RECOMMENDATION ITU-R BT.1368-5*

Planning criteria for digital terrestrial television services in the VHF/UHF bands

(Question ITU-R 4/6)

(1998-1998-2000-2002-2004-2005)

The ITU Radiocommunication Assembly,

considering

a) that systems are being developed for the transmission of digital terrestrial television services in the VHF/UHF bands;

b) that the VHF/UHF television bands are already occupied by analogue television services;

c) that the analogue television services will remain in use for a considerable period of time;

d) that the availability of consistent sets of planning criteria agreed by administrations will facilitate the introduction of digital terrestrial television services,

recommends

1 that the relevant protection ratios (PRs) and the relevant minimum field strength values given in Annexes 1, 2 and 3, and the additional information given in Annexes 4, 5, 6 and 7 be used as the basis for frequency planning for digital terrestrial television services.

Introduction

This Recommendation contains the following Annexes:

Annex 1 – Planning criteria for ATSC digital terrestrial television systems in the VHF/UHF bands

Annex 2 – Planning criteria for DVB-T digital terrestrial television systems in the VHF/UHF bands

Annex 3 – Planning criteria for ISDB-T digital terrestrial television systems in the VHF/UHF bands

Annex 4 – Other planning factors

Annex 5 – Subjective comparison method (SCM) with a reference interferer for assessment protection ratios for analogue television system

Annex 6 – Test methods for protection ratio measurements for wanted digital terrestrial signals

Annex 7 – Tropospheric and continuous interference

* The Administrations of the Islamic Republic of Iran, the Syrian Arab Republic and the United Arab Emirates reserve their position and do not fully abide by this Recommendation.

General

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

The reference level of the digital signal is defined as the r.m.s. value of the emitted signal power within the channel bandwidth. It should preferably be measured with a thermal power meter. All protection ratio values for wanted digital signals are to be measured with a –60 dBm receiver input power.

The reference level of the analogue vision-modulated signal is defined as the r.m.s. value of the vision carrier at peaks of the modulation envelope. All protection ratio values for wanted analogue signals are measured with a receiver input power of –39 dBm (70 dB(μV) at 75 Ω).

1 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 analogue 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. Results relevant to single frequency networks (SFN) are yet to be developed.

For the digital terrestrial television system, ATSC, the protection ratios are measured for a BER = 3×10^{-6} at the input of the MPEG-2 demultiplexer.

For the digital terrestrial television systems (digital video broadcasting-terrestrial (DVB-T) and integrated service digital broadcasting-terrestrial (ISDB-T)) the protection ratios are measured between the inner and outer codes, before Reed Solomon decoding, for a BER = 2×10^{-4}; this corresponds to a BER < 1×10^{-11} at the input of the MPEG-2 demultiplexer. For domestic receivers it may not be possible to measure the BER before Reed-Solomon decoding. The BER for such cases is under study.

To reduce the number of measurements and tables, it is proposed that protection ratio measurements for DVB-T systems should preferably be made with the following three modes shown in Table 1. Protection ratio values for the different required operational modes for fixed, portable or mobile reception can be calculated from the given measured values. A formula for calculation is still under study.

TABLE 1

Proposed preferable DVB-T mode types for measurements on protection ratios

Modulation	Code rate	*C*/*N*(1) (dB)	Bit rate(2) (Mbit/s)
QPSK	2/3	6.9	≈ 7
16-QAM	2/3	13.1	≈ 13
64-QAM	2/3	18.7	≈ 20

(1) The figures are given for a Gaussian channel (including a typical implementation margin) for a BER $< 1 \times 10^{-11}$.

(2) For a guard interval of 1/4.

2 Wanted analogue terrestrial television systems

Measurements of protection ratios for the vision signal of a wanted analogue terrestrial television system should preferably be made with the subjective comparison method with a sine-wave reference interferer described in Annex 5.

The values of protection ratio quoted apply to interference produced by a single source. Except where otherwise stated, the ratios apply to tropospheric, *T*, interference and correspond closely to a slightly annoying impairment condition. They are considered to be acceptable only if the interference occurs for a small percentage of the time, not precisely defined but generally considered to be between 1% and 10%. For substantially non-fading unwanted signals, it is necessary to provide a higher degree of protection and ratios appropriate to continuous, *C*, interference should be used (see Annex 7).

When the wanted signal is an analogue television signal, two or more protection ratio values should be considered, one for the protection ratio of the vision signal and others for the protection ratios of sound signals. The most stringent value should then be used.

Significantly strong wanted input signals can require higher protection ratio values because of non-linear effects in the receiver.

For 625-line systems, the reference impairment levels are those which correspond to co-channel protection ratios of 30 dB and 40 dB, when two-thirds line offset is used, see Recommendation ITU-R BT.655. These conditions approximate to impairment grades 3 (slightly annoying) and 4 (perceptible but not annoying) and apply to tropospheric, *T*, and continuous, *C*, interference, respectively.

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Annex 1

Planning criteria for ATSC digital television systems in the VHF/UHF bands

1 Protection ratios for ATSC wanted digital terrestrial television signals

Tables 2 to 4 and 5 to 8 show protection ratios for an ATSC digital terrestrial television signal interfered with by an ATSC digital terrestrial television signal, and by an analogue terrestrial television signal, respectively.

1.1 Protection of an ATSC digital terrestrial television signal interfered with by an ATSC digital terrestrial television signal

TABLE 2

Co-channel protection ratios (dB) for an ATSC signal interfered with by an ATSC signal

Wanted signal	Unwanted signal
	ATSC 6 MHz
ATSC 6 MHz	15 19(1)

(1) Based on equally partitioned noise and interference.

TABLE 3

Protection ratios (dB) for ATSC interfered with by an ATSC signal in the lower ($N – 1$) and upper ($N + 1$) adjacent channels

Channel	$N – 1$	$N + 1$
ATSC 6 MHz	–27	–27

The protection ratios are given in dB and apply to both continuous and tropospheric interference.

TABLE 4

Protection ratios (dB) for an ATSC signal interfered with by an ATSC signal in channel $N \pm 2$ and other out-of-band channels

Channel	$N \pm 2$ and other out-of-band channels
ATSC 6 MHz	–58

1.2 Protection of ATSC digital terrestrial television interfered with by analogue terrestrial television

1.2.1 Protection from co-channel interference

TABLE 5

Co-channel protection ratios (dB) for an ATSC signal interfered with by an analogue television signal

Wanted signal	**Unwanted signal (Analogue TV signal including sound carriers)**	
	M/NTSC	PAL B
ATSC 6 MHz	2 7[(1)]	9

(1) Using a comb filter in the digital television receiver and C/N of 19 dB.

1.2.2 Protection from lower adjacent channel (N – 1) interference

TABLE 6

Protection ratios (dB) for lower adjacent channel (N – 1) interference for an ATSC signal interfered with by an analogue television signal including sound

Wanted signal	Unwanted signal (Analogue TV signal including sound carriers)
	M/NTSC
ATSC 6 MHz	–48

1.2.3 Protection from upper adjacent channel (N + 1) interference

TABLE 7

Protection ratios (dB) for upper adjacent channel (N + 1) interference for an ATSC signal interfered with by an analogue television signal

Wanted signal	Unwanted signal (Analogue TV signal including sound carriers)
	M/NTSC
ATSC 6 MHz	–49

1.2.4 Protection from other channel interference

TABLE 8

Protection ratios (dB) for an ATSC 6 MHz signal interfered with by an M/NTSC signal at other out-of-band channels

Wanted signal	Unwanted signal	Unwanted channels	Protection ratio
ATSC	M/NTSC	$N \pm 2$ to $N \pm 8$	–58

2 Protection ratios for wanted analogue terrestrial television signals interfered with by unwanted ATSC digital terrestrial television signals

Table 9 and Tables 10 to 12 show protection ratios for wanted 525-line and 625-line, respectively, analogue television signals interfered with by ATSC digital terrestrial television signals.

2.1 Protection ratios for 525-line television systems

2.1.1 Protection for vision signals interfered with by ATSC digital television

In this section the protection ratios for an analogue wanted signal interfered by an unwanted ATSC digital signal apply only to the interference to the vision and colour carriers.

TABLE 9

Protection ratios (dB) for a wanted analogue vision signal (NTSC, 6 MHz) interfered with by an unwanted ATSC signal

Unwanted digital channel	Tropospheric interference grade 3	Continuous interference grade 4
N – 1 (lower)	–16	
N (co-channel)	34	
N + 1 (upper)	–17	
N + 14 (image)	–33	
N + 15 (image)	–31	
$N \pm 2$	–24	
$N \pm 3$	–30	
$N \pm 4$	–25	
$N \pm 7$	–34	
$N \pm 8$	–32	

2.2 Protection ratios for 625-line television systems

2.2.1 Protection of wanted vision signals interfered with by ATSC digital terrestrial television

In this section the protection ratios for an analogue wanted signal interfered by an unwanted digital signal relate only to the interference to the vision signal.

