadcasting systems in the VHF/UHF bands

BT Series

Broadcasting service (television)

International Telecommunication Union

Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

Policy on Intellectual Property Right (IPR)

ITU-R policy on IPR is described in the Common Patent Policy for ITU-T/ITU-R/ISO/IEC referenced in Annex 1 of Resolution ITU-R 1. Forms to be used for the submission of patent statements and licensing declarations by patent holders are available from http://www.itu.int/ITU-R/go/patents/en where the Guidelines for Implementation of the Common Patent Policy for ITU-T/ITU-R/ISO/IEC and the ITU-R patent information database can also be found.

Series of ITU-R Recommendations

(Also available online at http://www.itu.int/publ/R-REC/en)

Series	Title
BO	Satellite delivery
BR	Recording for production, archival and play-out; film for television
BS	Broadcasting service (sound)
BT	**Broadcasting service (television)**
F	Fixed service
M	Mobile, radiodetermination, amateur and related satellite services
P	Radiowave propagation
RA	Radio astronomy
RS	Remote sensing systems
S	Fixed-satellite service
SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	Spectrum management
SNG	Satellite news gathering
TF	Time signals and frequency standards emissions
V	Vocabulary and related subjects

Note*: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

Electronic Publication
Geneva, 2013

RECOMMENDATION ITU-R BT.2033

Planning criteria, including protection ratios, for second generation of digital terrestrial television broadcasting systems in the VHF/UHF bands

(Question ITU-R 132/6)

(2013)

Scope

This Recommendation defines planning criteria, including protection ratios, for various methods of providing second generation digital terrestrial television broadcasting (DTTB) systems in the VHF/UHF bands.

The ITU Radiocommunication Assembly,

considering

a) that the digital terrestrial television systems for use in broadcasting bands have been developed in Recommendation ITU-R BT.1306, which are referred to as the current systems;

b) that these current first generation DTTB systems have been deployed for the transmission of digital terrestrial television services in the VHF/UHF bands;

c) that analogue television services have migrated out of the VHF/UHF television bands within many administrations;

d) that DTTB television services will remain in use for a considerable period of time;

e) that many types of interference, including co-channel and adjacent channel, ignition noise, multipath and other signal distortions exist in the VHF/UHF bands;

f) that recent developments in the field of channel coding and modulation have produced new techniques with performances approaching the Shannon limit;

g) that the error-correction, data framing, modulation and emission methods for the second generation worldwide digital terrestrial television broadcasting systems have been defined in Recommendation ITU-R BT.1877;

h) that these new digital techniques would offer better spectrum and/or power efficiency, in comparison to the current systems, whilst maintaining the possibility to be flexibly configured to cope with the specific broadcasting bandwidth and power resources;

j) that the recommended system makes use of such techniques and thus allows for a wide-ranging trade-off between operation under minimal C/N levels or maximum transmission capacity;

k) that the planning criteria for various methods of providing first generation digital terrestrial television services in the VHF/UHF bands have been defined in Recommendation ITU-R BT.1368;

l) that the availability of consistent sets of planning criteria agreed by administrations will facilitate the introduction of second generation digital terrestrial television services, *recommends*

that the relevant planning criteria, including protection ratios (PRs) and the relevant minimum field strength values given in Annex 1 should be used as the basis for frequency planning for second generation digital terrestrial television services.

NOTE – Annexes 3 and 5 are an integral part of the Recommendation. Annexes 2 and 4 are provided for information.

Introduction

This Recommendation contains the following Annexes:

Annex 1 – Planning criteria, including protection ratios, for DVB second generation digital terrestrial television systems in the VHF/UHF bands

Annex 2 – Additional test results from UK and Russian Federation

Annex 3 – Other planning factors such as antenna types and antenna discrimination, height loss etc.

Annex 4 – Subjective failure point description

Annex 5 – Tropospheric and continuous interference.

General

The RF protection ratio is the minimum value of wanted-to-unwanted signal ratio, usually expressed in decibels at the receiver input.

The protection ratios defined in this recommendation are based on measurements using the test methodology and signal power references defined in [1].

Administrations are invited to contribute with additional results of measurements in order to complete this Recommendation.

Wanted digital terrestrial television systems

The protection ratios for digital terrestrial television systems apply to both continuous and tropospheric interference. The protection ratios refer to the centre frequency of the wanted digital terrestrial television system.

Because a digital television receiver needs to operate successfully in the presence of high level interference signals on nearby channels, a high degree of receiver front-end linearity is required.

The protection ratios for digital terrestrial television systems as the interfering system are those for the case where the wanted and unwanted signals are not synchronized and/or do not have a common programme source.

Protection ratios are measured at based on setting the interference conditions to be at the onset of picture failure using the subjective failure point (SFP) method as defined in [1].

CONTENTS

Annex 1
(Normative)

Planning criteria, including protection ratios, for DVB second generation digital terrestrial television systems in the VHF/UHF bands

1 Protection ratios for DVB-T2 wanted digital terrestrial television signals

1.1 Wanted signal configuration

To reduce the number of measurements and tables, it is proposed that protection ratio measurements for DVB-T2 systems should be made with the following mode shown in Table 1. Protection ratio values for the different required operational modes can be calculated from the given measured values. All data in this Annex corresponds to this mode unless stated otherwise.

TABLE 1

Preferable DVB-T2 mode type for measurements on protection ratios

Overall	Parameter Value
FFTSIZE	32 K
GI	1/128
Data symbols	59
SISO/MISO	SISO
PAPR	None
Frames per superframe	2
Bandwidth	8 MHz
Extended bandwidth mode	Yes
Pilot pattern	PP7
L1 Modulation	64 QAM
PLP #0	
Type	1
Modulation	256 QAM
Rate	2/3
FEC Type	64 800
Rotated QAM	Yes
FEC blocks per interleaving frame	202
TI blocks per frame (N_TI)	3
T2 frames per interleaving frame (P_I)	1
Frame interval (I_JUMP)	1
Type of time-interleaving	0
Time interleaving length	3
C/N (AWGN Channel) dB	19.7
Data rate Mbit/s	40.2

1.2 Characteristics of the LTE interfering signal

The protection ratios and overload thresholds for LTE base stations (BS) and User Equipment (UE) in this recommendation are based on measurements using recorded 10 MHz wide LTE waveforms from real BS and UE devices with three different traffic loadings. These recordings were filtered to remove out of band recording artifacts and formatted into I/Q data suitable for replay from standard laboratory vector signal generators.

The BS traffic loadings were categorized as:

a) Idle – consisting mainly of synchronization and broadcast signals with occasional data;

b) 50% loading – medium loading;

c) 100% loading – where all the resource blocks were used all the time.

The UE traffic loadings were categorized as:

a) 1 Mbit/s – light loading where only a small number of resource blocks are used for some of the time;

b) 10 Mbit/s – medium loading;

c) 20 Mbit/s – high loading.

There is significantly more time variation in the power of the lighter traffic loaded waveforms which can cause PR and O_{th} degradation in some receivers.

1.3 Notes applying to protection ratio and overload threshold tables

To avoid repetition, unless stated otherwise, the following notes apply to Tables 2 to 11 and Tables 14 to 18.

NOTE 1 – The 90^{th} 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 10^{th} percentile for the overload threshold should be used to protect 90% of receivers measured.

NOTE 2 – Δf is the difference between the centre frequency of the unwanted channel and the centre frequency of the wanted channel.

NOTE 3 – NR: O_{th} is not reached. That is at this frequency offset PR is the predominant criterion.

NOTE 4 – PR is applicable unless the interfering signal level 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 signal to interference ratio is.

NOTE 5 – At wanted signal level close to receiver sensitivity, noise should be taken into account, e.g. at sensitivity +3 dB, 3 dB should be added to the PR.

NOTE 6 − PR for different system variants and various reception conditions can be obtained using the correction factors in Table 10 of this Annex. The overload threshold is assumed to be independent of system variant and reception conditions.

NOTE 7 – Protection ratios are rounded to the nearest integer.

NOTE 8 – The Ricean and static Rayleigh channels are defined in section 14.1 of ETSI TS 102 831 Digital Video Broadcasting (DVB); Implementation guidelines for a second generation digital terrestrial television broadcasting system (DVB-T2). They are also described in ETSI EN 300 744 Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for digital terrestrial television (DVB-T).

NOTE 9 – The LTE BS interference signals used in the measurements had ACLRs of 60 dB or greater for N-1, and significantly higher ACLRs for N-2 and beyond.

Tables 2 to 11 and Tables 14 to 18 show protection ratios for the DVB-T2 wanted digital terrestrial television signals interfered with:

– by DVB-T2 digital terrestrial television signals;
– by LTE base station (BS) signals;
– by LTE user equipment (UE) signals.

1.4 Protection of a DVB-T2 digital terrestrial television signal interfered with by a DVB-T2 digital terrestrial television signal

The values in Table 2 are theoretical values calculated for the mode in Table 1 using the method described in Report ITU-R BT.2254-2012.

TABLE 2

Co-channel protection ratios (dB) for a DVB-T2 signal (defined in Table 1) interfered with by a DVB-T2 signal of similar mode

Modulation	Code rate	Gaussian channel	Ricean channel Note 8	Rayleigh channel (static) Note 8
QPSK	1/2	2.4	2.6	3.4
QPSK	3/5	3.6	3.8	4.9
QPSK	2/3	4.5	4.8	6.3
QPSK	3/4	5.5	5.8	7.6
QPSK	4/5	6.1	6.5	8.5
QPSK	5/6	6.6	7.0	9.3
16-QAM	1/2	7.6	7.8	9.1
16-QAM	3/5	9.0	9.2	10.7
16-QAM	2/3	10.3	10.5	12.2
16-QAM	3/4	11.4	11.8	13.9
16-QAM	4/5	12.2	12.6	15.1
16-QAM	5/6	12.7	13.1	15.9
64-QAM	1/2	11.9	12.2	14.0
64-QAM	3/5	13.8	14.1	15.8
64-QAM	2/3	15.1	15.4	17.2
64-QAM	3/4	16.6	16.9	19.3
64-QAM	4/5	17.6	18.1	20.9
64-QAM	5/6	18.2	18.7	21.8
256-QAM	1/2	15.9	16.3	18.3
256-QAM	3/5	18.2	18.4	20.5
256-QAM	2/3	19.7	20.0	22.1
256-QAM	3/4	21.7	22.0	24.6
256-QAM	4/5	23.1	23.6	26.6
256-QAM	5/6	23.9	24.4	28.0

Protection ratios in Table 3 are given for three types of propagation channels (i.e. Gaussian, Ricean and Rayleigh). For fixed and portable reception, the values relevant to the Ricean and Rayleigh channels, respectively, should be adopted.

