International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Report ITU-R BT.2265-1

(11/2014)

Guidelines for the assessment of interference into the broadcasting service

BT Series

Broadcasting service (television)

150

1865 - 2015

International Telecommunication Union

Foreword

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

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

Policy on Intellectual Property Right (IPR)

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

Series of ITU-R Reports

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

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

***Note**: This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

Electronic Publication
Geneva, 2015

REPORT ITU-R BT.2265-1

Guidelines for the assessment of interference into the broadcasting service

(2012-2014)

1 Introduction

This Report has been developed following the introduction of Recommendation ITU-R BT/BS.1895 which provides *I/N* thresholds above which further assessment of the interference should be carried out.

This Report provides possible approaches for protecting broadcasting from interference originating from other services and interference originating from devices/applications without a corresponding frequency allocation.

This Report is intended to provide guidance to assist administrations in planning the use of the spectrum in an efficient manner. There are many variables involved in this process because many different administrations have different needs and different experiences with the planning and utilization of broadcasting spectrum.

Notably, several different television systems are in use throughout the world, i.e. ATSC, DVB, ISDB and DTMB. Also, there are various different station allotment/assignment plans in use, either country-by-country or by regions. Generally, all of the existing television systems have been thoroughly planned and are in operation with well-defined service requirements and protection levels from specific/individual interference sources. These guidelines provide general information for evaluations on a theoretical basis which can then be amended as required. Information on the introduction of Mobile services in adjacent bands to broadcasting and measures implemented by Administrations on a national basis to protect DTTB reception can be found in ITU-R Report ITU-R BT.2301.

This Report attempts to supply information to provide administrations with suitable guidance and where there is a lack of information, highlights the need for further study.

2 Guidelines

The assessment of interference from different sources into the broadcasting service can be, based on the concept of noise power increment, viewed as a two-step process: a basic assessment and a further assessment:

– Basic assessment of interference

Interference power may be assessed on the basis of the *I/N* guideline criteria derived from Recommendation ITU-R BT.1895[1]. These values serve as a threshold in evaluating

---

[1] Recommendation ITU-R BT.1895 recommends:

1 that the values in *recommends* 2 and 3 be used as guidelines, above which compatibility studies on the effect of radiations and emissions from other applications and services into the broadcasting service should be undertaken;

2 that the total interference at the receiver from all radiations and emissions without a corresponding frequency allocation in the Radio Regulations should not exceed 1 per cent of the total receiving system noise power;

3 that the total interference at the receiver arising from all sources of radio-frequency emissions from radiocommunication services with a corresponding co-primary frequency allocation should not exceed 10 per cent of the total receiving system noise power.

interference risks into the broadcasting service[2]. A translation into a field-strength value is performed as described in Annex 1. The criterion in terms of C/N degradation is also introduced in Annex 1. If the I/N is found to be less than the value specified by Recommendation ITU-R BT.1895, the assessment can be completed with this basic assessment.

– Further assessment of interference

For further compatibility analysis, administrations may use different methodologies to evaluate the impact of interference to Digital Terrestrial Television Broadcasting (DTTB). The criteria may be a degradation to carrier-to-noise ratio, degradation to carrier-to-interferer-plus-noise or degradation to reception location probability to evaluate this impact in a numerical form.

Different approaches can be used for this purpose. Two examples of possible approaches are given in Annexes 2 and 3. The use of information on actual network deployments (broadcasting and mobile networks) in the described methods would allow administrations to predict more precisely where mitigation measures might be required in order to protect DTTB reception, and assist them to determine the potential costs of these measures.

In this Report, reception location probability is defined as the percentage of locations within a small area, referred to in this Report as "pixel"[3], where the wanted signal is high enough to overcome noise and interference for a given percentage of time taking into account the temporal and spatial statistical variations of the relevant fields.

3 Overview of the methodologies

Some example methodologies for assessment of interference into the digital broadcasting service are given in Annexes 1, 2 and 3 which describe in details the methods which may be used in the two steps described above. The features of these methodologies are:

1) Annex 1 shows the relationship between the I/N criterion, the C/N degradation and the corresponding interfering field strength. It provides an analytical methodology to calculate the individual and cumulative field strength (and power flux-density) above which compatibility studies should be undertaken to further assess the effect of interference. Annex 1 also describes the relationship between the I/N criterion and field strength, but taking into account environmental noise as well as thermal noise in different frequency bands. The Appendices to Annex 1 give numerical examples of the results obtained when applying the method in the Annex.