The protection ratio values given are related to an out-of-channel spectrum attenuation of the unwanted DVB-T transmitter of 40 dB.

2.2.1.1 Protection from co-channel interference

TABLE 10

Protection ratios (dB) for a wanted analogue vision signal interfered with by an unwanted ATSC 6 MHz signal

Wanted signal: analogue system	Unwanted signal: ATSC 6 MHz	
	Tropospheric interference	Continuous interference
B/PAL	38	45

2.2.1.2 Protection from lower adjacent channel interference

TABLE 11

Protection ratios (dB) for a wanted analogue vision signal interfered with by an ATSC 6 MHz signal (lower adjacent channel)

Wanted signal: analogue system	Unwanted signal: ATSC 6 MHz signal (lower adjacent channel)	
	Tropospheric interference	Continuous interference
B/PAL	–7	–1

2.2.1.3 Protection from upper adjacent channel interference

TABLE 12

Protection ratios (dB) for a wanted analogue vision signal interfered with by an ATSC 6 MHz signal (upper adjacent channel)

Wanted signal: analogue system	Unwanted signal: ATSC 6 MHz signal (upper adjacent channel)	
	Tropospheric interference	Continuous interference
B/PAL	–7	0

3 Protection ratios for sound signals of wanted analogue terrestrial television signals interfered with by unwanted ATSC digital terrestrial television signals

3.1 Protection for NTSC sound signals (BTSC MTS system and SAP) interfered with by an ATSC digital television signal (see Note 1)

In the case of an unwanted upper adjacent digital channel $N + 1$ the audio signals degrade before the vision signal. The protection ratio value for the interference into the BTSC MTS and SAP sound signals was measured with −12 dB. (Vision protection ratio for $N + 1$ is −17 dB.) The −12 dB sound protection ratio figure is related to the wanted NTSC vision carrier level.

NOTE 1 – BTSC MTS: broadcast television system committee multichannel television sound; SAP: sound audio programme.

4 Minimum field strengths for ATSC terrestrial digital television

TABLE 13

Derivation by the figure of merit method
ATSC 6 MHz system*

Planning parameter[(1)]	Low VHF 54-88 MHz	High VHF 174-216 MHz	UHF 470-806 MHz
Frequency (MHz)	69	194	615
C/N (dB)	19.5	19.5	19.5
k (dB)	–228.6	–228.6	–228.6
B (dB(Hz)) (6 MHz)	67.8	67.8	67.8
G_{1m^2} (dB)	–1.8	7.3	17.2
G_D (dB)	6	8	10
G_I (dB)	8.2	10.2	12.2
Transmission line loss (dB) α_{line}	1.1	1.9	3.3
Antenna 300/75 balun loss (dB) α_{balun}	0.5	0.5	0.5
Receiver noise figure (dB)	5	5	10
T_{rx} (K)	627.1	627.1	2 610
T_{line} (K)	65.0	102.9	154.4
LNA noise figure (dB)	5	5	5
LNA gain (dB)	20	20	20
T_{LNA} (dB)	627.1	627.1	627.1
T_{balun} (K)	31.6	31.6	31.6
T_a (K)	9 972.1	569.1	Negligible
$T_a\ \alpha_{balun}$ (K)	8 885.1	507.1	Negligible
$T_{line}/\alpha\ G$ (K)	0.8	1.6	3.3
$T_{rx}/\alpha\ G$ (K)	8.1	9.7	55.8
T_e (K)	9 552.6	1 176.8	717.8
10 log(T_e) (dB(K))	39.8	30.7	28.6
G_A (dB)	7.7	9.7	11.7
E_{rx} (dB(μV/m))[(2)] (TBC)	35	33	39

* The values in the Table were calculated assuming C/N with typical multipath reception impairment and equal partitioning for noise and interference. The receiving system model is a typical receiving installation located near the edge of coverage and consists of an externally mounted antenna, a low noise amplifier (LNA) mounted at the antenna, an interconnecting downlead cable and an ATSC receiver.

(1) For definitions see Appendix 1 to Annex 1.

(2) For formula see Appendix 1 to Annex 1.

Appendix 1
to Annex 1

Derivation by the figure of merit method

Required field strength

$$E_{rx}\text{ (dB(V/m))} = \varphi\text{ (dB(W/m}^2)) + 10\log(120\,\pi)$$

$$C/N = \varphi - G_{\text{lm}^2} + G_A/T_e - k - B_{rf}$$

$$E_{rx}\text{ (dB(}\mu\text{V/m))} = \varphi\text{ (dB(W/m}^2)) + 25.8\text{ (dB)} + 120\text{ (dB)}$$

$$= 145.8 + C/N + G_{\text{lm}^2} - G_A/T_e + 10\log(k) + 10\log(B_{rf})$$

E_{rx}: required field strength at the receive system antenna

φ: power flux-density at the receive system antenna

C/N: carrier-to-noise ratio

G_{lm^2}: gain of 1 m^2

G_A/T_e: figure of merit of the receive system

k: Boltzmann's constant (J/K)

B_{rf}: system equivalent noise bandwidth.

Receive system figure of merit

(For receiving system model with LNA)

$$G_A/T_e = (G - L)/(\alpha_{balun}\,T_a + T_{balun} + T_{LNA} + T_{line}/(\alpha_{line}\,G_{LNA}) + T_{rx}/(\alpha_{line}\,G_{LNA}))$$

Receiver noise temperature

$$T_{rx} = (10^{NF/10} - 1) \times 290°$$

LNA noise temperature

$$T_{LNA} = (10^{NF/10} - 1) \times 290°$$

Transmission line noise temperature

$$T_{line} = (1 - \alpha_{line}) \times 290°$$

Balun noise temperature

$$T_{balun} = (1 - \alpha_{balun}) \times 290°$$

Antenna noise temperature

$$T_a = 10^{(6.63 - 2.77(\log f))} \times 290° \quad \text{(for dipole antenna)}$$

where f is expressed in MHz.

Antenna noise temperature (referred to LNA input)

$$\alpha\,T_a = T_a(\alpha_{balun})$$

System noise temperature

$$T_e = (\alpha_{balun}\,T_a + T_{balun} + T_{LNA} + T_{line}/(\alpha_{line}\,G_{LNA}) + T_{rx}/(\alpha_{line}\,G_{LNA}))$$

$$T_e\,(\text{dB(K)}) = 10\log(\alpha_{balun}\,T_a + T_{balun} + T_{LNA} + T_{line}/(\alpha_{line}\,G_{LNA}) + T_{rx}/(\alpha_{line}\,G_{LNA}))$$

or

$$= 10\log(T_{balun} + T_{LNA} + T_{line}/(\alpha_{line}\,G_{LNA}) + T_{rx}/(\alpha_{line}\,G_{LNA})) + N_{ext}$$

when T_a is not known.

Gain of 1 m²

$$G_{1\text{m}^2} = 10\log(4\,\pi/\lambda^2)$$

Data

G_I: antenna gain (isotropic) (dB)
L: transmission line loss (dB)
α_{line}: transmission line loss (numeric ratio)
T_a: antenna noise temperature (K)
T_{rx}: receiver noise temperature (K)
n_f: noise factor (numeric ratio)
NF: noise figure (dB)
T_0: reference temperature = 290 K
λ: wavelength of frequency of operation
G_A: system gain (dB)
T_e: system noise temperature (K)
N_{ext}: dB value representing the contribution due to external noise
k: Boltzmann's constant 1.38×10^{-23} (–228.6 dB) (J/K)
B: system equivalent noise bandwidth (dB(Hz))
α_{balun}: antenna 300/75 Balun loss (numeric ratio)
LNA: low noise amplifier
T_{LNA}: LNA noise temperature (K)

Annex 2

Planning criteria for DVB-T digital television systems in the VHF/UHF bands

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

Tables 14 to 15, 16 to 21, 22 to 23 and 24 to 25 show protection ratios for the DVB-T wanted digital terrestrial television signals interfered with:

– by DVB-T digital terrestrial television signals,
– by analogue terrestrial television signals,
– by a single continuous wave (CW) or FM carrier
– by terrestrial digital audio broadcasting (T-DAB) signals,

respectively.