The same protection ratio corrections in Table 3 should be applied for DVB-T2 systems with 6, 7 and 8 MHz bandwidth.

TABLE 3

Protection ratios (dB) and overload threshold (dBm) for a DVB-T2 signal (defined in Table 1) interfered with by a DVB-T2 signal (defined in Table 1) in adjacent channels for silicon tuners

Channel offset N (8 MHz channels)	Centre frequency offset (MHz)	Number of receivers tested	PR (dB)		Oth (dBm)	
			Percentile		Percentile	
			50th	90th	10th	50th
–9	72	11	–54	–50	–14	0
–4	–32	11	–50	–44	–14	–2
–3	–24	11	–48	–44	–14	–2
–2	–16	11	–47	–43	–15	–6
–1	–8	11	–35	–33	–15	–6
Co-channel	0	11	19.0	19.0	–	–
1	8	11	–32	–30	–15	–6
2	16	11	–46	–43	–15	–5
3	24	11	–47	–43	–14	–2
4	32	11	–50	–44	–13	1
9	72	11	–54	–49	–13	1

The values given apply to the case where wanted and unwanted DVB-T2 signals have the same channel width. Other combinations of channel width need further studies.

The interfering signal had the same mode parameters as the wanted signal but was uncorrelated to it.

The protection ratio is given in dB and applies to both continuous and tropospheric interference.

1.5 Protection ratios and overload thresholds for DVB-T2 interfered with by LTE base station and user equipment signals

This section provides protection ratios and overload thresholds for DVB-T2 systems interfered with by LTE OFDMA (base station) and SC-FDM (user equipment) systems. All measurements to derive these parameters were performed on DVB-T2 receivers designed for a frequency tuning range from 470 to 862 MHz, all interfering signals were within the frequency range 759 to 862 MHz.

Only a small number (3) of DVB-T2 receivers with can tuners were available for testing, preventing any statistical analysis of the results. The individual receiver performance is tabulated for reference in Appendix 2 to this Annex.

The characteristics of the LTE signal used in the measurements are given in Report ITU-R BT.2215 “Measurement of protection ratios and overload threshold for broadcast TV receivers”.

The sharing between DVB-T2 and the mobile LTE service is an evolving situation where the design of both the television tuners and the implementation of base stations are changing. All parties involved are actively encouraged to improve the performance of their respective equipment so that these tables can be revisited in the near future.

Due to the time variation in the LTE signal, the worst-case degradation of PR and O_{th} in some tuner designs corresponds to very low BS and UE traffic loadings. Three levels of traffic load are provided here as the actual traffic load in the real BS and UE operation is unlikely to be predictable.

The highest level of protection (to protect broadcasting for all BS and UE traffic load cases) is achieved by taking the highest value for the protection ratio and the lowest value for the overload threshold for either tuner technology.

The frequency offset is measured between the centre frequencies of wanted and interfering signals.

1.5.1 Protection of a DVB-T2 digital terrestrial television signal interfered with by a LTE-BS signal

The following tables show protection ratios and overload thresholds for three different traffic loadings on the LTE base station.

TABLE 4

Measured protection ratios (dB) for a DVB-T2 signal (defined in Table 1) interfered with by an LTE BS signal in adjacent channels for silicon tuners

Channel Offset N (8 MHz channels)	Centre frequency offset (MHz)	Number of receivers tested	0% BS traffic loading PR (dB)		50% BS traffic loading PR (dB)		100% BS traffic loading PR (dB)	
			Percentile		Percentile		Percentile	
			50th	90th	50th	90th	50th	90th
Co-channel AWGN	0	11	19	19	19	19	19	19
Co-channel LTE	0	11	10	11	18	18	19	19
1	10	11	–44	–24	–40	–38	–38	–36
2	18	11	–50	–32	–48	–44	–47	–43
3	26	11	–51	–35	–49	–45	–48	–44
4	34	11	–52	–39	–51	–46	–50	–45
5	42	11	–53	–41	–51	–47	–51	–46
6	50	11	–55	–46	–54	–48	–52	–47
7	58	11	–56	–46	–54	–49	–54	–48
8	66	11	–57	–45	–54	–50	–53	–49
9	74	11	–58	–45	–55	–50	–53	–49

TABLE 5

Measured overload thresholds (dBm) for a DVB-T2 signal (defined in Table 1) interfered with by an LTE BS signal in adjacent channels for silicon tuners

Channel offset N (8 MHz channels)	Centre frequency offset (MHz)	Number of receivers tested	0% BS traffic loading O_{th} (dBm)		50% BS traffic loading O_{th} (dBm)		100% BS traffic loading O_{th} (dBm)	
			Percentile		Percentile		Percentile	
			10th	50th	10th	50th	10th	50th
1	10	11	–18	–6	–15	–6	–13	–8
2	18	11	–14	1	–12	–2	–13	–3
3	26	11	–12	3	–13	0	–12	–1
4	34	11	–11	5	–12	2	–12	0
5	42	11	–10	6	–12	3	–12	2
6	50	11	–10	4	–12	2	–12	2
7	58	11	–10	4	–11	2	–12	1
8	66	11	–10	4	–12	2	–12	1
9	74	11	–10	5	–12	3	–12	1

1.5.2 Protection of a DVB-T2 digital terrestrial television signal interfered with by a LTE-UE signal

The following tables show PR and O_{th} for three different UE traffic loadings:

Table 6 – Uncorrected UE PR results

Table 7 – Estimated UE ACLR based on 3GPP TS 36.101 and ETSI masks

Table 8 – UE PR results corrected for UE out-of-band noise degradation

Table 9 – UE overload threshold results.

TABLE 6

Un-corrected protection ratios (dB) for a DVB-T2 signal (defined in Table 1) interfered with by an LTE UE signal in adjacent channels for silicon tuners

Channel offset N 8 MHz channels/ (centre frequency offset)	No. of Rx. tested	1 Mbit/s UE traffic loading Signal generator ACLR = 100 dB all offsets		10 Mbit/s UE traffic loading Signal generator ACLR = 100 dB all offsets		20 Mbit/s UE traffic loading Signal generator ACLR = 67.8 dB (N+1) 80.4 dB (N+2) 100 dB (N+3 to N+9)	
		PR Percentile (dB)		PR Percentile (dB)		PR Percentile (dB)	
		50th	90th	50th	90th	50th	90th
Co-channel AWGN (0)	11	19	19	19	19	19	19
Co-channel LTE (0)	11	10	11	18	18	19	19
1/(10)	11	–36	–19	–41	–39	–41	–39
2 (18)	11	–41	–24	–47	–45	–47	–43
3 (26)	11	–44	–26	–48	–45	–50	–44
4 (34)	11	–46	–36	–48	–45	–52	–45
5 (42)	11	–47	–37	–48	–44	–54	–46
6 (50)	11	–50	–38	–49	–43	–52	–45
7 (58)	11	–50	–41	–49	–44	–53	–44
8 (66)	11	–50	–41	–49	–42	–54	–45
9 (74)	11	–50	–43	–49	–43	–54	–47

The UE protection ratios are corrected for the estimated UE ACLR in 8 MHz adjacent and non-adjacent channels to take account of the degradation in protection ratio caused by UE out-of band noise. The ACLR estimates based on the mask in Table 6.6.2.1.1 of 3GPP TS 36.101 v.11.1.0 and the draft ETSI 301-908-13 requirement for –65 dBm out-of-band noise in the band 470-790 MHz. These are shown in Table 7.

TABLE 7

Assumed UE ACLRs for corrected UE PR values

Channel offset N (8 MHz channels)	Centre frequency offset (MHz)	ACLR (dB)
1	10	25.2
2	18	32.2
Other offsets (corresponding to –65 dBm/8 MHz)	26-74	88.0

The co-channel PR_0 values used in the correction calculation were the AWGN figures in Table 8. The ACLR correction method is described below.

The final protection ratio is found in two stages; firstly, for a frequency offset Δf the adjacent channel selectivity (ACS) of the receiver is calculated from the measured protection ratio at the offset (PR(Δf)), the co-channel protection ratio PR_0 and the ACLR of the interference signal generator:

$$ACS(\Delta f) = -10\log(10^{-\frac{PR_0 - PR(\Delta f)}{10}} - 10^{-\frac{ACLR}{10}})$$

Secondly, the derived value of the DTT ACS is used to determine the appropriate adjacent channel protection ratios for interfering terminal that may have different ACLR characteristics.

The final protection ratio, PR′(Δf), is a function of the ACS and the ACLR of the LTE device at (Δf), ACLR′:

$$PR'(\Delta f) = PR_0 + 10\log(10^{\frac{-ACS}{10}} + 10^{\frac{-ACLR'}{10}})$$

This method can also be used to reverse the corrected PRs back to the uncorrected PRs to allow the effect of different UE ACLR assumptions to be calculated.

Note that the ACLR and ACLR′ in the equations above are based on power measurements using the channel bandwidth of the LTE interferer (e.g. 10 MHz) and the channel bandwidth of the wanted DVB-T2 signal (e.g. 8 MHz) at the appropriate frequency offsets of the interferer.