2) Annex 2 describes an example methodology, based on the analysis of $C/(N+I)$, that uses a statistical approach to evaluate the amount of interference in terms of degradation to the DTTB reception location probability with the possibility to consider multiple sources of interference. The degradation to the DTTB reception location probability by calculation the difference between the reception location probability when the interfering stations of other services/applications are implemented ("after") and the DTTB reception location probability when the interfering stations of other services/applications are not implemented ("before"). The degradation of the reception location probability is statistically the decrease of percentage of locations in the area where reception of the DTTB service is possible.

[2] Recognizing that a I/N criterion is not commonly used by the broadcasting services when establishing protection rules.

[3] Pixel is a small area of typically about 100 m × 100 m where the percentage of covered receiving locations is indicated.

Multiplying the degradation of the reception location probability by the population (or number of households) of any given pixel, when this information is available, gives the probable loss of population (or number of households) served by DTTB in that pixel due to interference.

3) Annex 3 describes an example methodology for the assessment of interference into the digital broadcasting service from a single main interferer in an interfering network. This analysis is based on *C/I* and *C/*(*N+I*) criteria, taking into account the statistics of distribution of the wanted (*C*) and interfering (*I*) signals.

It allows evaluation of the amount of population that could be impacted by the introduction of mobile networks operated in adjacent bands into the DTT reception.

It contains an example of application of this methodology using actual information on planned broadcasting and mobile service areas. For this, the actual deployments of both broadcasting and mobile networks are used combined with the use of a digital terrain model and adequate propagation models.

Before using one or the other of the described methodologies the Administration concerned will need to check that the related assumptions are appropriate for the intended use.

Annex 1

Relationship between the *I*/*N* criterion, the *C*/*N* degradation and the corresponding interfering field strength

Section A1.1 shows the relationship between the noise level *N* and the equivalent noise field strength E_{N}.

Section A1.2 shows the relationship between the equivalent noise level E_N and the minimum median field strength required for broadcasting coverage planning E_{MED}.

Section A1.3 shows the relationship between the *I/N* and the corresponding *I/N* field strength threshold E_{I/N_th}.

Section A1.4 derives the individual median effective interfering field strength E_{eff}.

Section A1.5 shows the relationship between multiple median effective interfering field strengths E^{Σ}_{eff} and *I/N* and introduces the equivalent *C/N* degradation C/N_{DEG}.

The Appendices to this Annex give numerical examples and details of the relationships described above.

– Attachment 1 gives examples of field strength threshold calculations and *C/N* degradation for the case of DTTB fixed reception.

– Attachment 2 gives the relationship between co-channel field strength threshold and adjacent-channel field strength threshold.

– Attachment 3 gives examples of co-channel interference assessment thresholds for co-primary frequency allocations.

– Attachment 4 presents numerical examples of adjacent channel field strength interference assessment thresholds for co-primary frequency allocations.

– Attachment 5 gives a method to assess of co- and multiple-adjacent channel interference into the broadcasting service from all radiations and emissions without a corresponding frequency allocation in the bands allocated to broadcasting.

A1.1 Received noise power and equivalent noise field strength

A1.1.1 Thermal noise power and equivalent noise field strength

Thermal noise power N_T (W) is calculated using Boltzmann's equation:

$$N_T = kTB \tag{1}$$

where:

k Boltzmann's constant (1.38×10^{-23} J·K^{-1})

T temperature (K)

B receiver bandwidth (Hz).

The receiver inherent noise (noise figure) is used to compute the receiver noise floor (receiving system noise power), N_R (dBW):

$$N_R = 10\log(N_T) + F \tag{2}$$

[4]

where F is the noise figure (dB).

The field strength, E_{NR} (dBµV/m) that corresponds to the receiving system noise power (noise equivalent field strength) can be expressed as a function of receiving system noise power, receiving antenna gain and frequency as[5]:

$$E_{NR} = N_R - G_R + 20\log(f) + 107.2 \tag{3}$$

where:

G_R : receiving antenna isotropic gain (dBi) including the feeder loss

f : frequency (MHz).