1.1 Protection of a DVB-T digital terrestrial television signal interfered with by a DVB-T digital terrestrial television signal

TABLE 14

Co-channel protection ratios (dB) for a DVB-T signal interfered with by a DVB-T signal

Modulation	Code rate	Gaussian Channel	Rice channel	Rayleigh channel
QPSK	1/2	5	6	8
QPSK	2/3	7	8	11
16-QAM	1/2	10	11	13
16-QAM	2/3	13	14	16
16-QAM	3/4	14	15	18
64-QAM	1/2	16	17	19
64-QAM	2/3	19	20	23
64-QAM	3/4	20	21	25

Protection ratios 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 ratios should be applied for DVB-T systems with 6, 7 and 8 MHz bandwidth.

Protection ratios are rounded to the nearest integer.

For overlapping channel, in absence of measurement information, and if the overlapping bandwidth between the wanted and unwanted signals is less than 1 MHz, the protection ratio, *PR*, should be extrapolated from the co-channel ratio figure as follows:

$$PR = CCI + 10 \log_{10}(BO/BW)$$

where:

- CCI: co-channel protection ratio
- BO: bandwidth (MHz) in which the two DVB-T signals are overlapping
- BW: bandwidth (MHz) of the wanted signal
- PR = –30 dB should be used when the above formula gives $PR < -30$ dB.

However, further studies are needed on this subject.

TABLE 15

Protection ratios (dB) for a DVB-T signal interfered with by a DVB-T signal in the lower ($N-1$) and upper ($N+1$) adjacent channels

Channel	$N-1$	$N+1$
PR	–30	–30

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

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

It is known from measurements of existing receivers that they permit lower protection ratios.

But for planning purposes it is an advantage to have this value.

1.2 Protection of DVB-T digital terrestrial television interfered with by analogue terrestrial television

1.2.1 Protection from co-channel interference

TABLE 16

Co-channel protection ratios (dB) for DVB-T 7 MHz and 8 MHz signals interfered with by analogue television (non-controlled frequency condition) signals

Modulation	Code rate	Gaussian channel	Rice channel	Rayleigh channel
QPSK	1/2	–12		–12
QPSK	2/3	–8		–8
QPSK	3/4	–4		
QPSK	5/6	3		
QPSK	7/8	9		
16-QAM	1/2	–8		–8
16-QAM	2/3	–3		3
16-QAM	3/4	0		5
16-QAM	5/6	9		
16-QAM	7/8	16		
64-QAM	1/2	–3		3
64-QAM	2/3	3		6
64-QAM	3/4	9		15
64-QAM	5/6	15		
64-QAM	7/8	20		

NOTE 1 – The PAL/SECAM values are valid for the following sound carrier modes:

– MONO FM with a single sound carrier at –10 dB referred to the vision carrier;

– DUAL FM and FM + NICAM with two sound carriers at –13 dB and –20 dB level;

– AM + NICAM with two sound carriers at respectively –10 dB and –27 dB level.

According to the available measurements, the same protection ratio values are applicable for 2k and 8k modes.

In all Tables except Table 23, the so-called non-controlled conditions are used.

Actual measurements of protection ratio values will reflect the cyclic variation that occurs when the offset between a wanted DVB-T signal and an unwanted analogue signal is varied over a frequency range equivalent to the spacing between carriers of coded orthogonal frequency division multiplex (COFDM) systems. The protection ratios given represent a conservative, but realistic, value that covers the expected offset performance of existing receivers. The adoption of fine offset between COFDM signals and interfering analogue TV signals will permit the achievement of up to 3 dB improvement in protection ratio. The required transmitter frequency stability is similar to that of analogue precision offset, that means a range of some ±1 Hz.

Protection ratios for DVB-T 6 MHz are missing due to lack of measurement results.

1.2.2 Protection from lower adjacent channel (*N* – 1) interference

TABLE 17

Protection ratios (dB) for lower adjacent channel (*N* – 1) interference for DVB-T 7 MHz and 8 MHz signals interfered with by analogue television signals including sound

Wanted signal		Unwanted signal					
Constellation	**Code rate**	**PAL B**	**PAL G, B1**	**PAL I**	**PAL D, K**	**SECAM L**	**SECAM D, K**
QPSK	1/2		–44				
QPSK	2/3	–44	–44				
16-QAM	1/2		–43	–43			
16-QAM	2/3	–42	–42				
16-QAM	3/4		–38				
64-QAM	1/2		–40	–38			
64-QAM	2/3	–35	–35	–34		–35	–37
64-QAM	3/4		–32				

All values applicable for fixed and portable reception conditions.

1.2.3 Protection from upper adjacent channel (*N* + 1) interference

TABLE 18

Protection ratios (dB) for upper adjacent channel (*N* + 1) interference for DVB-T 7 MHz and 8 MHz signals interfered with by an analogue television signal

Wanted signal		Unwanted signal
Constellation	**Code rate**	**PAL/SECAM**
QPSK	2/3	–47
16-QAM	2/3	–43
64-QAM	2/3	–38

1.2.4 Protection from overlapping channel interference

TABLE 19

Protection ratios (dB) for a DVB-T 8 MHz signal interfered with by an overlapping PAL B signal including sound

Unwanted signal: PAL B analogue TV system	Wanted signal: DVB-T, 8 MHz, 64-QAM, code rate 2/3												
Δ*f* (MHz)	–9.75	–9.25	–8.75	–8.25	–6.75	–3.95	–3.75	–2.75	–0.75	2.25	3.25	4.75	5.25
PR	–37	–14	–8	–4	–2	1	3	3	3	2	–1	–29	–36

The frequency difference Δ*f* is the vision carrier frequency of the analogue television signal minus the centre frequency of the DVB-T signal.

TABLE 20

Protection ratios (dB) for a DVB-T 7 MHz signal interfered with by an overlapping 7 MHz analogue TV signal including sound

Unwanted signal: 7 MHz analogue TV system	Wanted signal: DVB-T, 7 MHz, 64-QAM, code rate 2/3													
Δ*f* (MHz)	–9.25	–8.75	–8.25	–7.75	–6.25	–3.45	–3.25	–2.25	–1.25	0	1.75	2.75	4.25	4.75
PR	–35	–12	–11	–5	–3	–1	4	1	0	2	–5	–5	–36	–38

The frequency difference Δ*f* is the vision carrier frequency of the analogue television signal minus the centre frequency of the DVB-T signal.

TABLE 21

Protection ratios (dB) for a DVB-T 8 MHz signal interfered with by an overlapping 8 MHz analogue TV signal including sound

Unwanted signal: 8 MHz analogue TV system	Wanted signal: DVB-T, 8 MHz, 64-QAM, code rate 2/3													
Δ*f* (MHz)	–10.25	–9.75	–9.25	–8.75	–7.25	–3.45	–3.25	–2.25	–1.25	0	1.75	2.75	4.25	4.75
PR	–35	–12	–11	–5	–3	–1	4	1	0	2	–5	–5	–36	–38

The frequency difference Δ*f* is the vision carrier frequency of the analogue television signal minus the centre frequency of the DVB-T signal.

1.3 Protection of DVB-T digital terrestrial television signal from CW or FM signals

TABLE 22

Co-channel protection ratios (dB) for a DVB-T 8 MHz 64-QAM code rate 2/3 signal interfered with by a CW or a FM carrier (non-controlled frequency offset)

Unwanted signal: CW or FM carrier	Wanted signal: DVB-T, 8 MHz, 64-QAM, code rate 2/3						
Δf (MHz)	–12	–4.5	–3.9	0	3.9	4.5	12
PR	–38	–33	–3	–3	–3	–33	–38

The given protection ratio Tables can be used for interfering signals with narrow bandwidth e.g. analogue sound carriers or non-broadcast services.

TABLE 23

Co-channel protection ratios (dB) for a DVB-T 7 MHz 64-QAM code rate 2/3 signal interfered with by a CW carrier (controlled frequency offset)

Unwanted signal: CW carrier	Wanted signal: DVB-T, 7 MHz, 64-QAM, code rate 2/3						
Δf (MHz)	–8	–4	–3	0	3	4	8
PR	–48	–41	–8	–9	–6	–39	–48

The given protection ratio Tables can be used for interfering signals with narrow bandwidth e.g. analogue sound carriers or non-broadcast services. It should be noted that the fine structure of the protection ratio versus frequency offset between the OFDM signal and the interfering CW signal exhibits a cyclic variation. The values shown in Table 23 are for the optimum offset.