TABLE 8

Corrected protection ratios (dB) for a DVB-T2 signal (defined in Table 1) interfered with by an LTE UE signal in adjacent channels for silicon tuners

Channel offset N 8 MHz channels/ (centre frequency offset)	No. of Rx. tested	1 Mbit/s UE traffic loading Signal generator ACLR = 100 dB all offsets		10 Mbit/s UE traffic loading Signal generator ACLR = 100 dB all offsets		20 Mbit/s UE traffic loading Signal generator ACLR = 67.8 dB (N+1) 80.4 dB (N+2) 100 dB (N+3 to N+9)	
		PR Percentile (dB)		PR Percentile (dB)		PR Percentile (dB)	
		50th	90th	50th	90th	50th	90th
Co-channel AWGN (0)	11	19	19	19	19	19	19
Co-channel LTE (0)	11	10	11	18	18	19	19
1/(10)	11	–6	–6	–6	–6	–6	-6
2 (18)	11	–13	–13	–13	–13	–13	–13
3 (26)	11	–44	–26	-48	–45	–50	-44
4 (34)	11	–46	–36	–48	-45	–52	–45

TABLE 8 (*End*)

Channel offset N 8 MHz channels/ (centre frequency offset)	No. of Rx. tested	1 Mbit/s UE traffic loading Signal generator ACLR = 100 dB all offsets		10 Mbit/s UE traffic loading Signal generator ACLR = 100 dB all offsets		20 Mbit/s UE traffic loading Signal generator ACLR = 67.8 dB (N+1) 80.4 dB (N+2) 100 dB (N+3 to N+9)	
		PR Percentile (dB)		PR Percentile (dB)		PR Percentile (dB)	
		50th	90th	50th	90th	50th	90th
5 (42)	11	–47	–37	–48	–44	–54	–46
6 (50)	11	–50	–38	–49	–43	–52	–45
7 (58)	11	–50	–41	–49	–44	–53	-44
8 (66)	11	–50	–41	–49	–42	–54	–45
9 (74)	11	–50	–43	–49	–43	–54	–47

TABLE 9

Measured overload thresholds (dBm) for a DVB-T2 signal (defined in Table 1) interfered with by an LTE UE signal in adjacent channels for silicon tuners

Channel offset N (8 MHz channels)	Centre frequency offset (MHz)	Number of receivers tested	1 Mbit/s UE traffic loading		10 Mbit/s UE traffic loading		20 Mbit/s UE traffic loading	
			O_{th} (dBm)		O_{th} (dBm)		O_{th} (dBm)	
			10th	50th	10th	50th	10th	50th
1	10	11	–37	–6	–15	–5	–12	–5
2	18	11	–12	5	–11	0	–11	0
3	26	11	–10	6	–11	2	–11	0
4	34	11	–24	5	–11	2	–11	1
5	42	11	–10	6	–11	2	–11	1
6	50	11	–10	6	–11	2	–11	2
7	58	11	–10	5	–11	2	–11	2
8	66	11	–10	5	–11	2	–11	2
9	74	11	–11	6	–11	2	–11	2

1.6 Correction factors for different wanted DVB-T2 system variants and different reception conditions

Table 10 was developed for DVB-T2 signals using other modes interfered with by DVB-T2. It is calculated as the difference in AWGN *C*/*N* between other modes and the reference mode in Table 1 and should be used with caution, particularly if the difference in *C*/*N* for the required mode compared with the reference mode is large. The values have yet to be verified through measurement. It is proposed to be used for other types of interferers but further studies are required to confirm the values.

TABLE 10

Theoretical correction factor estimates for protection ratios (dB) for different wanted DVB-T2 system variants relative to the reference mode in Table 1 (interfered with by DVB-T2 or other services)

Modulation	Code rate	Gaussian channel	Rice channel Note 8	Rayleigh channel (static) Note 8
QPSK	1/2	–17.3	–17.1	–16.3
QPSK	3/5	–16.1	–15.9	–14.8
QPSK	2/3	–15.2	–14.9	–13.4
QPSK	3/4	–14.2	–13.9	–12.1
QPSK	4/5	–13.6	–13.2	–11.2
QPSK	5/6	–13.1	–12.7	–10.4
16-QAM	1/2	–12.1	–11.9	–10.6
16-QAM	3/5	–10.7	–10.5	–9.0
16-QAM	2/3	–9.4	–9.2	–7.5
16-QAM	3/4	–8.3	–7.9	–5.8
16-QAM	4/5	–7.5	–7.1	–4.6
16-QAM	5/6	–7.0	–6.6	–3.8
64-QAM	1/2	–7.8	–7.5	–5.7
64-QAM	3/5	–5.9	–5.6	–3.9
64-QAM	2/3	–4.6	–4.3	–2.5
64-QAM	3/4	–3.1	–2.8	–0.4
64-QAM	4/5	–2.1	–1.6	1.2
64-QAM	5/6	–1.5	–1.0	2.1
256-QAM	1/2	–3.8	–3.4	–1.4
256-QAM	3/5	–1.5	–1.2	0.8
256-QAM	2/3	0.0	0.3	2.4
256-QAM	3/4	2.0	2.3	4.9
256-QAM	4/5	3.4	3.9	6.9
256-QAM	5/6	4.2	4.7	8.3

As compared to a static Rayleigh transmission channel, the time-variant Rayleigh channel which is relevant for portable DVB-T2 reception shows a significantly higher need for protection ratios. Further measurement is needed for evaluation of this effect.

1.7 Selection of PR and O_{th} for sharing studies

Table 11 illustrates recommended values for PR and O_{th} to be used in sharing studies. By applying these values 90 percent of receivers (among all 14 tuners measured), would be protected across all traffic loadings. For the UE, the corrected PR 90th percentiles were used based on the UE ACLR assumptions in Table 7.

TABLE 11

Recommended sharing study values of PR and O_{th} for a DVB-T2 signal (defined in Table 1) in a clear channel, interfered with by an LTE BS or UE signal in adjacent channels for 3 can and 11 silicon tuners combined

Channel offset N (8 MHz channels)	Centre frequency offset (MHz)	LTE BS		LTE UE	
		PR (dB)	O_{th} (dBm)	Corrected PR (dB)	O_{th} (dBm)
Co-channel (AWGN)	0	19	–	19	–
Co-channel (LTE)	0	19	–	19	–
1	10	–25	–16	–6	–30
2	18	–33	–12	–13	–11
3	26	–36	–11	–28	–10
4	34	–40	–13	–37	–20
5	42	–43	–11	–38	–10
6	50	–46	–11	–40	–9
7	58	–47	–11	–42	–9
8	66	–46	–11	–43	–10
9	74	–46	–10	–44	–10

1.8 Effect of transient interference on protection ratios

In the previous sections, the interference has been active at the time the DTT wanted signal is acquired. Recent studies have shown significantly higher protection ratios (10-12 dB) are measured when the interference source is applied after the DTT wanted signal has been acquired. This is particularly relevant when the interference is occasional such as in the case of an LTE UE where the user may have long gaps (many seconds) of no activity allowing the DTT receiver AGC to stabilize in a "no interference" state. Examples include:

– regular polling of data "pull" servers (e.g. email updating, social networking applications);
– "keep alive" messages for stateful applications;
– other network signalling traffic.

Details of these measurements are given in Appendix 3 to Annex 1. These measurements are preliminary pending further study.

2 Minimum field strengths for DVB-T2 terrestrial digital television

The formula for calculating minimum field strength is given in Appendix 1 to Annex 1. For other reception modes (mobile rural, handheld portable outdoor and handheld mobile with integrated antenna) field strength calculations are available in Report ITU-R BT.2254 – Frequency and network planning aspects of DVB-T.

TABLE 12

Calculation of minimum field strength DVB-T2 8 MHz system at 200 MHz

DVB-T2 in Band III			Fixed	Portable outdoor/urban	Portable indoor/urban
Frequency	Freq	MHz	200	200	200
Minimum C/N required by system	C/N	dB	20.0	17.9	18.3
System variant (example)			256-QAM FEC 2/3, 32k, PP7 Normal	64-QAM FEC 2/3, 32k, PP4 Normal	64-QAM FEC 2/3, 16k, PP1 Normal
Bit rate (indicative values)		Mbit/s	30-35	22-25	19-24
Receiver noise figure	F	dB	6	6	6
Equivalent noise bandwidth	B	MHz	6.66	6.66	6.66
Receiver noise input power	P_n	dBW	–128.6	–128.9	–128.5
Min. receiver signal input power	$P_{s\ min}$	dBW	–109.7	–111.8	–111.4
Min. equivalent receiver input voltage, 75 Ω	U_{min}	dBμV	29.0	26.9	27.3
Feeder loss	L_f	dB	2	0	0
Antenna gain relative to half dipole	G_d	dB	7	–2.2	–2.2
Effective antenna aperture	A_a	dBm^2	1.7	–7.5	–7.5
Min power flux-density at receiving location	Φ_{min}	dB(W)/m^2	–109.4	–104.3	–103.9
Min equivalent field strength at receiving location	E_{min}	dBμV/m	36.4	41.5	41.9
Allowance for man-made noise	P_{mmn}	dB	2	8	8
Penetration loss (building or vehicle)	L_b, L_h	dB	0	0	9
Standard deviation of the penetration loss		dB	0	0	3
Diversity gain	Div	dB	0	0	0

TABLE 12 (*End*)

DVB-T2 in Band III			Fixed	Portable outdoor/urban	Portable indoor/urban
Location probability		%	70	70	70
Distribution factor			0.5244	0.5244	0.5244
Standard deviation			5.5	5.5	6.3
Location correction factor	C_l	dB	2.8842	2.8842	3.30372
Minimum median power-flux density at reception height(1); 50% time and 50% locations	Φ_{med}	dB(W)/m^2	–104.5	–93.4	–83.6
Minimum median equivalent field strength at reception height(1); 50% time and 50% locations	E_{med}	dBμV/m	41.3	52.4	62.4
Location probability		%	95	95	95
Distribution factor			1.6449	1.6449	1.6449
Standard deviation			5.5	5.5	6.3
Location correction factor	C_l	dB	9.04695	9.04695	10.36287
Minimum median power flux-density at reception height(1); 50% time and 50% locations	Φ_{med}	dB(W)/m^2	–98.4	–87.3	–77.6
Minimum median equivalent field strength at reception height(1); 50% time and 50% locations	E_{med}	dBμV/m	47.4	58.5	69.2

(1) 10 m for fixed reception and 1.5 m for the other reception modes.