A1.1.2 Environmental noise power and equivalent noise field strength

Recommendation ITU-R P.372 expresses each of average strength of atmospheric noise, man-made noise, and cosmic noise compared with the thermal noise level (F_{am} dB relative to kT) when they are received through a lossless short vertical monopole with a perfectly grounded plane. In all cases, results are consistent with a linear variation of the median value, F_{am}, with frequency f of the form:

$$F_{am} = c - d \log f \qquad \text{(dB relative to } kT\text{)} \tag{4}$$

With f expressed in MHz, c and d take the values given in Table 1.

[4] log = $\log_{10}$ in this Report.

[5] The relationship between power and field strength is further described in formula (5) of Recommendation ITU-R P.845-3.

TABLE 1

Values of the constants *c* and *d*

Environmental category	*c*	*d*
City	76.8	27.7
Residential	72.5	27.7
Rural	67.2	27.7
Quiet rural	53.6	28.6

Since the above are received values with lossless short vertical monopole above a perfect ground plane, the vertical component of the r.m.s. field strength is obtained as F_{am} dB above $E(kTB)$ dB given by equation (4).

$$E_{NE} = F_{am} + 20 \log f + 10 \log B - 95.5 \qquad \text{dB}(\mu\text{V/m}) \qquad (5)$$

where:

E_{NE}: equivalent field strength of the environmental noise in bandwidth B

f: frequency (MHz)

B: receiver effective noise bandwidth (Hz).

By substituting F_{am} expressed by equation (4) into equation (5)

$$E_{NE} = c - d \log f + 20 \log f + 10 \log B - 95.5 \qquad \text{dB}(\mu\text{V/m}) \qquad (6)$$

Similarly, for a half-wave dipole in free space:

$$E_{NE} = c - d \log f + 20 \log f + 10 \log B - 98.9 \qquad \text{dB}(\mu\text{V/m}) \qquad (7)$$

For a system with a receiving antenna with an isotropic gain G_R:

$$E_{NE} = c - d \log f + G_R - 2.15 + 20 \log f + 10 \log B - 98.9 \qquad \text{dB}(\mu\text{V/m}) \qquad (8)$$

A1.1.3 Total receiver noise power and equivalent noise field strength

The field strength equivalent to the total receiver noise power can be calculated from both the field strength equivalent to the thermal noise power and the field strength equivalent to the environmental noise power in the following equation[6]:

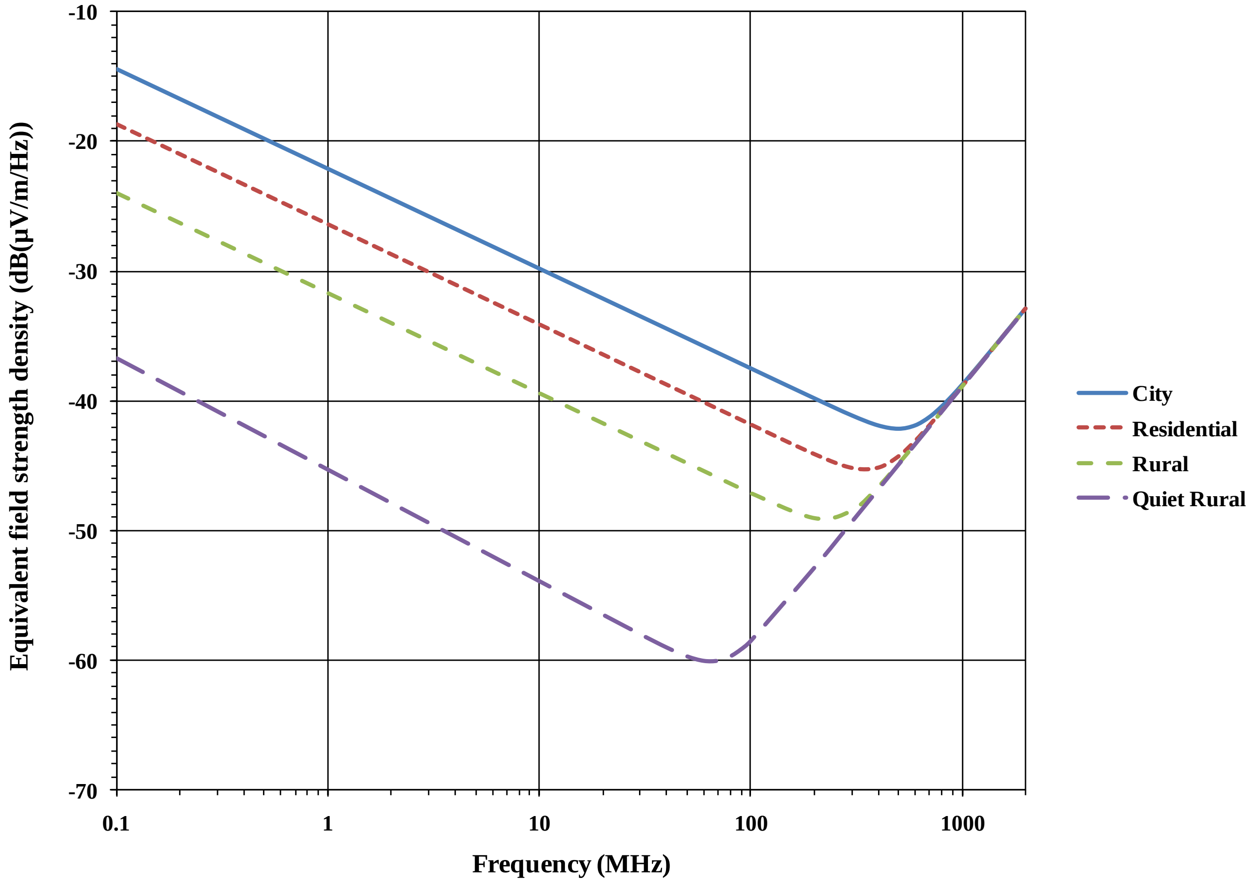
$$E_N = 10 \log\left(10^{\frac{E_{NR}}{10}} + 10^{\frac{E_{NE}}{10}}\right) \qquad (9)$$

Figure 1 illustrates the result of this linear power summation in equation (9) for a dipole in free space. Note that the environmental man-made noise dominates at low frequencies. Thermal noise from the receiving system dominates at the higher frequencies.

[6] If only thermal noise is considered, $E_N = E_{NR}$.

FIGURE 1

Equivalent field strength density of the total receiving system noise using a dipole antenna in free space



A1.2 Equivalent noise field strength and minimum median field strength for planning

Minimum median field strength, E_{MED} (dBµV/m) required for broadcasting coverage planning is linked to the noise equivalent field strength by the following relationship:

$$E_{MED} = E_N + \mu\sigma_{BS} + SNR \quad (10)$$

where:

- μ Gaussian confidence factor related to target location percentage where broadcast coverage is sought
- σ_{BS} standard deviation of the shadowing between the broadcast transmitter and the broadcast receiver (dB)
- SNR signal-to-noise ratio (dB).

A1.3 Field strength threshold related to *I/N*

The *I/N* criterion and the *I/N* field strength threshold, E_{I/N_th} (dBµV/m) are related as follows:

$$E_{I/N\_th} = E_N + I/N \quad (11)$$

Attachment 3 tabulates an example of the interfering field strength thresholds at a dipole receive antenna located in free-space and at the edge of the coverage area. The thresholds, for each of the terrestrial broadcast frequency bands, are relative to I/N equal to −10 dB without consideration for the location correction factor ($E_{I/N\_th} = E_N + I/N$), E_N is derived from equation (9).

A1.4 Individual median effective interfering field strength

The individual median effective (i.e. taking account of the protection ratio relative to the co-channel case) interfering field strength, E_{eff} (dBμV/m) is defined as:

$$E_{eff} = E_{INT} - D_{DIR} - D_{POL} + PR(f_{INT} - f_{BS}) - PR(0) \tag{12}$$

where:

E_{INT}	individual median interfering field strength (dBμV/m)
D_{DIR}	broadcast receiver antenna directivity discrimination with respect to the interfering signal (dB)
D_{POL}	broadcast receiver polarization discrimination with respect to the interfering signal (dB)
$PR(f_{INT} - f_{BS})$	appropriate broadcasting protection ratio for a frequency offset $f_{INT} - f_{BS}$ to protect the broadcast reception from interference (dB)
$PR(0)$	co-channel protection ratio (dB).