1.4 Protection of DVB-T digital terrestrial television signals from T-DAB signals

TABLE 24

Co-channel protection ratios (dB) for a DVB-T 7 MHz and 8 MHz signal interfered with by a T-DAB signal

Wanted signal DVB-T		PR
Constellation	**Code rate**	
QPSK	1/2	10
QPSK	2/3	12
QPSK	3/4	14
16-QAM	1/2	15
16-QAM	2/3	18
16-QAM	3/4	20
64-QAM	1/2	20
64-QAM	2/3	24
64-QAM	3/4	26
64-QAM	7/8	31

NOTE 1 – The given protection ratios for DVB-T signals represent the worst case of interference from T-DAB.

TABLE 25

Protection ratios (dB) for a DVB-T 7 MHz and 8 MHz signal interfered with by a T-DAB signal in the lower (N – 1) or upper (N + 1) adjacent channels

Channel	$N - 1$	$N + 1$
PR	–30	–30

The protection ratio is given in dB.

1.5 Protection of DVB-T from wideband signals other than terrestrial broadcasting

1.5.1 Protection ratios for DVB-T interfered with by the fixed service (relocatable system)

TABLE 26

Protection ratios for DVB-T 8 MHz 64-QAM code rate 2/3 signal interfered with by emissions of the fixed service

Δf (MHz)	–12	–4.5	–3.75	0	3.75	4.5	12
PR (dB)	–45	–27	1	4	1	–27	–45

Δf: difference between the centre frequencies.

Technical characteristics of the interferer

– Modulation 2-FSK

– Bandwidth: 750 kHz (3 dB)

1.5.2 Protection ratios for DVB-T interfered with by code-division multiple access (CDMA)

It should be noted that the Tables 27 and 28 refer to the situation where one single channel of the CDMA system is interfering with DVB-T.

TABLE 27

Protection ratios for DVB-T 8 MHz 64-QAM code rate 2/3 signal interfered with by emissions of CDMA-1X

Δf (MHz)	–12	–4.5	–3.75	0	3.75	4.5	12
PR (dB)	–38	–20	–3	10	–3	–20	–38

Δf: difference between the centre frequencies.

Characteristics of the interfering signal

– Modulation: QPSK

– Bandwidth: 1.25 MHz (99%)

TABLE 28

Protection ratios for DVB-T 8 MHz 64-QAM code rate 2/3 signal interfered with by emissions of CDMA-3X

Δf (MHz)	–12	–4.5	–3.75	0	3.75	4.5	12
PR (dB)	–38	8	13	18	13	8	–38

Δf: difference between the centre frequencies.

Characteristics of the interfering signal

– Modulation: QPSK

– Bandwidth: 4 MHz (99%)

2 Protection ratios for wanted analogue terrestrial television signals interfered with by unwanted DVB-T digital terrestrial television signals

Tables 29 to 36 show protection ratios for a wanted 625-line analogue television signal interfered with by a DVB-T digital terrestrial television signal.

2.1 Protection ratios for 625-line television systems

2.1.1 Protection of wanted vision signals interfered with by DVB-T digital terrestrial television signal

In this section the protection ratios for an analogue wanted signal interfered by an unwanted DVB-T digital signal relate only to the interference to the vision signal.

The protection ratio values given are related to an out-of-channel spectrum attenuation of the unwanted DVB-T transmitter of 40 dB.

2.1.1.1 Protection from co-channel interference

TABLE 29

Protection ratios (dB) for a wanted analogue vision signal interfered with by an unwanted DVB-T 8 MHz signal

Wanted signal: analogue system	Unwanted signal: DVB-T, 8 MHz	
	Tropospheric interference	Continuous interference
B, D, D1, G, H, K/PAL	34	40
I/PAL	37	41
B, D, K, L/SECAM	35	41

TABLE 30

Protection ratios (dB) for a wanted analogue vision signal interfered with by an unwanted DVB-T 7 MHz signal

Wanted signal: analogue system	Unwanted signal: DVB-T, 7 MHz	
	Tropospheric interference	Continuous interference
B/PAL, B/SECAM	35	41

2.1.1.2 Protection from lower adjacent channel interference

TABLE 31

Protection ratios (dB) for a wanted analogue vision signal interfered with by DVB-T 7 MHz and 8 MHz signals (lower adjacent channel)

Wanted signal: analogue system	Unwanted signal: DVB-T, 7 or 8 MHz (lower adjacent channel)	
	Tropospheric interference	Continuous interference
B, D, D1, G, H, I, K/PAL	–9	–5
B, D, K, L/SECAM	–5	–1

2.1.1.3 Protection from upper adjacent channel interference

TABLE 32

Protection ratios (dB) for a wanted analogue vision signal interfered with by DVB-T 7 MHz and 8 MHz signals (upper adjacent channel)

Wanted signal: analogue system	Unwanted signal: DVB-T, 7 or 8 MHz (upper adjacent channel)	
	Tropospheric interference	Continuous interference
PAL and SECAM	–8	–5

2.1.1.4 Protection from image channel interference

TABLE 33

Protection ratios (dB) for a wanted analogue vision signal interfered with by a DVB-T 8 MHz signal (image channel)

Wanted analogue system	Unwanted DVB-T channel	Tropospheric interference	Continuous interference
D1, G/PAL	$N + 9$	–19	–15
I/PAL	$N + 9$		
L/SECAM(1)	$N + 9$	–24	–22
D, K/SECAM(1)	$N + 8$, $N + 9$	–16	–11
D, K/PAL	$N + 8$, $N + 9$		

(1) Provisional values still under study.

TABLE 34

Protection ratios (dB) for a wanted analogue vision signal interfered with by a DVB-T 7 MHz signal (image channel)

Wanted analogue system	Unwanted DVB-T channel	Tropospheric interference	Continuous interference
B/PAL	$N + 10$, $N + 11$	–22	–18

2.1.1.5 Protection from overlapping interference

TABLE 35

Protection ratios (dB) for analogue B, D, D1, G, H, K/PAL vision signals*
interfered with by a DVB-T 7 MHz signal
(overlapping channels)

Frequency of the centre of the unwanted DVB-T signal minus the vision carrier frequency of the wanted analogue television signal (MHz)		Protection ratio	
		Tropospheric interference	Continuous interference
	–7.75	–16	–11
(*N* – 1)	–4.75	–9	–5
	–4.25	–3	4
	–3.75	13	21
	–3.25	25	31
	–2.75	30	37
	–1.75	34	40
	–0.75	35	41
(*N*)	2.25	35	41
	4.25	35	40
	5.25	31	38
	6.25	28	35
	7.25	26	33
	8.25	6	12
(*N* + 1)	9.25	–8	–5
	12.25	–8	–5

* For all SECAM systems similar values are expected. The values are still under study.

TABLE 36

**Protection ratios (dB) for analogue B, D, D1, G, H, K/PAL vision signals*
interfered with by a DVB-T 8 MHz signal
(overlapping channels)**

Frequency of the centre of the unwanted DVB-T signal minus the vision carrier frequency of the wanted analogue television signal (MHz)		Protection ratio	
		Tropospheric interference(1)	Continuous interference(1)
	–8.25	–16	–11
(*N* – 1)	–5.25	–9	–5
	–4.75	–4	3
	–4.25	12	20
	–3.75	24	30
	–3.25	29	36
	–2.25	33	39
	–1.25	34	40
(*N*)	2.75	34	40
	4.75	34	39
	5.75	30	37
	6.75	27	34
	7.75	25	32
	8.75	5	11
(*N* + 1)	9.75	–8	–5
	12.75	–8	–5

* For all SECAM systems similar values are expected. The values are still under study.

(1) The values for tropospheric and continuous interference have been arrived at from Table 35 by calculation.

3 Protection ratios for sound signals of wanted analogue terrestrial television signals interfered with by unwanted DVB-T digital terrestrial television signals

Tables 37 to 39 in this Annex show protection ratios for wanted FM, AM and NICAM television sound carriers interfered with by unwanted digital terrestrial television signals.

All protection ratios in this section refer to the level of the wanted television sound carriers. The reference level of the sound carriers is the r.m.s. value of the unmodulated carrier.

The sound quality for tropospheric interference corresponds to grade 3, for continuous interference to grade 4.

The reference (S/N) for FM sound signals are:

– 40 dB (approximates to impairment grade 3) – tropospheric case;
– 48 dB (approximates to impairment grade 4) – continuous case.

The reference S/Ns are measured as S/N peak-to-peak weighted, given in Recommendation ITU-R BS.468 and Recommendation ITU-R BS.412.

The reference FM sound signal level corresponds to a maximum frequency deviation of ±50 kHz.