TABLE 13

Calculation of minimum field strength DVB-T2 8 MHz system at 650 MHz

DVB-T2 in Band IV/V			Fixed	Portable outdoor/urban	Portable indoor/urban
Frequency	Freq	MHz	650	650	650
Minimum C/N required by system	C/N	dB	20.0	17.9	18.3
System variant (example)			256-QAM FEC 2/3, 32k, PP7 Extended	64-QAM FEC 2/3, 32k, PP4 Extended	64-QAM FEC 2/3, 16k, PP1 Extended
Bit rate (indicative values)		Mbit/s	35-40	26-29	23-28
Receiver noise figure	F	dB	6	6	6
Equivalent noise bandwidth	B	MHz	7.77	7.77	7.77
Receiver noise input power	P_n	dBW	–128.0	–128.3	–127.9

TABLE 13 (*End*)

DVB-T2 in Band IV/V			Fixed	Portable outdoor/urban	Portable indoor/urban
Min. receiver signal input power	$P_{s\,min}$	dBW	–109.1	–111.2	–110.8
Min. equivalent receiver input voltage, 75Ω	U_{min}	dBμV	29.7	27.6	28.0
Feeder loss	L_f	dB	4	0	0
Antenna gain relative to half dipole	G_d	dB	11	0	0
Effective antenna aperture	A_a	dBm^2	–4.6	–15.6	–15.6
Min power flux-density at receiving location	Φ_{min}	dB(W)/m^2	–100.5	–95.6	–94.2
Min equivalent field strength at receiving location	E_{min}	dBμV/m	45.3	50.2	50.6
Allowance for man-made noise	P_{mmn}	dB	0	1	1
Penetration loss (building or vehicle)	L_b, L_h	dB	0	0	11
Standard deviation of the penetration loss		dB	0	0	6
Diversity gain	*Div*	dB	0	0	0
Location probability		%	70	70	70
Distribution factor			0.5244	0.5244	0.5244
Standard deviation			5.5	5.5	8.1
Location correction factor	C_l	dB	2.8842	2.8842	4.24764
Minimum median power flux-density at reception height(1); 50% time and 50% locations	Φ_{med}	dB(W)/m^2	–97.6	–91.7	–79.0
Minimum median equivalent field strength at reception height(1); 50% time and 50% locations	E_{med}	dBμV/m	48.2	54.1	66.8
Location probability		%	95	95	95
Distribution factor			1.6449	1.6449	1.6449
Standard deviation			5.5	5.5	8.1
Location correction factor	C_l	dB	9.04695	9.04695	13.32369
Minimum median power flux-density at reception height(1); 50% time and 50% locations	Φ_{med}	dB(W)/m^2	–91.5	–85.6	–72.3
Minimum median equivalent field strength at reception height(1); 50% time and 50% locations	E_{med}	dBμV/m	54.3	60.2	75.9

(1) 10 m for fixed reception and 1.5 m for the other reception modes.

3 References

[1] Report ITU-R BT.2215 – Measurements of protection ratios and overload thresholds for broadcast TV receivers.

[2] Report ITU-R BT.2254 – Frequency and network planning aspects of DVB-T2.

Appendix 1
to Annex 1

Calculation of minimum field strength and minimum median equivalent field strength

The minimum field strength and minimum median equivalent field strength values calculated using the following equations:

$$P_n = F + 10 \log (k\, T_0\, B)$$

$$P_{s\,min} = C/N + P_n$$

$$A_a = G + 10 \log (1.64\lambda^2/4\,\pi)$$

$$\varphi_{min} = P_{s\,min} - A_a + L_f$$

$$E_{min} = \varphi_{min} + 120 + 10 \log (120\,\pi)$$

$$= \varphi_{min} + 145.8$$

$E_{med} = E_{min} + P_{mmn} + C_l$ for roof top level fixed reception

$E_{med} = E_{min} + P_{mmn} + C_l + L_h$ for portable outdoor and mobile reception

$E_{med} = E_{min} + P_{mmn} + C_l + L_h + L_b$ for portable indoor and mobile hand-held reception

$$C_l = \mu \cdot \sigma_t$$

$$\sigma_t = \sqrt{\sigma_b^2 + \sigma_m^2}$$

where:

P_n : receiver noise input power (dBW);

F : receiver noise figure (dB);

k : Boltzmann's constant ($k = 1.38 \times 10^{-23}$ (J/K));

T_0 : absolute temperature ($T_0 = 290$ (K));

B : receiver noise bandwidth ($B = 7.61 \times 10^6$ (Hz));

$P_{s\,min}$: minimum receiver input power (dBW);

C/N : RF S/N at the receiver input required by the system (dB);

A_a : effective antenna aperture (dBm^2);

G : antenna gain related to half dipole (dBd);

λ : wavelength of the signal (m);

φ_{min} : minimum pfd at receiving place (dB(W/m^2));

L_f : feeder loss (dB);

E_{min} : equivalent minimum field strength at receiving place (dB(µV/m));

E_{med} : minimum median equivalent field strength, planning value (dB(µV/m));

P_{mmn} : allowance for man-made noise (dB);

L_h : height loss (reception point at 1.5 m above ground level) (dB);

L_b : building or vehicle entry loss (dB);

C_l : location correction factor (dB);

σ_t : total standard deviation (dB);

σ_m : standard deviation macro-scale (σ_m = 5.5 (dB));

σ_b : standard deviation building entry loss (dB);

μ : distribution factor being 0.52 for 70%, 1.28 for 90%, 1.64 for 95% and 2.33 for 99%.

Appendix 2
to Annex 1

Can tuner test results

LTE BS PR & O_{th}

Tables 14 and 15 give the raw measurement results for three can tuners for the case of LTE BS interference. These values are for guidance and should be used carefully.

TABLE 14

Measured protection ratios (dB) for a DVB-T2 signal (defined in Table 1) interfered with by an LTE BS signal in adjacent channels for can tuners

Channel offset N (8 MHz channels)	Centre frequency offset (MHz)	0% BS traffic loading PR (dB)			50% BS traffic loading PR (dB)			100% BS traffic loading PR (dB)		
		Rx 5	Rx 6	Rx 28	Rx 5	Rx 6	Rx 28	Rx 5	Rx 6	Rx 28
Co-channel AWGN (0)	0	19	19	19	19	19	19	19	19	19
Co-channel LTE (0)	0	11	10	10	18	18	18	19	19	19
1	10	–43	–44	–40	–41	–42	–39	–40	–41	–36
2	18	–58	–55	–43	–57	–51	–39	–56	–47	–38
3	26	–55	–55	–38	–42	–47	–36	–41	–45	–35
4	34	–50	–64	–43	–45	–55	–32	–45	–45	–33

TABLE 14 (*End*)

Channel offset N (8 MHz channels)	Centre frequency offset (MHz)	0% BS traffic loading PR (dB)			50% BS traffic loading PR (dB)			100% BS traffic loading PR (dB)		
		Rx 5	Rx 6	Rx 28	Rx 5	Rx 6	Rx 28	Rx 5	Rx 6	Rx 28
5	42	–53	–71	–58	–50	–65	–55	–49	–67	–54
6	50	–56	–72	–72	–53	–69	–60	–52	–67	–58
7	58	–58	–73	–74	–55	–70	–61	–54	–68	–68
8	66	–60	–72	–68	–55	–67	–64	–54	–66	–62
9	74	–58	–63	–52	–50	–56	–46	–50	–55	–44

TABLE 15

Measured overload thresholds (dBm) for a DVB-T2 signal (defined in Table 1) interfered with by an LTE BS signal in adjacent channels for can tuners

Channel offset N (8 MHz channels)	Centre frequency offset (MHz)	0% BS traffic loading O_{th} (dBm)			50% BS traffic loading O_{th} (dBm)			100% BS traffic loading O_{th} (dBm)		
		Rx 5	Rx 6	Rx 28	Rx 5	Rx 6	Rx 28	Rx 5	Rx 6	Rx 28
1	10	–12	–11	–10	–15	–13	–12	–16	–15	–15
2	18	0	–1	–2	–5	–2	–5	–4	–3	–5
3	26	–2	–1	2	–3	–2	1	–4	–3	0
4	34	1	–3	3	–5	–14	–8	–3	–2	–8
5	42	4	2	2	–2	–2	2	2	–2	–2
6	50	5	3	2	0	0	1	5	–1	0
7	58	5	4	5	1	1	2	5	0	0
8	66	5	4	2	1	0	–3	4	0	–4
9	74	5	4	3	5	0	–3	4	–2	–3

LTE UE PR & O_{th}

Table 16 shows uncorrected UE PR measurements for three can tuners. Table 17 shows the same tuners with the PR values corrected for the assumed UE ACLR values shown in Table 7.

The co-channel PR_0 values used in the correction calculation were the AWGN figures in Table 8. Table 18 shows the overload threshold for the same three can tuners.

Due to the small number of can tuners available on T2 receivers, these values are for guidance only and should be used carefully.

TABLE 16

Uncorrected protection ratios (dB) for a DVB-T2 signal (defined in Table 1) interfered with by an LTE UE signal in adjacent channels for can tuners

Channel offset N 8 MHz channels/ (centre frequency offset)	**No. of Rx. tested**	**1 Mbit/s UE traffic loading Signal generator ACLR = 100 dB all offsets**			**10 Mbit/s UE traffic loading Signal generator ACLR = 100 dB all offsets**			**20 Mbit/s UE traffic loading Signal generator ACLR = 67.8 dB (N+1) 80.4 dB (N+2) 100 dB (N+3 to N+9)**		
		PR (dB)			**PR (dB)**			**PR (dB)**		
		Rx 5	**Rx 6**	**Rx 28**	**Rx 5**	**Rx 6**	**Rx 28**	**Rx 5**	**Rx 6**	**Rx 28**
Co-channel AWGN (0)	11	19	19	19	19	19	19	19	19	19
Co-channel LTE (0)	11	11	10	10	18	18	18	19	19	19
1/(10)	11	–40	–44	–28	–42	–43	–41	–42	–43	–40
2 (18)	11	–57	–55	–31	–58	–51	–35	–58	–51	–39
3 (26)	11	–48	–59	–39	–44	–52	–38	-42	–51	–38
4 (34)	11	–49	–60	–41	–45	–54	–33	–45	–51	–33
5 (42)	11	–53	–72	–52	–50	–70	–65	–50	–68	–66
6 (50)	11	–56	–74	–64	–53	–71	–65	–53	–70	–66
7 (58)	11	–55	–75	–63	–54	–71	–65	–55	–70	–70
8 (66)	11	–60	–72	–68	–56	–68	–65	–56	–67	–65
9 (74)	11	–62	–67	–56	–52	–57	–47	–50	–55	–45

TABLE 17

Corrected protection ratios (dB) for a DVB-T2 signal (defined in Table 1) interfered with by an LTE UE signal in adjacent channels for can tuners