A1.5 Multiple median effective interfering field strengths corresponding to *I/N* and equivalent *C/N* degradation

For each interfering source i, calculate its median effective interfering field strength $E^{i}{}_{eff}$ using equation (12):

$$E^1{}_{eff}, E^2{}_{eff}, \ldots E^n{}_{eff}$$

where n is the number of interfering sources.

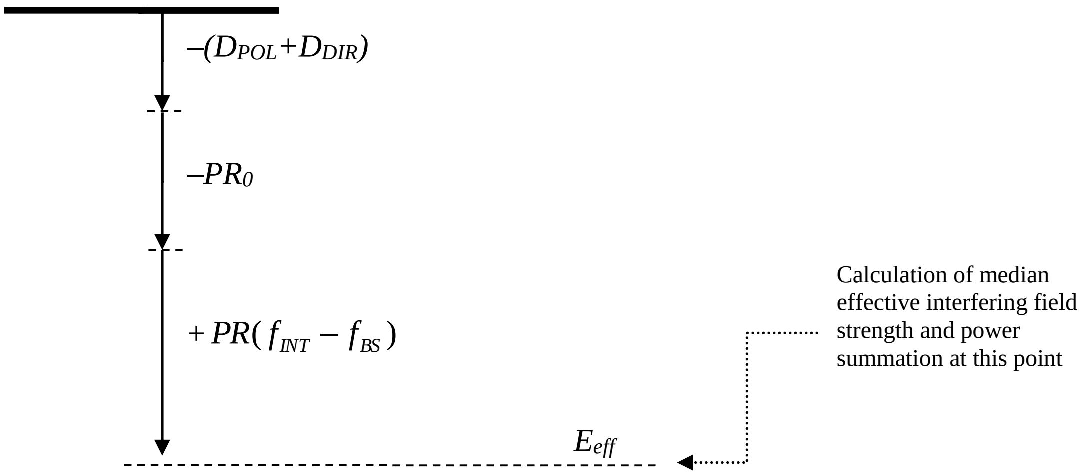
Calculate the cumulative median effective interfering field strength, $E^{\Sigma}{}_{eff}$, using the power sum method:

$$E_{eff}^{\Sigma} = 10\log\left(\sum_{i=1}^{n} 10^{\frac{E_{eff}^{i}}{10}}\right) \tag{13}$$

The individual median effective interfering field strengths are power summed at the power summation point indicated in Fig. 2.

FIGURE 2

Individual median effective interfering field strength and power summation



A1.5.1 Threshold based on median effective field strength

Interference from all interference sources into the broadcasting service $E^{\Sigma}{}_{eff}$ within the broadcasting coverage area with respect to the *I/N* field strength threshold E_{I/N_th} is considered to be acceptable if the following equation is satisfied:

$$E_{eff}^{\Sigma} \le E_{I/N\_th} \tag{14}$$

A1.5.2 Statistical considerations for threshold based on median effective field strength

Considering the variation of field strength with location, inherent to any terrestrial propagation environment, field strength levels for wanted or interfering signals are usually calculated in terms of median levels, i.e. as levels exceeded in 50% of locations in small areas of 100 m × 100 m. The variation with locations is usually approximated using Log-normal distribution, characterized with a standard deviation obtained from field measurements. The Log-normal assumption permits deriving median field strengths required to insure coverage or protection for any other target location percentages, like 70% or 95%, instead of 50%, by using adequate correction factors (see also Recommendation ITU-R-1368, Attachment 1 to Annex 2 and Attachment 1 to Annex 3). In the interference assessment on a case-by-case basis, suitable parameters such as location and time probabilities, and applicability of directional and polarization discriminations of the receiving antenna could be considered by each administration.

The multiple median effective interfering field strength meets a reception location probability of 50%. If a reception location probability other than 50% is envisaged, equation (15) can be used as the threshold.

$$E_{eff}^{\Sigma} + \mu\sigma_{eff}^{\Sigma} \le E_{I/N\_th} \tag{15}$$

where:

σ_{eff}^{Σ} standard deviation of the shadowing of the sum of the signals of the interfering transmitters[7].