The reference BERs for NICAM digital sound signals are:

– BER = 1×10^{-4} (approximates to impairment grade 3), tropospheric case;
– BER = 1×10^{-5} (approximates to impairment grade 4), continuous case.

In the case of a two-sound carrier transmission, each of the two-sound signals must be considered separately. Multiplex modulated sound signals may require higher protection.

3.1 Protection for FM, AM and NICAM sound signals of analogue television systems interfered with by DVB-T digital terrestrial television signals

TABLE 37

Co-channel protection (dB) ratios for a wanted sound signal interfered with by DVB-T digital terrestrial television signals

Protection ratio related to the wanted sound carrier		Unwanted signal	
Wanted sound signal		DVB-T 7 MHz	DVB-T 8 MHz
FM	Tropospheric case	6	5
	Continuous case	16	15
AM	Tropospheric case	21	20
	Continuous case	24	23
NICAM PAL B/G	Tropospheric case	5	4
	Continuous case	6	5
NICAM System I	Tropospheric case		
	Continuous case		
NICAM System L	Tropospheric case	12	11
	Continuous case	13	12

TABLE 38

Protection ratios (dB) for a wanted FM sound signal interfered with by a DVB-T 7 MHz signal (overlapping channels)

		Frequency of the 3 dB point of DVB-T signal minus sound carrier frequency						
Frequency of the DVB-T signal relative to an FM carrier	**Protection ratio related to the wanted sound carrier**	**–500 kHz**	**–250 kHz**	**–50 kHz**	**0.0 kHz**	**50 kHz**	**250 kHz**	**500 kHz**
DVB-T below FM	Tropospheric case	0	0	0	5	5	6	6
	Continuous case	9	9	9	14	14	15	16
DVB-T above FM	Tropospheric case	5	5	4	3	–9	–22	–32
	Continuous case	15	15	14	12	–6	–16	–27

NOTE 1 – The protection ratio figures are related to an out-of-channel spectrum attenuation of 40 dB.

NOTE 2 – This Table is still under study.

TABLE 39

Protection ratios (dB) for a wanted AM sound signal interfered with by a DVB-T 8 MHz signal for different frequency offsets (upper adjacent channel)

Protection ratio related to the wanted sound carrier	**Centre frequency of the DVB-T signal minus sound carrier frequency**		
	With negative offset	**No offset**	**With positive offset**
	4.250 – 0.166 MHz = 4.084 MHz	**4.250 MHz**	**4.250 + 0.166 MHz = 4.416 MHz**
Tropospheric case	–1	–2	– 4
Continuous case	+1	0	–2

4 Protection ratios for a T-DAB signal interfered with by an unwanted digital terrestrial television signal

TABLE 40

Protection ratios (dB) for a T-DAB signal interfered with by a DVB-T 8 MHz signal

64-QAM, code rate 2/3									
Δf[(1)] (MHz)	–5	– 4.2	– 4	–3	0	3	4	4.2	5
PR	–50	– 1	0	1	1	1	0	–1	–50

(1) Δf: centre frequency of the DVB-T signal minus centre frequency of the T-DAB signal.

TABLE 41

Protection ratios (dB) for a T-DAB signal interfered with by a DVB-T 7 MHz signal

64-QAM, code rate 2/3									
Δf (1) (MHz)	–4.5	–3.7	–3.5	–2.5	0	2.5	3.5	3.7	4.5
PR	–49	0	1	2	2	2	1	0	–49

(1) Δf: centre frequency of the DVB-T signal minus centre frequency of the T-DAB signal.

5 Minimum field strengths for DVB-T terrestrial digital television, fixed reception

The formula for calculating minimum field strength is given in Appendix 1 to Annex 2.

TABLE 42

Calculation of minimum field strength DVB-T 8 MHz system

Frequency (MHz)	200			550			700		
System variant guard interval 1/4	QPSK 2/3	16-QAM 2/3	64-QAM 2/3	QPSK 2/3	16-QAM 2/3	64-QAM 2/3	QPSK 2/3	16-QAM 2/3	64-QAM 2/3
Receiver noise figure, F (dB)	5	5	5	7	7	7	7	7	7
Receiver carrier/noise ratio(1) (C/N) (dB)	8	14	20	8	14	20	8	14	20
Feeder loss A_f (dB)	3	3	3	3	3	3	5	5	5
Antenna gain, G (dB)	5	5	5	10	10	10	12	12	12
Minimum field strength for fixed reception, E_{min} (dB(μV/m))(2)	27	33	39	33	39	45	35	41	47

(1) For Rice channel.

(2) For formula, see Appendix 1 to Annex 2.

6 Minimum median field strength for mobile DVB-T reception

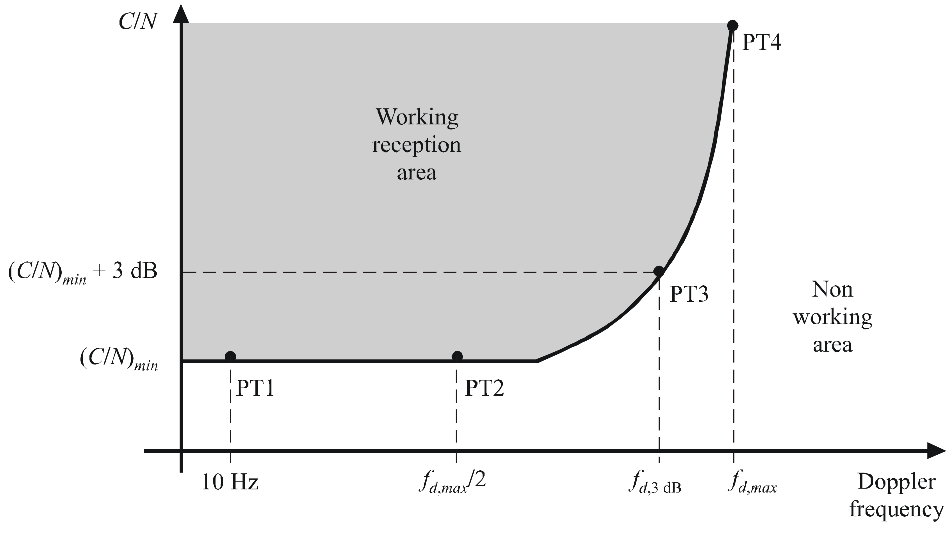
The equations for calculating the minimum median field strength are given in Appendix 1 to this Annex. The input values to the calculation are found in this section and in Annex 4. Mobile reception should be calculated with a location probability of 99%.

6.1 Required average *C*/*N* for mobile reception

For a given DVB-T mode the required average *C*/*N* for a certain quality level is a function of Doppler frequency only, and a graph like the one presented in Fig. 1 can be drawn.

FIGURE 1

Required average *C*/*N* in a mobile propagation channel



The minimum required average *C*/*N* values (C/N_{min}), Doppler frequency for an average *C*/*N* equal to C/N_{min} + 3 dB and the maximum Doppler (speed) limits for mobile reception are given in Table 43 and Table 44. The speed limits for C/N_{min} + 3 dB are given for three frequencies (200 MHz, 500 MHz and 800 MHz). The average *C*/*N* value, C/N_{min} + 3 dB, is suitable for calculation of required field strength. Table 43 shows values for the required average *C*/*N* and the speed limits in the non-diversity case. Table 44 contains the corresponding values for the diversity case. The values are based on the typical channel profile "typical urban" shown in Table 45. Quality criteria is the subjective failure point (SFP) corresponding to erroneous seconds ratio, –ESR = 5%, and packet error ratio, PER = 1×10^{-4}.

