RECOMMENDATION ITU-R BT.1368-2

PLANNING CRITERIA FOR DIGITAL TERRESTRIAL TELEVISION SERVICES IN THE VHF/UHF BANDS

(Question ITU-R 121/11)

(1998-1998-2000)

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

that the relevant protection ratios (PRs) given in Annexes 1, 2, 3 and 7, the relevant minimum field strength values given in Annex 4, and the additional information given in Annexes 5, 6, 8 and 9 be used as the basis for frequency planning for digital terrestrial television services.

Introduction

This Recommendation contains the following Annexes:

Annex 1 – Protection ratios for wanted digital terrestrial television systems

Annex 2 – Protection ratios for wanted analogue terrestrial television systems interfered with by unwanted digital terrestrial television systems

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

Annex 4 – Minimum field strengths for terrestrial digital television

Annex 5 – Other planning factors

Annex 6 – Subjective comparison method (SCM) with a reference interferer for assessment protection ratios for analogue television system

Annex 7 – Protection ratios for T-DAB interfered with by an unwanted digital terrestrial television system

Annex 8 – Test methods for protection ratio measurements for wanted digital terrestrial signals

Annex 9 – 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 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 be preferably measured by thermal power meter. All protection ratio values for wanted digital signals are 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 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 digital terrestrial television system (digital video broadcasting-terrestrial (DVB-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 < 1×10^{-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 6.

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 9.)

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.

ANNEX 1

Protection ratios for wanted digital terrestrial television systems

The Tables in Annex 1 show protection ratios for different wanted digital terrestrial television systems interfered with by digital terrestrial television systems, by analogue terrestrial television systems, by a single continuous wave (CW) and FM carrier and by terrestrial digital audio broadcasting (T-DAB) signals, respectively.

1 Protection of digital terrestrial television systems interfered with by digital terrestrial television systems

TABLE 2

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

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 system interfered with by ATSC signal in channel *N* ± 2 and other out-of-band channels

Channel	*N* ± 2 and other out-of-band channels
ATSC 6 MHz	–58

TABLE 5

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

Modulation	Code rate	Gaussian channel	Rice channel	Rayleigh channel
QPSK	1/2	5	7	8
QPSK	2/3	7		
16-QAM	2/3	13		
16-QAM	3/4	14	16	20
64-QAM	2/3	19	20	22

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 the protection ratio 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.

TABLE 6

Protection ratios (dB) for a DVB-T system 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 ratios are given in dB and apply to both continuous and tropospheric interference.

The values are given, when wanted and unwanted DVB-T signal has the same channel width.

TABLE 7

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

Channel	$N \pm 2$ and other out-of-band channels
PR	

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

The values are given, when wanted and unwanted DVB-T signal has the same channel width.

2 Protection of digital terrestrial television interfered with by analogue terrestrial television

2.1 Protection from co-channel interference

TABLE 8

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

Wanted signal	Unwanted signal (Analogue TV system 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.

TABLE 9

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

	Protection Ratio														
Constellation	QPSK					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	1/2	2/3	3/4	5/6	7/8
PAL/SECAM(1)	–12	–8	–4	3	9	–8	–3	3	9	16	–3	3	9	15	20

(1) With teletext and sound carriers.

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 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 the analogue precision offset, that means in a range of some Hz.

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

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

TABLE 10

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

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

TABLE 11

Protection ratios (dB) for lower adjacent channel (*N* – 1) interference for DVB-T 7 MHz and 8 MHz systems 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	2/3	–44					
16-QAM	1/2			–43			
16-QAM	2/3	–42					
64-QAM	1/2			–38			
64-QAM	2/3	–35		–34		–35	

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

TABLE 12

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

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

TABLE 13

Protection ratios (dB) for upper adjacent channel ($N + 1$) interference for DVB-T 7 MHz and 8 MHz systems 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

2.4 Protection from overlapping channel interference

TABLE 14

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

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 15

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

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 16

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

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.

2.5 Protection from other channel interference

TABLE 17

Protection ratios (dB) for an ATSC 6 MHz system interfered with by a M/NTSC system 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

2.6 Protection from CW and FM signals

TABLE 18

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

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 19

Co-channel protection ratios (dB) for a DVB-T 7 MHz 64-QAM code rate 2/3 system interfered with by a CW or a FM carrier

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.