A1.5.3 Threshold based on *C/N* degradation

The criterion of the *C/N* degradation, $\Delta_{C/N}$ can be derived from the I/N [8] criterion as follows:

$$\Delta_{C/N} = 10\log\left(1 + 10^{\frac{(I/N)}{10}}\right) \tag{16}$$

The *C/N* degradation, C/N_{DEG} related to the median effective interfering, E_{eff} field strength is as follows.

$$C/N_{DEG} = 10\log(10^{\frac{E_{eff}^{\Sigma}}{10}} + 10^{\frac{E_N}{10}}) - E_N \tag{17}$$

Similarly to § A1.5.1, interference from all interference sources into the broadcasting service coverage area with the noise equivalent field strength E_N is considered to be acceptable if the following equation is satisfied:

$$C/N_{DEG} \le \Delta_{C/N} \tag{18}$$

Attachment 1 to Annex 1

Examples of field strength threshold calculation and *C/N* degradation for the case of DTTB fixed reception

Example, for

$$F_{dB} = 7 \text{ dB}$$

$$T_K = 290 \text{ K}$$

And B_{MHz} = 7.61 MHz (in the case of 8 MHz DVB-T system)

Then $N_{R(dBm)}$ = −98.2 dBm

And with

$G_{(dBi)}$ = 9.15 dBi (consisting in 12 dBd antenna gain relative to dipole and 5 dB feeder loss)

---

7 There are numerous approximations that can be used to derive the standard deviation σ_{eff}^{Σ}. In the absence of a suitable method, a possible approximation may be the value σ_{eff}^{Σ} = 5.5 dB.

8 Example:

I/N = –10 dB results in $\Delta_{C/N}$=0.414 dB (often rounded to 0.5 dB).

I/N = –20 dB results in $\Delta_{C/N}$=0.04 dB (often rounded to 0.05 dB).

And $f_{(MHz)}$ = 790 MHz,

No environmental noise is considered.

Then the field strength corresponding to the total system noise level is:

$$E_N = E_{NR} = 27.8 \text{ dB}\mu\text{V/m}$$

With I/N = –10 dB according to *recommends* 3 of Recommendation ITU-R BT.1895, the corresponding I/N field strength threshold obtained from equation (11) is:

$$E_{I/N\_th} = 27.8 - 10 = 17.8 \text{ dB}\mu\text{V/m}$$

Co-channel case

Assuming a single interferer with no polarization or directivity discrimination is considered, then

$$D_{POL} = 0 \text{ and}$$

$$D_{DIR} = 0$$

The median effective interfering field strength which respects the I/N field strength threshold can be calculated using equation (14):

$$E_{eff}^{\Sigma} \leq E_{I/N\_th}$$

A co-channel interferer has to be equal to or less than E_{I/N_th} = 17.8 dBμV/m.

The median effective interfering field strength for a reception location probability of 95%, derived from equation (15) is:

$$17.8 - 9 = 8.8 \text{ dB}\mu\text{V/m}$$

where the distribution characteristics of E_{eff} is assumed to be Log-normal distribution of standard deviation 5.5 dB.

The allowable C/N degradation $\Delta_{C/N}$ for I/N = −10 dB is calculated as follows using equation (16) of Annex 1:

$$\Delta_{C/N} = 10\log\left(1 + 10^{\frac{(I/N)}{10}}\right)$$

$$= 0.414 \text{ dB}$$

The C/N degradation C/N_{DEG} using equation (17) has to be less than or equal to 0.414 dB and calculated as follows:

$$C/N_{DEG} = 10\log(10^{\frac{E_{eff}^{\Sigma}}{10}} + 10^{\frac{E_N}{10}}) - E_N$$

$$= 10\log(10^{\frac{17.8}{10}} + 10^{\frac{27.8}{10}}) - 27.8$$

$$= 0.414 \text{ dB}$$

First adjacent channel case

Assuming no polarization or directivity discrimination is considered, then

$$D_{POL} = 0 \text{ and}$$

$$D_{DIR} = 0$$

Co-channel protection ratio for the interfering system: 21 dB

First adjacent channel protection ratio: −30 dB

The median effective interfering field strength which respects the I/N field strength threshold can be calculated using equation (14):

$$E_{eff}^{\Sigma} \leq E_{I/N\_th}$$

A first adjacent channel interferer has to have a field strength equal to or less than E_{I/N_th} = 17.8 dBμV/m within the receiver channel.