TABLE 43

Required average C/N, speed limits for mobile reception for the non-diversity case

Guard interval = 1/32			2k			Speed at F_d, 3 dB (km/h)			8k			Speed at F_d, 3 dB (km/h)		
Modulation	**Bit rate (Mbit/s)**	**Code rate**	C/N_{min} **(dB)**	$F_{d,\ max}$ **(Hz)**	F_d **at** C/N_{min} **+ 3 dB**	**200 MHz**	**500 MHz**	**800 MHz**	C/N_{min} **(dB)**	$F_{d,\ max}$ **(Hz)**	F_d **at** C/N_{min} **+ 3 dB**	**200 MHz**	**500 MHz**	**800 MHz**
QPSK	6.03	1/2	13.0	318	259	1 398	559	349	13.0	76	65	349	140	87
QPSK	8.04	2/3	16.0	247	224	1 207	483	302	16.0	65	53	286	114	71
16-QAM	12.06	1/2	18.5	224	182	985	394	246	18.5	59	47	254	102	64
16-QAM	16.09	2/3	21.5	176	147	794	318	199	21.5	41	35	191	76	48
64-QAM	18.10	1/2	23.5	141	118	635	254	159	23.5	35	29	159	64	40
64-QAM	24.13	2/3	27.0	82	65	349	140	87	27.0	24	18	95	38	24

TABLE 44

Required average C/N, speed limits for mobile reception for the diversity case

Guard interval = 1/32			2k			Speed at F_d, 3 dB (km/h)			8k			Speed at F_d, 3 dB (km/h)		
Modulation	**Bit rate (Mbit/s)**	**Code rate**	C/N_{min} **(dB)**	$F_{d,\ max}$ **(Hz)**	F_d **at** C/N_{min} **+ 3 dB**	**200 MHz**	**500 MHz**	**800 MHz**	C/N_{min} **(dB)**	$F_{d,\ max}$ **(Hz)**	F_d **at** C/N_{min} **+ 3 dB**	**200 MHz**	**500 MHz**	**800 MHz**
QPSK	6.03	1/2	7.0	560	518	2 795	1 118	699	7.0	140	129	699	280	175
QPSK	8.04	2/3	10.0	494	447	2 414	966	604	10.0	129	106	572	229	143
16-QAM	12.06	1/2	12.5	447	365	1 969	788	492	12.5	118	94	508	203	127
16-QAM	16.09	2/3	15.5	353	294	1 588	635	397	15.5	82	71	381	152	95
64-QAM	18.10	1/2	17.5	282	235	1 271	508	318	17.5	71	59	318	127	79
64-QAM	24.13	2/3	21.0	165	129	699	280	175	21.0	47	35	191	76	48

TABLE 45

Channel profile for measurement of required average *C*/*N* for mobile reception of DVB-T reception "typical urban"

Tap number	Delay (µs)	Power (dB)	Doppler category
1	0	–3	Rayleigh
2	0.2	0	Rayleigh
3	0.5	–2	Rayleigh
4	1.6	–6	Rayleigh
5	2.3	–8	Rayleigh
6	5	–10	Rayleigh

The values for the bit rate correspond to the shortest guard interval 1/32 which is the least critical case in terms of Doppler. It is to be expected that when the guard interval increases the maximum speed decreases. For instance with 1/4 guard interval, the maximum Doppler, $F_{d,\ max}$, decreases to about 85%.

The performance in a mobile channel depends to large extend on the design of the DVB-T receiver. Improvements may be achieved with receivers particularly designed for mobile reception.

DVB-H uses the DVB-T transmission system as the physical layer and adds extra error correction and time-slicing mechanism on the link layer. The maximum Doppler frequency (speed) in mobile reception will be improved due to the additional time interleaving. *C*/*N* values for DVB-H reception need to be developed.

6.2 Receiver noise figure

Noise figure of 5 dB is for integrated vehicle mobile receivers. A lower noise figure is possible when the antenna is internally matched to the first amplifier stage without a need for a loop through connection.

Appendix 1 to Annex 2

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 ($\sigma_m = 5.5$ (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%.

Annex 3

Planning criteria for ISDB-T digital television system in the VHF/UHF bands

1 Protection ratios for ISDB-T wanted digital terrestrial television signals

Tables 46 to 48 and 49 to 51 show protection ratios for an ISDB-T wanted digital terrestrial television signal interfered with by an ISDB-T digital terrestrial television signal and by an analogue terrestrial television signal, respectively.

1.1 Protection of an ISDB-T digital terrestrial television signal interfered with by an ISDB-T digital television signal

TABLE 46

Co-channel protection ratios (dB) for ISDB-T 6 MHz interfered with by ISDB-T 6 MHz

Coding rate	Modulation		
	DQPSK	16-QAM	64-QAM
7/8	10	17	23
5/6	9	16	22
3/4	9	15	21
2/3	8	14	20
1/2	6	12	17

TABLE 47

Protection ratios (dB) for ISDB-T 6 MHz interfered with by ISDB-T 6 MHz in lower adjacent channel (N – 1)

Coding rate	Modulation		
	DQPSK	16-QAM	64-QAM
7/8	–28	–27	–24
5/6	–28	–27	–25
3/4	–29	–27	–26
2/3	–29	–28	–26
1/2	–29	–28	–27

TABLE 48

Protection ratios (dB) for ISDB-T 6 MHz interfered with by ISDB-T 6 MHz in upper adjacent channel ($N + 1$)

Coding rate	Modulation		
	DQPSK	16-QAM	64-QAM
7/8	–29	–28	–27
5/6	–29	–28	–27
3/4	–29	–28	–27
2/3	–30	–29	–27
1/2	–30	–29	–28

1.2 Protection of ISDB-T digital terrestrial television interfered with by analogue terrestrial television

1.2.1 Protection from co-channel interference

TABLE 49

Co-channel protection ratios (dB) for ISDB-T 6 MHz interfered with by analogue television

	Protection ratio									
Modulation	DQPSK					QPSK				
Code rate	1/2	2/3	3/4	5/6	7/8	1/2	2/3	3/4	5/6	7/8
M/NTSC	–5	–3	–1	2	6	–16	–11	–8	0	2
Modulation	16-QAM					64-QAM				
Code rate	1/2	2/3	3/4	5/6	7/8	1/2	2/3	3/4	5/6	7/8
M/NTSC	–11	–5	–1	6	10	–6	–1	5	9	14

NOTE 1 – The sound carrier level is 6 dB lower than NTSC vision carrier level.

NOTE 2 – The values in this Table give the reception threshold. Taking into account the performance variation in domestic receivers, long-term degradation of reception condition etc., a margin of several dBs should preferably be added in actual frequency planning.

1.2.2 Protection from lower adjacent channel (*N* – 1) interference

TABLE 50

Protection ratios (dB) for lower adjacent channel (*N* – 1) interference for ISDB-T 6 MHz interfered with by NTSC signals including sound

Wanted signal		Unwanted signal
Modulation	**Coding rate**	**M/NTSC**
DQPSK	1/2	–34
DQPSK	2/3	–34
DQPSK	3/4	–33
16-QAM	1/2	–34
16-QAM	2/3	–33
16-QAM	3/4	–32
64-QAM	2/3	–32
64-QAM	3/4	–31
64-QAM	5/6	–29
64-QAM	7/8	–29

1.2.3 Protection from upper adjacent channel (*N* + 1) interference

TABLE 51

Protection ratios (dB) for upper adjacent channel (*N* + 1) interference for ISDB-T 6 MHz interfered with by NTSC 6 MHz signal

Wanted signal		Unwanted signal
Modulation	**Coding rate**	**M/NTSC**
DQPSK	1/2	–35
DQPSK	2/3	–35
DQPSK	3/4	–34
16-QAM	1/2	–35
16-QAM	2/3	–34
16-QAM	3/4	–33
64-QAM	2/3	–33
64-QAM	3/4	–33
64-QAM	5/6	–32
64-QAM	7/8	–31

2 Protection ratios for wanted analogue terrestrial television signals interfered with by unwanted ISDB-T digital terrestrial television signals

Table 52 shows protection ratios for a 525-line analogue television signal interfered with by an ISDB-T digital terrestrial television signal.

The protection ratio values given are related to a spectrum shoulder attenuation of the unwanted digital signal of 38 dB.

2.1 Protection ratios for 525-line television systems

2.1.1 Protection for NTSC vision signals interfered with by ISDB-T digital television signals

TABLE 52

Protection ratios (dB) for analogue vision signal (NTSC, 6 MHz) interfered with by ISDB-T signal

Unwanted digital channel	Tropospheric interference	Continuous interference
N – 1 (lower)	–6	–3
N (co-channel)	39	44
N + 1 (upper)	–6	–3

3 Protection ratios for sound signals of wanted analogue terrestrial television systems interfered with by ISDB-T unwanted digital terrestrial television system

3.1 Protection for NTSC sound signals interfered with by an ISDB-T digital television signal

As shown in Table 53, the sound signal of NTSC broadcasting is robust compared with the vision signal when interfered with by an ISDB-T signal. Therefore protection ratios for NTSC broadcasting are determined by the protection ratios for the vision signal, which are shown in Table 52.

TABLE 53

Sound quality related to the vision protection ratio of grade 3 when NTSC 6 MHz signal interfered with by ISDB-T 6 MHz signal

	Measurement condition (see Note 3)	Sound quality
Co-channel interference	$D/U = 39$ dB	> grade 4 ($S/N = 54$ dB)
Upper adjacent channel interference	$D/U = -6$ dB	> grade 4 ($S/N = 53$ dB)
Lower adjacent channel interference	$D/U = -6$ dB	> grade 4 ($S/N = 52$ dB)

NOTE 1 – The sound carrier level is 6 dB lower than NTSC vision carrier level.