2.7 Protection from T-DAB signals

TABLE 20

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

64-QAM code rate 2/3									
Δf[(1)] (MHz)	–5	–4.2	–4	–3	0	3	4	4.2	5
PR	–30	–6	–5	28	29	28	–5	–6	–30

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

TABLE 21

Protection ratios (dB) for a DVB-T 7 MHz system interfered with by a T-DAB 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	–30	–6	–5	28	29	28	–5	–6	–30

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

ANNEX 2

Protection ratios for wanted analogue terrestrial television systems interfered with by unwanted digital terrestrial television systems

The Tables in Annex 2 show protection ratios for different wanted 525- and 625-line analogue television systems interfered with by digital terrestrial television systems.

1 Protection ratios for 525-line television systems

1.1 Protection for vision and sound signals interfered with by digital television

1.1.1 Protection for vision signals interfered with by digital television (ATSC)

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

TABLE 22

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 ± 2	–24	
N ± 3	–30	
N ± 4	–25	
N ± 7	–34	
N ± 8	–32	

2 Protection ratios for 625-line television systems

2.1 Protection of wanted vision signals interfered with by 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.

2.1.1 Protection from co-channel interference

TABLE 23

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

Wanted analogue system	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 24

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

Wanted analogue system	Tropospheric interference	Continuous interference
B/PAL, B/SECAM	35	41

TABLE 25

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

Wanted analogue system	Tropospheric interference	Continuous interference
B/PAL	38	45

2.1.2 Protection from lower adjacent channel interference

TABLE 26

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

Wanted analogue system	Tropospheric interference	Continuous interference
B, D, D1, G, H, I, K/PAL	– 9	–5
B, D, K, L/SECAM	– 6	–1

TABLE 27

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

Wanted analogue system	Tropospheric interference	Continuous interference
B/PAL	–7	–1

2.1.3 Protection from upper adjacent channel interference

TABLE 28

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

Wanted analogue system	Tropospheric interference	Continuous interference
PAL and SECAM	–9	–5

TABLE 29

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

Wanted analogue system	Tropospheric interference	Continuous interference
B/PAL	–7	0

2.1.4 Protection from image channel interference

TABLE 30

Protection ratios (dB) for a wanted analogue vision signal interfered with by a DVB-T 8 MHz system (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 31

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

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

2.1.5 Protection from overlapping interference

TABLE 32

Protection ratios (dB) for analogue B, D, D1, G, H, K/PAL vision signals(1) interfered with by a DVB-T 7 MHz system (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	–9	–5
	12.25	–9	–5

(1) For all SECAM systems similar values are expected. The values are still under study.

TABLE 33

Protection ratios (dB) for analogue B, D, D1, G, H, K/PAL vision signals[(1)] interfered with by a DVB-T 8 MHz system (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[(2)]	Continuous interference[(2)]
– 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* 0+ 1) 9.75	–9	–5
12.75	–9	–5

(1) For all SECAM systems similar values are expected. The values are still under study.

(2) The values for tropospheric and continuous interference have been arrived at from Table 32 by calculation.

ANNEX 3

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

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

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.

1 Protection for NTSC sound signals (BTSC MTS system and SAP) interfered with by a digital television system (ATSC) (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.

2 Protection for FM, AM and NICAM sound signals of analogue television systems interfered with by a digital terrestrial television system

TABLE 34

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

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	Tropospheric case	5	4
PAL B/G	Continuous case	6	5
NICAM	Tropospheric case		
System I	Continuous case		
NICAM	Tropospheric case	12	11
System L	Continuous case	13	12

TABLE 35

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						
Protection ratio related to the wanted sound carrier	Frequency of the DVB-T signal relative to an FM carrier	–500 kHz	–250 kHz	–50 kHz	0.0 kHz	50 kHz	250 kHz	500 kHz
Tropospheric case	DVB-T below FM	0	0	0	5	5	6	6
Continuous case	DVB-T below FM	9	9	9	14	14	15	16
Tropospheric case	DVB-T above FM	5	5	4	3	–9	–22	–32
Continuous case	DVB-T above FM	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 – The protection ratio figures for other television systems in use have to be added.

NOTE 3 – This Table is still under study.

TABLE 36

Protection ratios (dB) for a wanted AM sound signal interfered with by a DVB-T 8 MHz system 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

ANNEX 4

Minimum field strengths for terrestrial digital television

Two methods are given for the calculation of minimum field strength values. Each of these methods may be used to give the identical minimum field strength values for a given set of parameters.