The co-channel and the adjacent channel protection ratios have to be taken into account after reforming equation (12)

$$E_{eff} = E_{INT} - D_{DIR} - D_{POL} + PR(f_{INT} - f_{BS}) - PR(0)$$

$$E_{INT} = E_{eff} + D_{DIR} + D_{POL} - PR(f_{INT} - f_{BS}) + PR(0)$$

$$E_{INT} = 17.8\,\text{dB}\mu\text{V}/m + 30\,\text{dB} + 21\,\text{dB}$$

$$E_{INT} = 68.8\,\text{dB}\mu\text{V/m}$$

The median effective interfering field strength in the first adjacent channel has to be less than or equal to 68.8 dBμV/m to respect the I/N threshold.

The median effective interfering field strength for a reception location probability of 95%, derived from equation (15) is:

$$68.8 - 9 = 59.8 \text{ dB}\mu\text{V/m}$$

where the distribution characteristics of E_{eff} is assumed to be Log-normal distribution of standard deviation 5.5 dB.

The allowable C/N degradation $\Delta_{C/N}$ for I/N = –10 dB is calculated as follows using equation (16) of Annex 1:

$$\Delta_{C/N} = 10\log\left(1 + 10^{\frac{(I/N)}{10}}\right)$$

$$= 0.414 \text{ dB}$$

The C/N degradation C/N_{DEG} using equation (17) has to be less than or equal to 0.414 dB and calculated as follows:

$$C/N_{DEG} = 10\log(10^{\frac{E_{eff}^{\Sigma}}{10}} + 10^{\frac{E_N}{10}}) - E_N$$

$$= 10\log(10^{\frac{17.8}{10}} + 10^{\frac{27.8}{10}}) - 27.8$$

$$= 0.414 \text{ dB}$$

Attachment 2 to Annex 1

Relationship between co-channel field strength and adjacent-channel[9] field strength

The explanation of the terms $(PR(f_{INT} - f_{BS}) - PR(0))$ in equation (12) of Annex 1 is given in the following:

The protection ratio corresponding to the frequency offset between the wanted broadcasting signal power P_{BS} and interfering signal power P_{INT} is defined as follows (in dB):

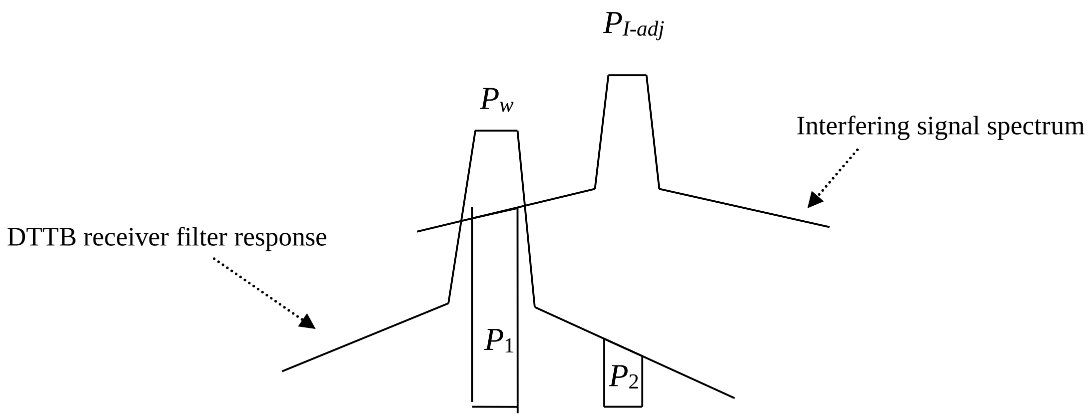
$$PR(f_{INT} - f_{BS}) = P_{BS} - P_{INT} \tag{19}$$