Channel offset N 8 MHz channels/ (centre frequency offset)	No. of Rx. tested	1 Mbit/s UE traffic loading Signal generator ACLR = 100 dB all offsets			10 Mbit/s UE traffic loading Signal generator ACLR = 100 dB all offsets			20 Mbit/s UE traffic loading Signal generator ACLR = 67.8 dB (N+1) 80.4 dB (N+2) 100 dB (N+3 to N+9)		
		PR (dB)			PR (dB)			PR (dB)		
		Rx 5	Rx 6	Rx 28	Rx 5	Rx 6	Rx 28	Rx 5	Rx 6	Rx 28
Co-channel AWGN (0)	11	19	19	19	19	19	19	19	19	19
Co-channel LTE (0)	11	11	10	10	18	18	18	19	19	19
1/(10)	11	–6	–6	–6	–6	–6	–6	–6	–6	–6
2 (18)	11	–13	–13	–13	–13	–13	–13	–13	–13	–13
3 (26)	11	–48	–59	–39	–44	–52	–38	–42	–51	–38
4 (34)	11	–49	–60	–41	–45	–54	–33	–45	–51	–33
5 (42)	11	–53	–67	–52	–50	–67	–64	–50	–66	–64
6 (50)	11	–56	-68	–63	–53	–67	–64	–53	–67	–64
7 (58)	11	–55	–68	–62	–54	–67	–64	–55	–67	–66
8 (66)	11	–60	–67	–65	–56	–66	–64	–56	–65	–64
9 (74)	11	–61	–65	–56	–52	–57	–47	–50	–55	–45

TABLE 18

Measured overload thresholds (dBm) for a DVB-T2 signal (defined in Table 1) interfered with by an LTE UE signal in adjacent channels for can tuners

Channel offset N (8 MHz channels)	Centre frequency offset (MHz)	1 Mbit/s UE traffic loading O_{th} (dBm)			10 Mbit/s UE traffic loading O_{th} (dBm)			20 Mbit/s UE traffic loading O_{th} (dBm)		
		Rx 5	Rx 6	Rx 28	Rx 5	Rx 6	Rx 28	Rx 5	Rx 6	Rx 28
1	10	–6	–4	NR	–9	–7	–13	–14	–7	–10
2	18	2	2	NR	–2	–2	–3	–2	–2	–6
3	26	1	0	5	–4	–1	1	–3	–2	1
4	34	2	–9	0	–3	–15	–8	–2	–18	–8
5	42	6	3	5	1	0	–4	2	0	–3

TABLE 18 (*End*)

Channel offset N (8 MHz channels)	Centre frequency offset (MHz)	1 Mbit/s UE traffic loading O_{th} (dBm)			10 Mbit/s UE traffic loading O_{th} (dBm)			20 Mbit/s UE traffic loading O_{th} (dBm)		
		Rx 5	Rx 6	Rx 28	Rx 5	Rx 6	Rx 28	Rx 5	Rx 6	Rx 28
6	50	8	5	3	4	1	0	4	0	0
7	58	8	5	4	4	1	1	4	1	0
8	66	8	4	1	–4	0	–2	4	0	–3
9	74	8	5	2	4	0	–3	4	0	–3

Appendix 3
to Annex 1

Effect of transient interference on protection ratios

1 Background

Initial measurements of protection ratios for DVB-T2 when interfered with a LTE interferer have been made. For these tests, the effect of the interferer starting to transmit in the vicinity of the DVB T2 receiver has been simulated, by using a "gated" test signal. The interfering test signal is stored and played out from a generator, which can be configured to first play out nothing, then play out the required test signal.

This test is most appropriate in the case of interference from a UE, as generally speaking it is expected that the BS will be switched on once and then remain on almost continuously – any transient effects from a BS being switched on can therefore effectively be ignored. Conversely, it is expected that the UE will tend to transmit a short burst of signal whilst communicating with the BS, and then remain off for a period of time. Therefore TV receivers with UE's operating nearby and on close RF channels can expect to see interference from UE starting and stopping repeatedly. Hence the transient effects of interference from UE signals are an important area to study.

In the longer term, LTE devices may be deployed in machine-machine (M2M) applications in domestic environments implying a significant density of UE terminals that are required to activate periodically. It is therefore considered important to understand the effects of this transient interference.

It should be noted that at the time of making this submission, relatively few results had been obtained. However, given that significant degradation in performance had been noted, it was felt important to submit these initial results. It is hoped to submit further results either to a later meeting of WP 6A and/or direct to the JTG in due course.

2 Measurements

2.1 Signal sources

The wanted signal is a DVB-T2 waveform, frequency 706 MHz, provided by a DTT signal generator. The DVB parameters used are those most frequently encountered in the UK (option 6 from the DVB-T2 specification [2]). The parameters are given in Table 19.

TABLE 19

Standard	DVB-T2
Number of OFDM carriers	27 841 (32KE)
Modulation	256QAM
Inner coding Rc	2/3
Guard interval (Δ/Tu)	1/128
Pilot pattern	PP7
Frame length (data symbols)	59
FEC blocks per interleaving frame	202
Transport stream data rate	40.2146452

The LTE interfering signal is a gated version of that used in previous tests [1]. The underlying waveforms represent typical outputs from UEs at 2 traffic levels, captured using prototype LTE equipment. The two traffic levels were generated by connecting a BS and UE pair to form an end-to-end link and using an IP traffic tool to load the link. The waveforms captured represent data transfer rates of 20 Mbit/s and 1 Mbit/s.

To ensure that the measurements were not contaminated by any out-of-band signals captured in the recording process, the test waveforms were band-pass filtered in software prior to playback. A channel bandwidth of 10 MHz was used. This guarantees that the protection ratio measurements are a function only of the receiver selectivity and the adjacent channel leakage ratio (ALCR) of the arbitrary signal generator.

The signal source used to provide the LTE signal was an arbitrary signal generator. The transient nature of the signal was achieved by replaying each of the underlying waveform in sequence with a signal comprising null samples. By looping each of the signals a number of times in turn, it is possible to build a longer sequence with a defined on/off pattern. The final gated signal comprises approximately 4 seconds of silence, followed by around 5 seconds of either the 1 Mbit/s or 20 Mbit/s signal. Time domain plots of the signals are given in Figs 1 and 2.

FIGURE 1

Gated LTE 20 Mbit/s signal

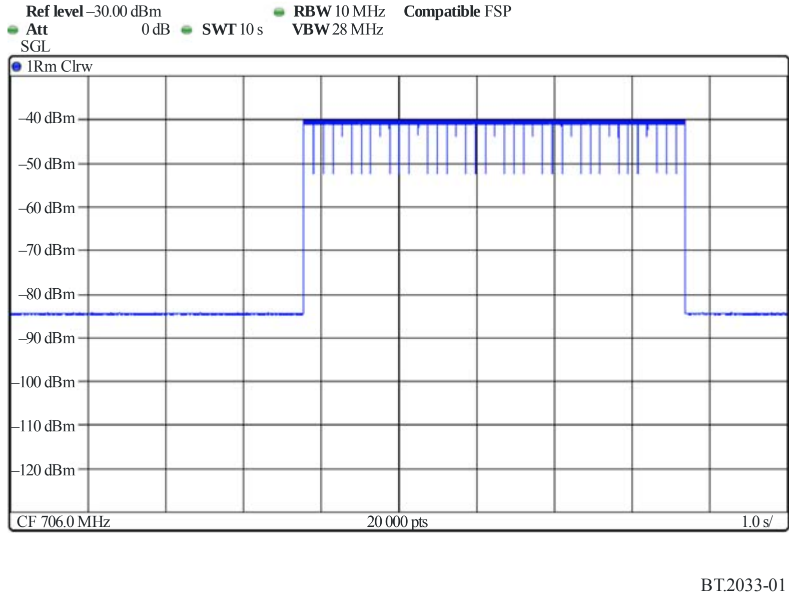
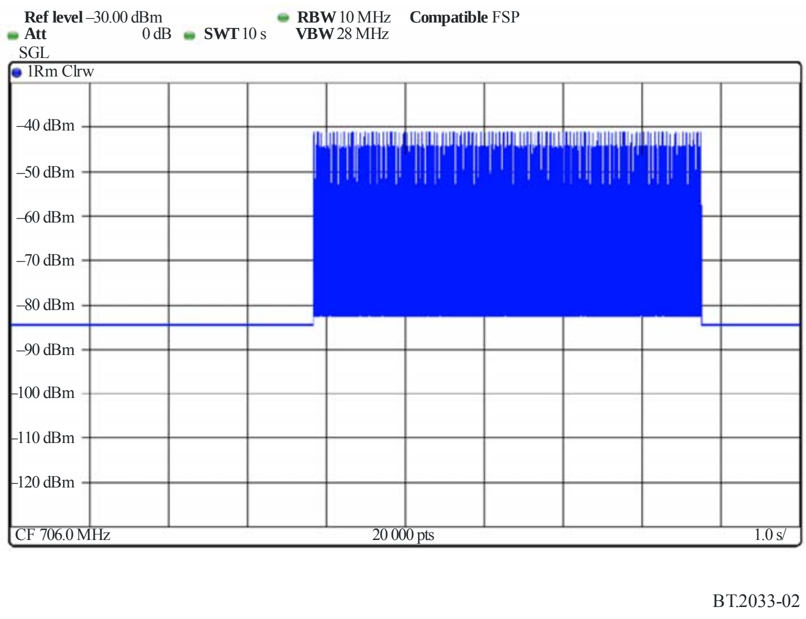


FIGURE 2

Gated LTE 1 Mbit/s signal



2.2 Frequency offsets

Centre frequency offsets between DVB-T2 and LTE of +11 and +18 MHz have been considered (i.e. interfering signals of 717 and 724 MHz). Assuming an LTE signal of bandwidth 10 MHz, these would represent the LTE UE interference into an adjacent TV channel separated by a guard band of either 2 MHz or 9 MHz from the LTE uplink band.

2.3 Measurement procedure

The protection ratio was found by combing the wanted and interfering signals and presenting them to the DTT receiver under test. The wanted signal was increased until satisfactory signal decoding occurred. Full details of the measurement procedure can be found in [1].

2.4 Receivers tested

In this early phase of work, three receivers were selected for test.