TABLE 37

Derivation by the voltage method

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
Noise bandwidth, B (MHz)	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6
Receiver noise figure, F (dB)	5	5	5	7	7	7	7	7	7
Receiver noise input voltage, U_N (1) (dB(μV))	8.4	8.4	8.4	10.4	10.4	10.4	10.4	10.4	10.4
Receiver carrier/noise ratio(2) (C/N) (dB)	6.9	13.1	18.7	6.9	13.1	18.7	6.9	13.1	18.7
Urban noise (dB)	1	1	1	0	0	0	0	0	0
Minimum receiver input voltage, U_{min} (dB(μV))(1)	16.3	22.5	28.1	17.3	23.5	29.1	17.3	23.5	29.1
Conversion factor (1) K (dB)	12.4	12.4	12.4	20.5	20.5	20.5	24.5	24.5	24.5
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))(1)	26.7	32.9	38.5	31.8	37.6	42.6	35.8	41.6	46.6

(1) For formula, see Appendix 1.

(2) For noise bandwidth noted above.

TABLE 38

Derivation by the figure of merit method

ATSC 6 MHz system(1)

Planning parameter(2)	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)	67.78	67.78	67.78
G_{1m^2} (dB)	–1.77	7.25	17.23
G_D (dB)	6	8	10
G_I (dB)	8.15	10.15	12.15
Transmission line loss (dB) α_{line} (numeric)	1.05 0.786	1.81 0.659	3.29 0.468
Antenna 300/75 balun loss (dB) α_{balun} (numeric)	0.5 0.891	0.5 0.891	0.5 0.891
Receiver noise figure (dB)	5	5	10
T_{rx}	627.1	627.1	2 610
T_{line}	62.1	98.9	154.3
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)	0.79	1.5	3.3
$T_{rx}/\alpha\ G$ (K)	7.98	9.52	55.8
T_e (K)	9 552.6	1 176.8	717.8
10 log(T_e) (dB(K))	39.8	30.71	28.56
G_A (dB)	7.65	9.65	11.65
E_{rx} (dB(μV/m))(3)	35	33	39

(1) 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.

(2) For definitions see Appendix 2.

(3) For formula see Appendix 2.

APPENDIX 1

TO ANNEX 4

Derivation by the voltage method	Formulae	(dB)
	$P = U^2/R$	
Thermal noise power:	$k\,T\,B$	$10 \log (k\,T\,B)$
Receiver noise input power, P_N:	$n\,k\,T\,B$	$10 \log (k\,T\,B) + F$
Thermal noise voltage, U_T:	$U_T = \sqrt{k\,T\,B\,R}$	
Receiver noise input voltage, U_N:	$U_N = \sqrt{n\,k\,T\,B\,R}$	$10 \log (k\,T\,B) + F + 10 \log (R)$
Minimum receiver input voltage, U_{min}:	$U_{min} = U_N \sqrt{C/N}$	$U_N + C/N$

Relationship between voltage and field strength:

$$U = \sqrt{P_r\,R} = \sqrt{\varphi\,A\,R} = \sqrt{\frac{E^2}{120\,\pi}\,1.64\,g_0\,\frac{\lambda^2}{4\,\pi}\,R}$$

Therefore,

$$U = E\sqrt{\frac{\lambda^2}{480\,\pi^2}} = R\,1.64\,g_0$$

Conversion factor, K:	$K = \dfrac{E}{U} = \sqrt{\dfrac{480\,\pi^2}{1.64\,g_0\,\lambda^2\,R}}$	$K = 10 \log\ 480\,\pi^2 - 20 \log \lambda$ $- 10 \log R - 10 \log 1.64 - G_D + L$
Conversion factor, K_0:	$K_0 = \dfrac{E}{U} = \sqrt{\dfrac{4\,\pi^2}{g_0\,\lambda^2}}$	$K_0 = 20 \log (2\,\pi/\lambda) - G_D + L$
Minimum field strength:		$E_{min} = U_{min} + K_0$

Data

k:	Boltzmann' constant (1.38×10^{-23})
T_0:	reference temperature = 290 K
F:	receiver noise figure (dB)
n:	receiver noise figure (factor)
B:	equivalent noise bandwidth (Hz)
C/N:	radio-frequency carrier/noise ratio (dB)
P_r:	minimum receiver input power
E:	field strength
R:	impedance of half-wave dipole ($R = 73\ \Omega$)
f:	frequency (Hz)
G_D:	antenna gain related to half-wave dipole (dB)
L:	transmission line loss (dB)
φ:	power flux-density
g_0:	gain of receiving antenna system related to half-wave dipole (factor)
A:	effective antenna aperture