NOTE 2 – The reference FM sound signal level corresponds to a maximum frequency deviation of ±25 kHz.

NOTE 3 – D/U ratio that gives vision quality of grade 3 (corresponding to protection ratio for tropospheric interference).

4 Minimum field strengths for ISDB-T terrestrial digital television

To reduce the number of tables for the minimum field strengths of an ISDB-T system, the derivation of minimum field strengths is made with the typical transmission modes shown in Table 54. The minimum field strengths for the different modes can be calculated from the given values in Table 54.

TABLE 54

Derivation by the voltage method ISDB-T 6 MHz system

Frequency (MHz)	Low VHF				High VHF				UHF			
	100				200				600			
System	DQPSK 1/2	QPSK 1/2	16-QAM 3/4	64-QAM 7/8	DQPSK 1/2	QPSK 1/2	16-QAM 3/4	64-QAM 7/8	DQPSK 1/2	QPSK 1/2	16-QAM 3/4	64-QAM 7/8
Noise bandwidth, B (MHz)	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6
Receiver noise figure, NF (dB)	5	5	5	5	5	5	5	5	7	7	7	7
Receiver noise input voltage, U_N (1) (dB(µV))	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	9.1	9.1	9.1	9.1
Receiver carrier/noise ratio(2) (C/N) (dB)	6.2	4.9	14.6	22.0	6.2	4.9	14.6	22.0	6.2	4.9	14.6	22.0
Urban noise (dB)	1	1	1	1	1	1	1	1	0	0	0	0
Minimum receiver input voltage, U_{min} (dB(µV))(1)	14.3	13.0	22.7	30.1	14.3	13.0	22.7	30.1	15.3	14.0	23.7	31.1
Conversion factor (1) K (dB)	6.4	6.4	6.4	6.4	12.4	12.4	12.4	12.4	21.9	21.9	21.9	21.9
Feeder loss, A_f (dB)	3	3	3	3	3	3	3	3	3	3	3	3
Antenna gain, G (dB)	3	5	3	3	5	5	5	5	10	10	10	10
Minimum field strength for fixed reception, E_{min} (dB(µV/m))(1)	20.7	23.4	29.1	36.5	24.7	23.4	33.1	40.5	30.2	28.9	38.6	46.0

(1) For formula, see Appendix 1 to Annex 3.

(2) For noise bandwidth noted above.

Appendix 1

to Annex 3

Derivation by the figure of merit method

Required field strength

$$E_{rx}\ (\text{dB(V/m)}) = \varphi\ (\text{dB(W/m}^2)) + 10\log(120\ \pi)$$

$$C/N = \varphi - G_{lm^2} + G_A/T_e - k - B_{rf}$$

$$E_{rx}\ (\text{dB}(\mu\text{V/m})) = \varphi\ (\text{dB(W/m}^2)) + 25.8\ (\text{dB}) + 120\ (\text{dB})$$

$$= 145.8 + C/N + G_{lm^2} - G_A/T_e + 10\log(k) + 10\log(B_{rf})$$

E_{rx}: required field strength at the receive system antenna

φ: power flux-density at the receive system antenna

C/N: carrier-to-noise ratio

G_{lm^2}: gain of 1 m^2

G_A/T_e: figure of merit of the receive system

k: Boltzmann's constant (J/K)

B_{rf}: system equivalent noise bandwidth.

Receive system figure of merit

(For receiving system model with LNA)

$$G_A/T_e = (G - L)/(\alpha_{balun}\ T_a + T_{balun} + T_{LNA} + T_{line}/(\alpha_{line}\ G_{LNA}) + T_{rx}/(\alpha_{line}\ G_{LNA}))$$

Receiver noise temperature

$$T_{rx} = (10^{NF/10} - 1) \times 290°$$

LNA noise temperature

$$T_{LNA} = (10^{NF/10} - 1) \times 290°$$

Transmission line noise temperature

$$T_{line} = (1 - \alpha_{line}) \times 290°$$

Balun noise temperature

$$T_{balun} = (1 - \alpha_{balun}) \times 290°$$

Antenna noise temperature

$$T_a = 10^{(6.3 - 2.77(\log f))} \times 290° \quad \text{(for dipole antenna)}$$

with f expressed in MHz.

Antenna noise temperature (referred to LNA input)

$$\alpha\, T_a = T_a(\alpha_{balun})$$

System noise temperature

$$T_e = (\alpha_{balun}\, T_a + T_{balun} + T_{LNA} + T_{line}/(\alpha_{line}\, G_{LNA}) + T_{rx}/(\alpha_{line}\, G_{LNA}))$$

$$T_e\ (\text{dB(K)}) = 10 \log(\alpha_{balun}\, T_a + T_{balun} + T_{LNA} + T_{line}/(\alpha_{line}\, G_{LNA}) + T_{rx}/(\alpha_{line}\, G_{LNA}))$$

or

$$= 10 \log(T_{balun} + T_{LNA} + T_{line}/(\alpha_{line}\, G_{LNA}) + T_{rx}/(\alpha_{line}\, G_{LNA})) + N_{ext}$$

when T_a is not known.

Gain of 1 m²

$$G_{1\text{m}^2} = 10 \log(4\, \pi/\lambda^2)$$

Data

- G_I: antenna gain (isotropic) (dB)
- L: transmission line loss (dB)
- α_{line}: transmission line loss (numeric ratio)
- T_a: antenna noise temperature (K)
- T_{rx}: receiver noise temperature (K)
- nf: noise factor (numeric ratio)
- NF: noise figure (dB)
- T_0: reference temperature = 290 K
- λ: wavelength of frequency of operation
- G_A: system gain (dB)
- T_e: system noise temperature (K)
- N_{ext}: dB value representing the contribution due to external noise
- k: Boltzmann's constant 1.38×10^{-23} (–228.6 dB) (J/K)
- B: system equivalent noise bandwidth (dB(Hz))
- α_{balun}: antenna 300/75 Balun loss (numeric ratio)
- LNA: low noise amplifier
- T_{LNA}: LNA noise temperature (K)

Annex 4

Other planning factors

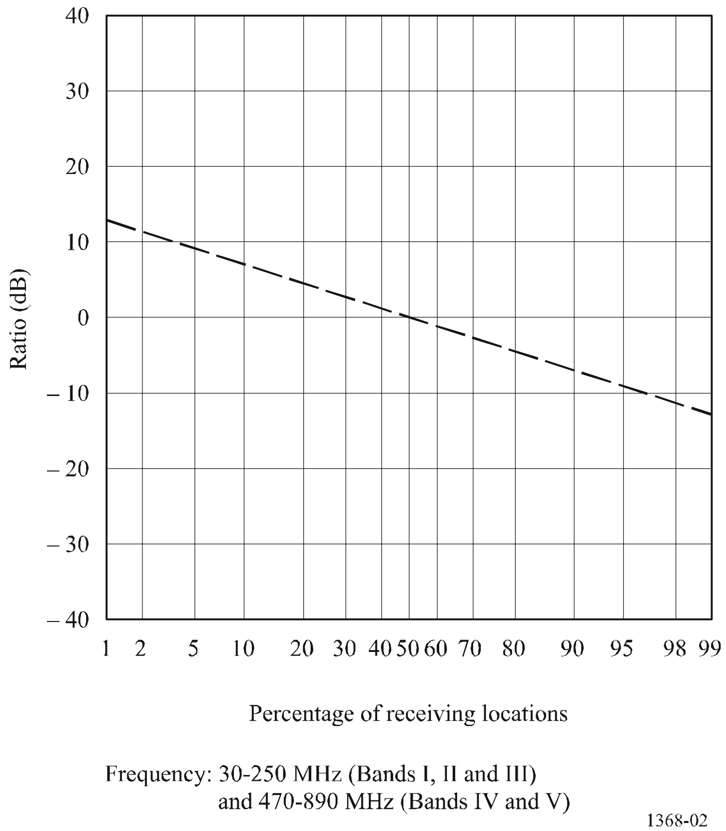
1 Field strength distribution with location

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 Table 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. 2 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 2

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 55 gives three classes of the relative possibilities to achieve indoor reception and the corresponding mean and standard deviations values of the building entry losses, for the same outdoor field strength, based on UHF measurements.

TABLE 55

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 metallized 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 metallized 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 56

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 57. Nominal antenna gain between these frequencies can be obtained by linear interpolation.

TABLE 57

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 58 can be expected.

TABLE 58

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.