TABLE 20

Receiver	Type	Tuner type
R1	STB/PVR	Silicon
R2	STB	Can
R3	STB	Can

3 Results

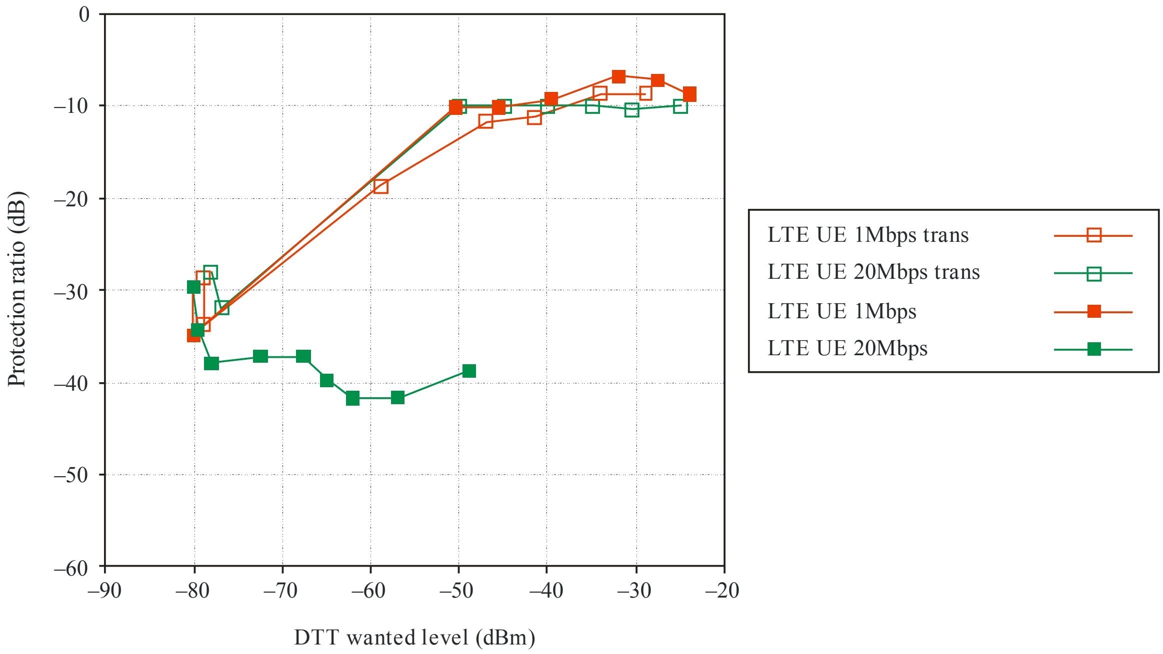
The data presented represents the protection ratios measured using the test equipment, which incorporated an arbitrary signal generator with a good adjacent channel leakage ratio (ACLR); better than 50 dB in the first adjacent channel. No correction has been made to account for the likelihood that LTE equipment will have a worse adjacent channel performance than the test equipment used.

Previous results [1] corrected the protection ratios according to the specified out of band performance of LTE equipment, and showed that this can be more significant than the selectivity of the receiver.

Figures 3 to 8 show the performance of the receivers currently tested in the presence of the transient interference provided by the LTE UE 20 Mbit/s and 1 Mbit/s waveforms. For reference, the performance of the receivers with the non-transient waveforms is also plotted.

FIGURE 3

Receiver R1 11 MHz offset



BT.2033-03

FIGURE 4

Receiver R1 18 MHz offset

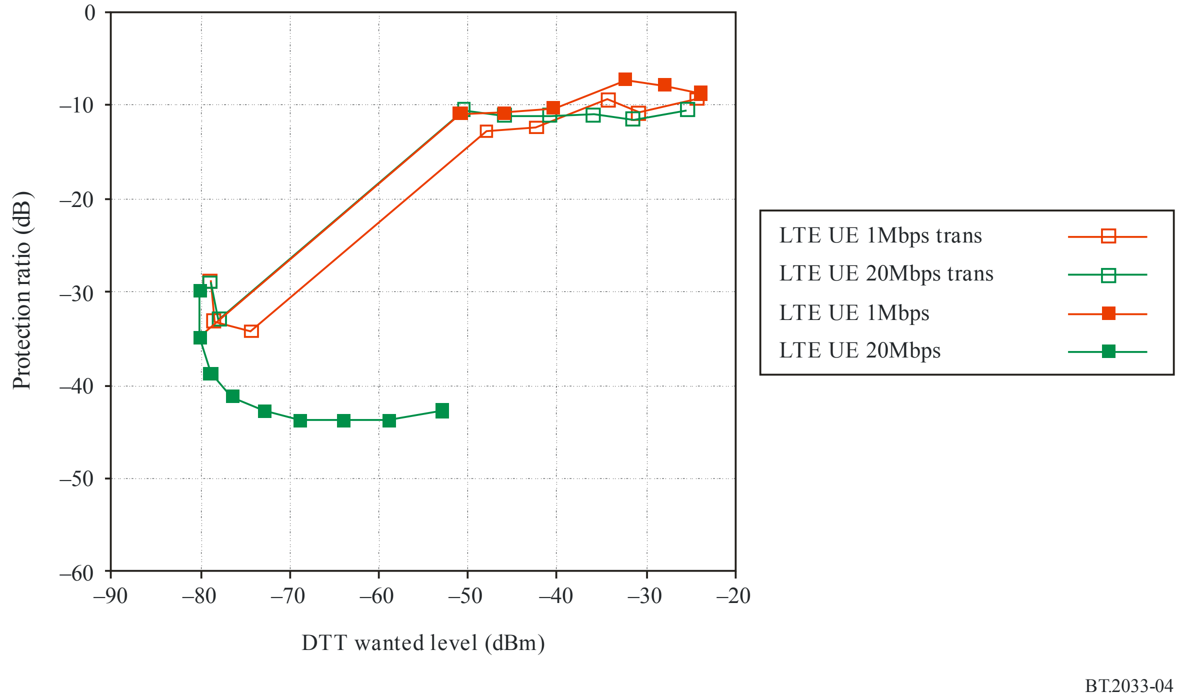


FIGURE 5

Receiver R2 11 MHz offset

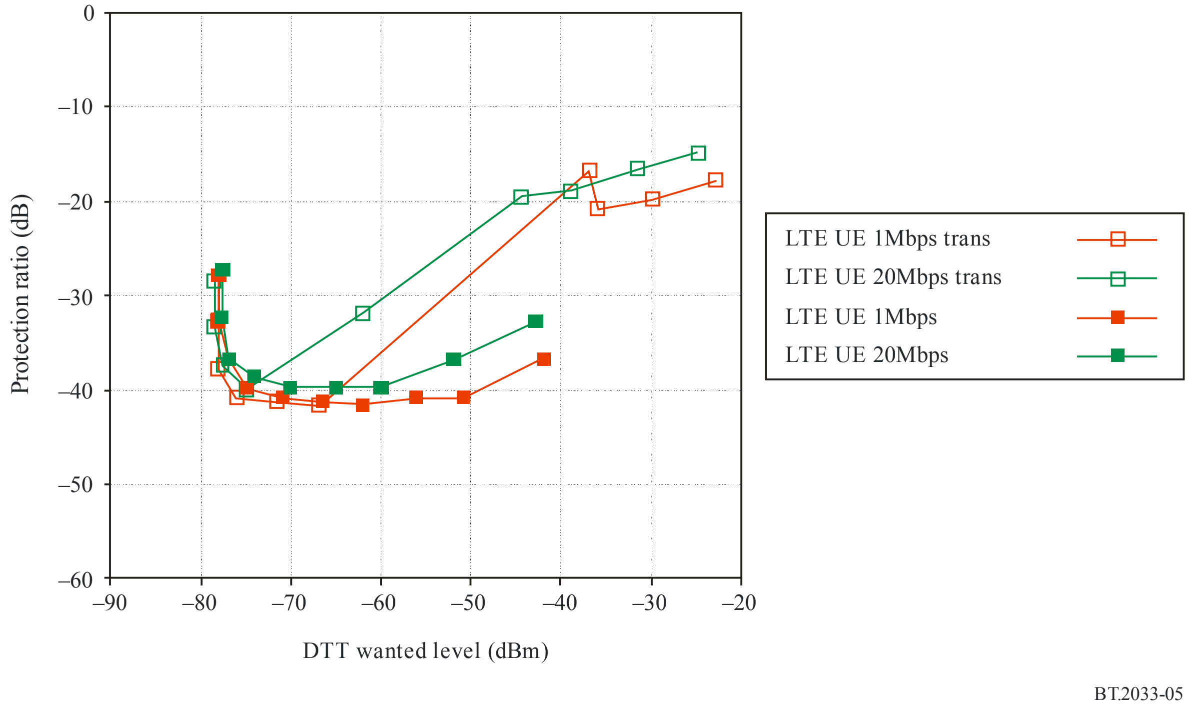
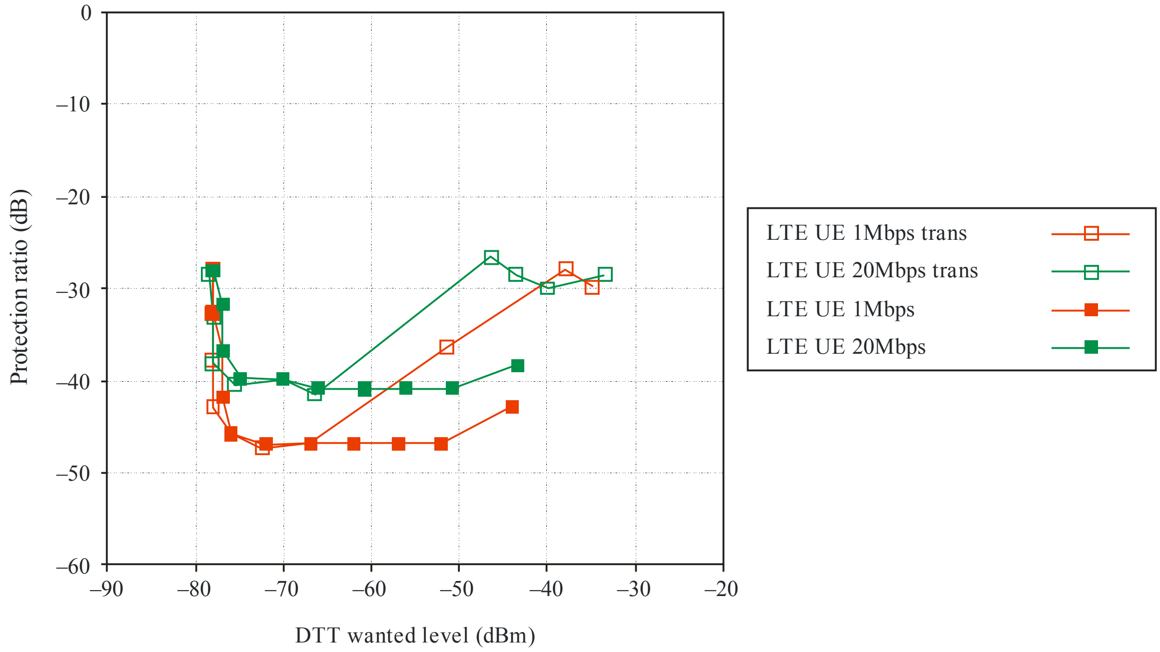