Formulae used

Thermal noise:	$k\,T_0\,B$
Receiver noise temperature:	$T_{rx} = T_0\,(10^{F/10} - 1)$
g_0:	$10^{(G_D - L)/10}$
n:	$10^{F/10}$
A:	$\dfrac{1.64\,g_0\lambda^2}{4\,\pi}$
φ:	$\dfrac{E^2}{120\,\pi}$

APPENDIX 2

TO ANNEX 4

Derivation by the figure of merit method

Required field strength

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

$$C/N = \varphi - G_{1\mathrm{m}^2} + G_A/T_e - k - B_{rf}$$

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

$$= 145.8 + C/N + G_{1\mathrm{m}^2} - G_A/T_e + 10\log(k) + 10\log(B_{rf})$$

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

$G_{1\mathrm{m}^2}$: gain of 1 m^2

G_A/T_e: figure of merit of the receive system

k: Boltzmann's constant

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

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

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)

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 5

Other planning factors

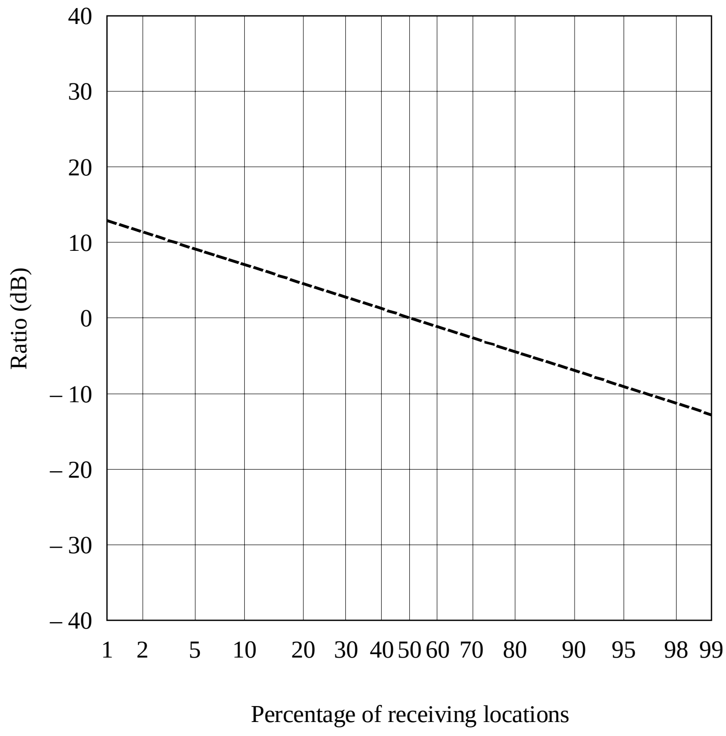
1 Field strength distribution with location

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 and given in Figs. 5 and 12 of Recommendation ITU-R P.370.

The results of propagation studies for digital systems are given in Fig.1 for the VHF and UHF bands. These results may also be used to derive propagation prediction curves for location percentages other than 50%. Refer to Figs. 5 and 12 of Recommendation ITU-R P.370 for the location percentages other than 50% for analogue and digital systems, where the digital system bandwidth is greater than 1.5 MHz.

FIGURE 1

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



Frequency: 30-250 MHz (Bands I, II and III)
and 470-890 MHz (Bands IV and V)

1368-01

2 Reception using portable television equipment

The methods given in Annex 4 may be used to derive the minimum field strength required in the vicinity of a receiving antenna. By convention, field strength predictions are made for a receiving antenna height of 10 m above ground or roof-top level. In the case of reception using a portable receiver, an estimate will be needed of the difference in field strength between that at 10 m or roof-top level and that at the place where the portable receiver is situated. Representative values, including both indoor and outdoor operation, have yet to be developed. Recommendation ITU-R P.370 notes that by using equation (5), a correction to the predicted field strengths can be made for various receiving antenna heights ranging from 1.5 m to 40 m above ground.

An approximation for the indoor field strength relative to the ground floor outdoor field strength for the VHF and UHF bands in suburban areas is given by:

$$\text{Field strengths (indoor)} = \text{Field strengths (outdoor at ground level)} + 2N - 10$$

where N is the number of the floor where the indoor receiver is located and for N ranging from 0 to 2.

