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

BT Series
Broadcasting service
(television)



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RECOMMENDATION ITU-R BT.2033-1

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

(2013-2015)

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.

Keywords

DTTB, DVB-T2, ISDB-T, planning criteria, protection ratio, second generation

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;
- i) 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;
- j) 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;
- k) 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 Annexes 1 and 2 should be used as the basis for frequency planning for second generation digital terrestrial television services.

NOTE – Annexes 4 and 6 are an integral part of the Recommendation. Annexes 3 and 5 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 for 7 and 8 MHz channel bandwidth

Annex 2 – Planning criteria, including protection ratios, for DVB second generation digital terrestrial television systems in the VHF/UHF bands for 6 MHz channel bandwidth

Annex 3 – Additional test results from UK and Russian Federation

Annex 4 – Other planning factors such as antenna types and antenna discrimination, height loss, etc.

Annex 5 – Subjective failure point description

Annex 6 – 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].

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Annex 1

(Normative)

Planning criteria, including protection ratios, for DVB second generation digital terrestrial television systems in the VHF/UHF bands for 7 and 8 MHz channel bandwidth

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 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 10th 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)		O _{th} (dBm)	
			Percentile		Percentile	
			50 th	90 th	10 th	50 th
–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 Attachment 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	
			50 th	90 th	50 th	90 th	50 th	90 th
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	
			10 th	50 th	10 th	50 th	10 th	50 th
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)	
		50 th	90 th	50 th	90 th	50 th	90 th
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 ($PR(\Delta f)$), 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, $PR'(\Delta f)$, 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)	
		50 th	90 th	50 th	90 th	50 th	90 th
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