FIGURE 6

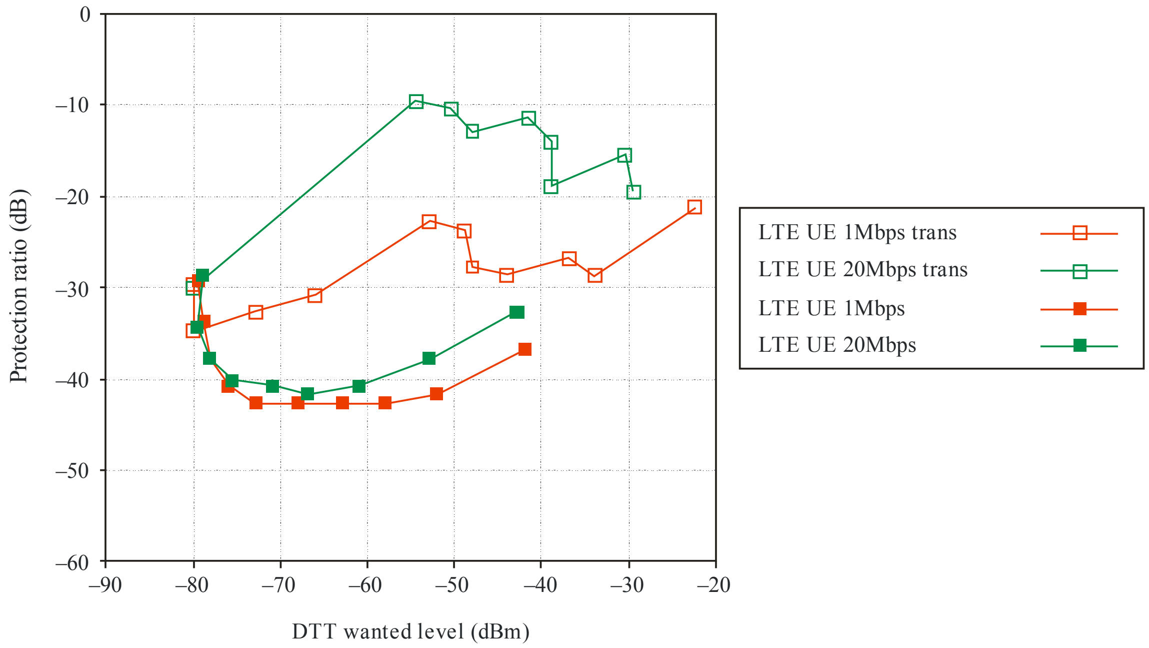
Receiver R2 18 MHz offset



BT.2033-06

FIGURE 7

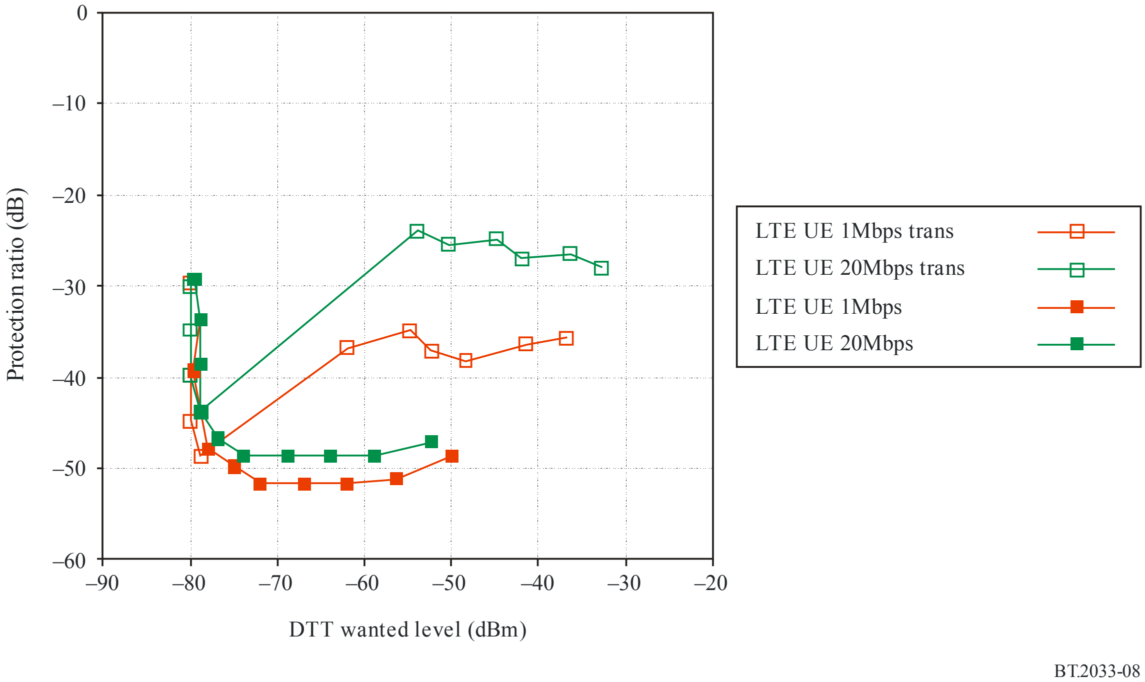
Receiver R3 11 MHz offset



BT.2033-07

FIGURE 8

Receiver R3 18 MHz offset



4 Conclusions

R1 is shown to perform poorly with the non-transient version of the low traffic waveform. When the transient version of either waveform is used, similar performance to the non-transient low traffic case is seen. There is no improvement with increased frequency offset.

Receivers R2 and R3's performance is adequate with the conventional waveforms (even the low traffic version), but suffers when the transient versions are used. The protection ratio is around 10-12 dB better when the offset is increased from 11 MHz to 18 MHz.

In all cases, it is the transient version of the 20 Mbit/s UE waveform which requires greater protection than the 1 Mbit/s version.

The protection ratio numbers presented in this Recommendation are based on measurements made with a signal generator with a good adjacent channel performance and therefore will need to be corrected to take account of the out-of-band emission figures for LTE hardware.

Although only a small set of receivers has been investigated so far, there is an important conclusion to be drawn that certain units that were previously thought to be less vulnerable to low duty cycle traffic are affected by the transient nature of the switched waveform. As this transient waveform is expected to be a feature of future LTE UE equipment deployments, it is considered important that these interim results based on limited measurements are presented now, with a recommendation that further measurements are undertaken.

References

[1] Document 6A/41 – *Measured DVB-T protection ratios and overload thresholds in the presence of LTE signals* Source: British Broadcasting Corporation (UK).

[2] ETSI EN 302 755 – *Frame structure channel coding and modulation for a second generation digital terrestrial television broadcasting system (DVB-T2).*

Appendix 4
to Annex 1

TV tuner technologies and characteristics

The protection ratio and overload threshold can be significantly different for silicon tuners[1] and can tuners[2]. Silicon tuners are increasingly being used in TV receiver equipment including high-end products such as iDTVs and PVRs.

As silicon and can tuners have different performance characteristics, planners are advised to consider the relative usage volumes of each tuner type and the difference in characteristics during network planning. Compared to can tuners, silicon tuners do not suffer from degradations in PR and O_{th} when the interferer is at the 36 MHz IF frequency or at the $2 \times IF = 72$ MHz image frequency; however some have higher protection ratios at other interferer offsets.

It is likely that a mixture of these types of tuners will exist and their proportion is likely to change with time. This Recommendation provides separate results for each type of tuners. (For further information the technical explanation of the differences can be found in Report ITU-R BT.2215 – Measurement of protection ratios and overload threshold for TV receivers.)

For the case of larger guardbands where the can tuner image channel may not coincide with N+9, PR and O_{th} performance can be estimated by using the N+9 figures for the frequency offset when the image channel occurs, and the N+8 figures for the nearby frequency offsets that are close but not on image channel frequency offset.

Annex 2
(Informative)

Additional test results

1 Additional test result from the UK

A set of measurements on the performance of TV receivers in the presence of LTE base station signals were performed by the UK to support a field trial and subsequent modelling analysis and assessment.

The report on the protection ratio measurements for LTE base stations into DVB-T and T2 reception in a comparative way is attached as an embedded word file below.

---

[1] "Silicon" tuners are IC-based tuners integrating all tuner circuitry into a small package directly to be fitted onto main boards. The tuned circuits may be completely absent or can be integrated onto the silicon. The silicon chip may be protected from external electromagnetic interference by a metallic cover. When integrated onto the silicon there are different compromises in performance when compared with discrete classical layouts. The units measured represent a mixture of early and recent generations on the market. This technology is still developing.

[2] "Can" tuners are classical super heterodyne tuners housed in a metal enclosure containing discrete components. Classically, there are fixed and tuneable circuits made up from discrete inductors and transistors usually with varactor diode frequency control. The metal enclosure should minimize RF interference and eliminate crosstalk and stray radiation.

The testing covered the fixed roof top reception modes in use in the UK. For DVB-T this is 8k at 64-QAM 2/3 using MPEG-2, while for DVB-T2 the mode is 32k at 256-QAM 2/3 with MPEG-4. The transmissions are in the 8 MHz bandwidth channels of the standard European raster. The two transmission modulation modes were chosen to give almost the same transmission coverage, and this has been proven in practice during the ongoing digital switchover in the UK.

The LTE base station signals were recorded from an actual unit in both fully loaded and idle formats and could be played back through a signal generator and amplifier plus filtering. The transmission mask of the 10 MHz LTE signal was set to conform to EC Decision 2010/267/EU for the 800 MHz band.

The units tested included TV sets, set top boxes, and a personal video recorder with twin tuners.