Annex 5

Subjective comparison method (SCM) with a reference interferer for assessment of protection ratios for analogue television systems

1 Introduction

Subjective methods for assessment of impairment grades involve extensive tests, are time consuming, require large numbers of observers and consider the full impairment grade range.

For assessing protection ratios only two fixed impairment types are necessary, approximately grade 3 for tropospheric and grade 4 for continuous, see Table 59.

This Annex gives a method of assessing protection ratios for wanted analogue TV systems based on the subjective comparison of the impairment of an interferer with that of a reference interferer. Usable and reliable results are produced with only a small number of observers and one still picture.

This subjective comparison method is appropriate for the evaluation of interference from any unwanted digital or analogue transmission system into a wanted analogue television channel. The application of a defined fixed reference interferer results in a reproducible set of figures with a low deviation (approximately ±1 dB standard deviation). Only a small number of observers – three to five experts or non-experts – is necessary.

There are two reference interferers which may be used:

– sine-wave interference

– Gaussian-noise interferer.

Tests have shown that for unwanted digital television systems a noise reference interferer can improve the assessment decision by the observer. The use of noise reference interferer shows the same results as the defined sine-wave interferer. The disadvantage is that a more complicated test arrangement may be necessary. Further tests are necessary, especially by fixing the equivalent noise reference.

(For the time being the sine-wave reference interferer should be used until an agreement on a common test procedure and an agreement on a harmonized unified noise reference figure has been obtained.)

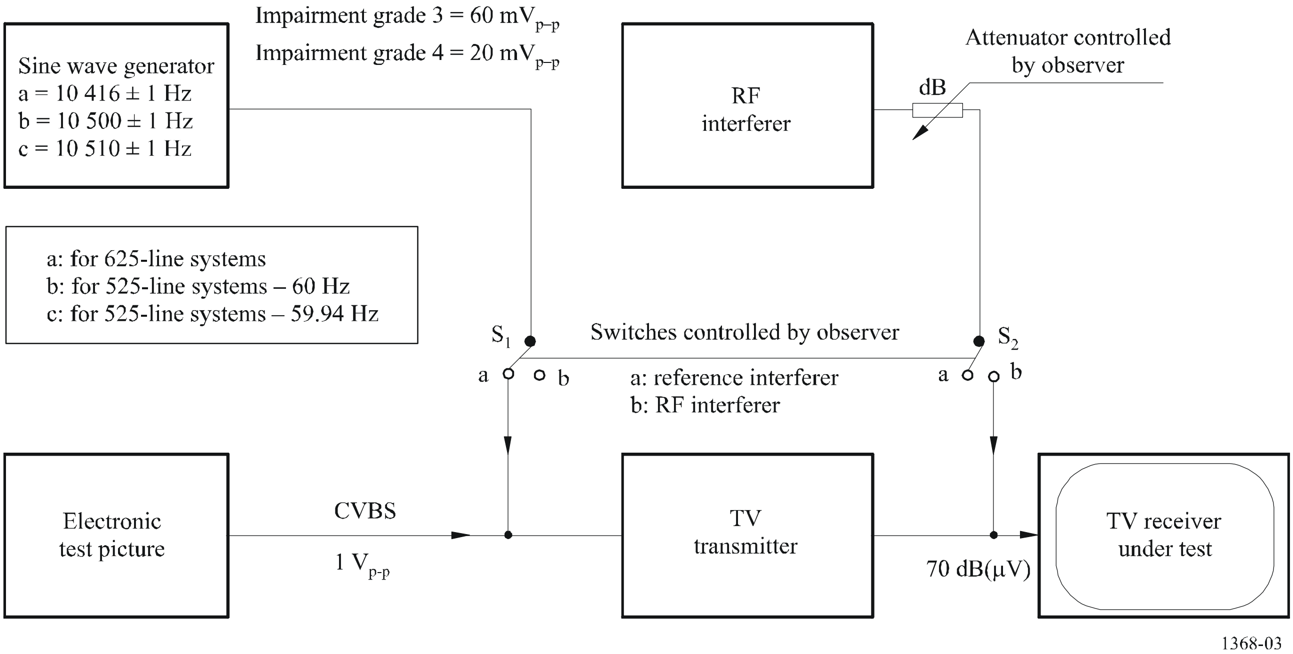
2 SCM for assessment of protection ratios using a sine-wave reference

2.1 General description

Figure 3 shows the test arrangement for the subjective comparison method with sine-wave interferer. The lower three blocks are the main signal path, the wanted video source, the television transmitter and the TV receiver under test. The reference video interferer is a simple sine-wave signal. The amplitude of the sine-wave generator is switchable between tropospheric interference and continuous interference. The unwanted RF interferer is added to the wanted signal path. The amplitude and frequency of the interferer are calculated from the RF reference interferer given in Recommendation ITU-R BT.655, Annex 1, § 2.3.

FIGURE 3

SCM for assessment of protection ratios



The intensity of the RF interferer can be changed with an attenuator controlled by the observer. The RF interferer is adjusted to produce the same impairment grade as the reference interferer by comparing the interfered pictures on the TV screen.

The RF protection ratio is the difference between the wanted and the unwanted signal levels at the receiver input. The test arrangement can be adjusted in such a way that the value in dB shown at the attenuation box gives directly the protection ratio.

2.2 Realization of the reference interferer

For 625-line systems the reference impairment levels are those which correspond to co-channel protection ratios of 30 dB and 40 dB with a frequency offset between the wanted and unwanted vision carriers close to two-thirds of the line frequency but adjusted for maximum impairment. The precise frequency difference is 10 416 Hz. These conditions approximate impairment grades 3 (slightly annoying) and 4 (perceptible, but not annoying) and apply to tropospheric (1% of time) and continuous interference (50% of time), respectively. The impairment grade of the given video baseband reference interferer is independent of the analogue television system and independent of the RF modulation parameters such as modulation polarity, residual carrier etc.

The RF reference interferer can be realized as a simple sine-wave signal at baseband frequency as shown in Fig. 3. The sine-wave reference interferer has a fixed frequency of 10 416 Hz for 625-line systems or 10 500 Hz for 525-line systems –60 Hz and 10 510 Hz for 525-line systems –59.94 Hz, an amplitude of either 60 mV_{p-p} or 20 mV_{p-p} referring to a black-to-white level of 700 mV_{p-p} or a CVBS level of 1 V_{p-p}. These amplitudes correspond to the RF protection ratios of 30 dB and 40 dB respectively (2/3 line offset). The frequency stability of the sine-wave generator must be within ±1 Hz.

2.3 Test conditions

Wanted video signal: only an electronic test picture is required (e.g. FuBK, Philips or others).

Viewing conditions: as given in Recommendation ITU-R BT.500.

Viewing distance: five times the picture height.

Test receiver: up to five different domestic sets, not older than five years, for co-channel measurements a professional receiver can be used.

Receiver input signal: –39 dBm (70 dB(μV) at 75 Ω).

Observers: five observers, experts or non-experts, are necessary. For initial tests less than five observers are possible. Each single test should be made with one observer only. Observers should be introduced to the method of assessment.

2.4 Presentation of the results

The results should be presented together with the following information:

– mean and standard deviation of the statistical distribution of the protection ratio values;
– test configuration, test picture, type of picture source;
– number of observers;
– reference interferer type;
– the spectrum of the unwanted signal (RF interferer), including the out-of-channel range;
– the used RF level for the wanted signal at the receiver input (for domestic receivers an input voltage of –39 dBm (70 dB(μV) at 75 Ω should be used);
– when domestic sets are used, type, display size and year of production.

3 Table of important parameters

TABLE 59

Basic terms and relations for the SCM

Quality impairment	Grade 3	Grade 4
Interference type	Tropospheric	Continuous
Time allowance	1% to 5% of time	50% of time
Subjective impairment	Slightly annoying	Perceptible, but not annoying
Reference interferer (mV_{p-p})	60	20
RF protection ratio (dB)	30	40

Annex 6

Test methods for protection ratio measurements for wanted digital terrestrial signals

1 Background

Initial studies of the protection ratios for the DVB-T system were based on a target BER of 2×10^{-4} measured between the inner and outer codes, before Reed-Solomon decoding. For the case of a noise-like interferer, this has been taken to correspond to a quasi-error-free (QEF) picture quality with the BER $< 1 \times 10^{-11}$ at the input of the MPEG-2 demultiplexer.

2 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-T 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. 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 method with a BER of 2×10^{-4} and the SFP method is less than 1 dB. All protection ratio values for wanted digital TV signals are measured with a receiver input power of −60 dBm.

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 7

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:

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