3 Receiving antenna discrimination

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

ANNEX 6

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

1 Introduction

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.

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 three fixed impairment types are necessary, approximately grade 3 for tropospheric and grade 4 for continuous, see Table 39. The 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 - are necessary.

There are two reference interferers which may be used:

– sine-wave interference

  (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 have been obtained.)

– 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.

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

2.1 General description

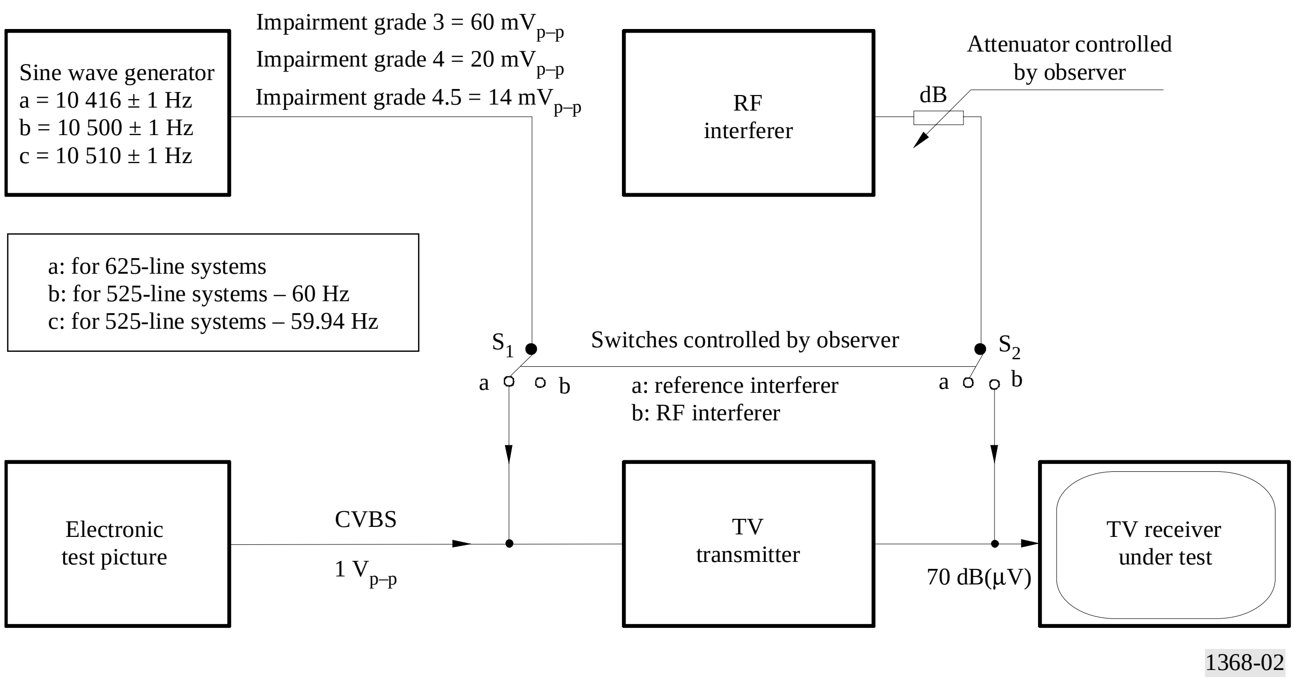
Figure 2 shows the test arrangement for the subjective comparison method with sine-wave interferer. The lower three blocks are the main signal path, the wanted video source, the television transmitter and the TV receiver under test. The reference video interferer is a simple sine-wave signal. The amplitude of the sine-wave generator is switchable between tropospheric interference, continuous interference and steady interferences type. 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.

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.

FIGURE 2

SCM for assessment of protection ratios



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 kHz. 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 from the analogue television system and independent from the RF modulation parameters like 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. 2. The sine-wave reference interferer has a fixed frequency of 10.416 kHz for 625-line systems or 10.500 kHz for 525-line systems –60 Hz and 10.510 kHz 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 then 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 39

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 7

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

1 T-DAB systems interfered with by DVB-T systems

TABLE 40

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

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 system interfered with by a DVB-T 7 MHz system

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.

ANNEX 8

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 < 1×10^{-11} at the input of the MPEG-2 demultiplexer.

2 The 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 "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 9

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:

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