Microsoft Office
Word 97 - 2003 D

2 Additional test result from the Russian Federation

The attached contribution presents the results of the preliminary comparative evaluation of DVB-T and DVB-T2 system characteristics on the basis of measurements performed in the Russian Federation.

extract from
6A-592.docx

Annex 3
(Normative)

Other planning factors

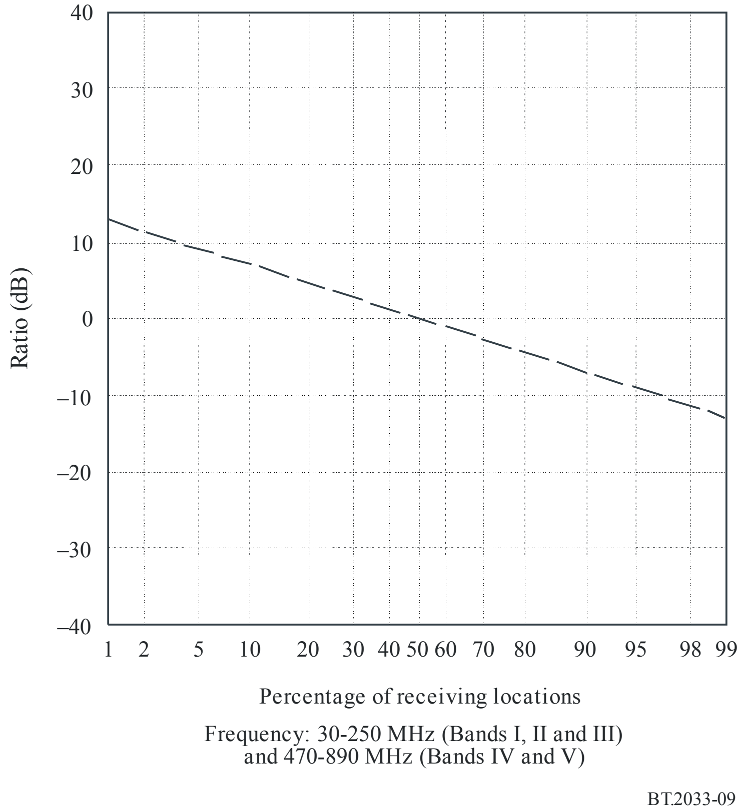
1 Field strength distribution with location

It is to be expected that the distributions of field strength with location for digital television signals will not be the same as those applicable to analogue television signals. Recommendation ITU-R P.1546 includes the standard deviation for the analogue and for the digital case in Tables 1, 2 and 3 for 100 MHz, 600 MHz and 2 000 MHz, respectively.

The results of propagation studies for digital systems are given in Fig. 9 for the VHF and UHF bands. The figure corresponds to a standard deviation of 5.5 dB. These results may also be used to derive propagation prediction curves for location percentages other than 50%. Refer to Recommendation ITU-R P.1546 for the location percentages other than 50% for analogue and digital systems, where the digital system bandwidth is greater than 1.5 MHz.

FIGURE 9

Ratio (dB) of the field strength for a given percentage of the receiving locations to the field strength for 50% of the receiving locations



2 Reception using portable equipment inside buildings and vehicles

2.1 Height loss: L_h

For land paths, the curves in Recommendation ITU-R P.1546 give field-strength values for a receiving antenna height above ground equal to the *representative height* of ground cover around the receiving antenna location. Subject to a minimum height value of 10 m, examples of reference heights are 20 m for an urban area, 30 m for a dense urban area and 10 m for a suburban area. (For sea paths, the notional value is 10 m.)

If the receiving antenna height is different from the representative height, a correction is applied to the field strength taken from the curves of Recommendation ITU-R P.1546 according to a procedure given in the Recommendation.

2.2 Building entry loss: L_b

Losses due to penetration into a building depend significantly on the building material, angle of incidence and frequency. Consideration should also be given as to whether reception is in an interior room or in one located near an exterior wall. The building entry loss is defined as the difference (dB) between the mean field strength inside a building at a given height above ground level and the mean field strength outside the same building at the same height above ground level.

Whilst no single comprehensive formula is available for computing building entry loss, useful statistical information based on measured losses in several types of building, at frequencies from about 500 MHz to 5 GHz, are given in Recommendation ITU-R P.679. Once inside the building, propagation loss due to walls and floors are dealt with in Recommendation ITU-R P.1238.

A large spread of building entry losses have been measured. Table 21 gives three classes of the relative possibilities to achieve indoor reception and the corresponding mean and standard deviation values of the building entry losses, for the same outdoor field strength, based on UHF measurements.

TABLE 21

Building entry loss variations in the UHF Bands IV/V

Classification of the relative possibilities to achieve indoor reception	Mean building entry loss (dB)	Standard deviation (dB)
High	7	5
Medium	11	6
Low	15	7

Examples of buildings with different relative possibilities to achieve indoor reception:

High:

– suburban residential building without metallised glass windows;

– room with a window on the exterior wall in an apartment in an urban environment.

Medium:

– exterior rooms in an urban environment with metallised glass windows;

– inner rooms in an apartment in an urban environment.

Low:

– inner rooms in office buildings.

If more precise values based on local measurements are available, these could be used as a basis for planning a specific service.

2.3 Vehicle entry loss: L_v

For reception with a hand-held device inside a vehicle, the vehicle body loss should be taken into account. A typical vehicle entry loss for the UHF Bands IV/V, based on cellular radio experience, is 6 dB.

3 Receiving antenna discrimination

Information concerning the directivity and polarization discrimination of domestic receiving antennas is given in Recommendation ITU-R BT.419.

4 Antennas for portable and mobile receivers

4.1 Antennas for portable reception

A spread in antenna gain has been measured for different types of antenna. The following antenna gain values are typical:

TABLE 22

Antenna gain (dBd) for portable reception

Band	Gain (dBd)
VHF Band III	–2
UHF Band IV	0
UHF Band V	0

No polarization discrimination is expected.

4.2 Antennas for hand-held reception

The antenna in a small hand-held terminal has to be an integral part of the terminal construction and will therefore be small when compared to the wavelength. Current understanding of the design problem indicates that the worst-case antenna gain is in the lowest part of the UHF band. The antenna gain for three frequencies in the UHF band is given in Table 23. Nominal antenna gain between these frequencies can be obtained by linear interpolation.

TABLE 23

Antenna gain (dBd) for hand-held reception

Frequency (MHz)	Gain (dBd)
474	–12
698	–9
858	–7

Generally, no polarization discrimination is expected from this type of portable reception antenna and the radiation pattern in the horizontal plane is omnidirectional.

4.3 Antennas for mobile reception

The practical standard antenna for vehicle reception is l/4 monopole, which uses the metallic roof as a ground plane. The antenna gain for conventional incident wave angles depends on the position of the antenna on the roof. For passive antenna systems the values in Table 24 can be expected.

TABLE 24

Antenna gain (dBd) for mobile reception

Band	Gain (dBd)
VHF Band III	–5
UHF Band IV	–2
UHF Band V	–1

The polarization discrimination is theoretically about 4 to 10 dB depending on the roof position of the antenna.

5 Man-Made Noise (MMN)

For planning purposes, the man-made noise figures in Tables 25 and 26 are used.

TABLE 25

Allowance for man-made noise used in the calculation for urban areas

Urban	Band III	Bands IV/V
Allowance for man-made noise		
Relevant value for integrated antenna in a handheld portable receiver	0	0
Relevant value for external antenna* in a handheld portable receiver	1	0
Relevant value for rooftop antenna	2 dB	0 dB
Relevant value for adapted antenna for portable and mobile receivers	8 dB	1 dB

* Telescopic or wired handsets.

TABLE 26

Allowance for man-made noise used in the calculation for rural areas

Rural	Band III	Bands IV/ V
Allowance for man-made noise		
Relevant value for integrated antenna in a handheld portable receiver	0	0
Relevant value for external antenna* in a handheld portable receiver	0	0
Relevant value for rooftop antenna	2 dB	0 dB
Relevant value for adapted antenna for portable and mobile receivers	5 dB	0 dB

Annex 4
(Informative)

Failure point assessment methods

1 Subjective failure point (SFP) method for protection ratio measurements

For domestic receivers it may not be possible to measure the BER and therefore a new method called the SFP method has been proposed for protection ratio measurements in a unified manner. The quality criterion for protection ratio measurements is to find a limit for a just error-free picture at the TV screen. The RF protection ratio for the wanted DVB-T2 signal is a value of wanted-to-unwanted signal ratio at the receiver input, determined by the SFP method, and rounded to the next higher integer value.

The SFP method corresponds to the picture quality where no more than one error is visible in the picture for an average observation time of 20 s over 30 s. The adjustment of the wanted and unwanted signal levels for the SFP method is to be carried out in small steps, usually in steps of 0.1 dB. For a “noise-like” interferer the difference in a value of wanted-to-unwanted signal ratio between the QEF condition (post BCH BER of 1×10^{-11}) and the SFP method is a few points of a dB due to the sharp “waterfall” characteristic of LDPC decoding. Historically, protection ratio values for wanted digital TV signals are measured with a receiver input power of –60 dBm. Where possible, protection ratios for digital TV systems are derived from measurements using a range of signal levels as described in the recommended methodology (Report ITU-R BT.2215).

It is proposed that the SFP method should be adopted for assessment of all DTTB systems. (For the digital system ISDB-T this method will be studied in Japan.)

Annex 5
(Normative)

Tropospheric and continuous interference

1 Tropospheric and continuous interference

When using the protection ratios in planning, it is necessary to determine whether, in particular circumstances, the interference should be considered as tropospheric or continuous. This can be done by comparing the nuisance fields for the two conditions, the nuisance field being defined as the field strength of the interfering transmitter (at its pertinent e.r.p.) enlarged by the relevant protection ratio.

Thus, the nuisance field for continuous interference:

$$E_C = E(50, 50) + P + A_C$$

and the nuisance field for tropospheric interference:

$$E_T = E(50, t) + P + A_T$$

where:

- $E(50, t)$: field strength (dB(μV/m)) of the interfering transmitter, normalized to 1 kW, and exceeded during t% of the time;
- P: e.r.p. (dB(1 kW)) of the interfering transmitter;
- A: protection ratio (dB);
- C and T: continuous and tropospheric interference, respectively.

The protection ratio for continuous interference is applicable when the resulting nuisance field is stronger than that resulting from tropospheric interference, that is, when $E_C > E_T$.

This means that A_C should be used in all cases when:

$$E(50, 50) + A_C > E(50, t) + A_T$$

____