As shown in Fig. 3, the interfering components P_1 (due to out-of-band emission of the interfering signal, expressed in terms of a finite adjacent channel leakage ratio, ACLR) and P_2 (due to imperfect filtering characteristics of the wanted receiver, expressed in terms of a finite adjacent channel selectivity, ACS) together act as the total co-channel interference. The co-channel protection ratio applies for the power sum ($P_1 \oplus P_2$), as follows (in dB):

$$PR_0 = P_{BS} - 10\log(10^{\frac{P_1}{10}} + 10^{\frac{P_2}{10}}) \tag{20}$$

FIGURE 3

Relationship between adjacent-channel and co-channel interference



From equations (19) and (20), we can derive:

$$P_{INT} = 10\log(10^{\frac{P_1}{10}} + 10^{\frac{P_2}{10}}) - PR(f_{INT} - f_{BS}) + PR_0 \tag{21}$$

It can be converted to field strength:

$$E_{INT} = 10\log(10^{\frac{E_1}{10}} + 10^{\frac{E_2}{10}}) - PR(f_{INT} - f_{BS}) + PR_0 \tag{22}$$

---

9 Represents 1st, 2nd, …, nth adjacent channel.

Attachment 3 to Annex 1

Example of co-channel interference assessment threshold for co-primary frequency allocations

With I/N = −10 dB according to *recommends* 3 of Recommendation ITU-R BT.1895 for co-primary frequency allocations, the corresponding co-channel field strength assessment threshold for a dipole receive antenna located in free-space and at any point within the coverage area can be calculated for a dipole in free space from the power summation of the thermal noise and the environmental noise, and the I/N value of −10 dB. Table 2 below tabulates the assessment thresholds for each of the frequency bands allocated to the broadcasting service in terms of field-strength density (dB (μV/m/Hz)) at the broadcast receiving system without consideration for the location correction factor ($E_{I/N\_th} = E_N + I/N$), where E_N is derived from equation (9) of this Annex.

TABLE 2

Co-channel interference field-strength density assessment thresholds for the broadcast frequency bands for an *I/N* of –10 dB and a dipole antenna (location correction factor is not taken into consideration)

Broadcast frequency band*	Interference field-strength density assessment thresholds (dB (μV/m/Hz))**			
	City	Residential	Rural	Quiet Rural
148.5-283.5 kHz	–25.7	–30.0	–35.3	–48.2
525-1 705 kHz	–29.9	–34.2	–39.5	–52.9
2 300-2 498 kHz	–34.9	–39.2	–44.5	–58.4
3 200-3 400 kHz	–36.0	–40.3	–45.6	–59.6
3 900-4 000 kHz	–36.7	–41.0	–46.3	–60.4
4 750-4 995 kHz	–37.3	–41.6	–46.9	–61.1
5 005-5 060 kHz	–37.5	–41.8	–47.1	–61.3
5 900-6 200 kHz	–38.0	–42.3	–47.6	–61.9
7 200-7 450 kHz	–38.7	–43.0	–48.3	–62.7
9 400-9 900 kHz	–39.6	–43.9	–49.2	–63.7
11 600-12 100 kHz	–40.3	–44.6	–49.9	–64.5
13 570-13 870 kHz	–40.8	–45.1	–50.4	–65.0
15 100-15 800 kHz	–41.2	–45.5	–50.8	–65.4
17 480-17 900 kHz	–41.7	–46.0	–51.3	–66.0
18 900-19 200 kHz	–41.9	–46.2	–51.5	–66.3
21 450-21 850 kHz	–42.4	–46.7	–52.0	–66.7
25 670-26 100 kHz	–43.0	–47.3	–52.6	–67.4
47-72 MHz	–45.0	–49.3	–54.6	–69.5
76-88 MHz	–46.6	–50.9	–56.2	–69.9
88-108 MHz	–47.1	–51.4	–56.7	–69.3
174-230 MHz	–49.3	–53.6	–58.8	–64.1

TABLE 2 (*end*)

Broadcast frequency band*	**Interference field-strength density assessment thresholds (dB (μV/m/Hz))****			
	City	**Residential**	**Rural**	**Quiet Rural**
470-806 MHz	–52.1	–54.6	–55.4	–55.5
806-960 MHz	–50.4	–50.7	–50.8	–50.8
1 452-1 492 MHz	–45.6	–45.7	–45.7	–45.7

* Broadcast frequency bands do not include regional variations given in Article 5 of the Radio Regulations.

** The values of the total receiving noise level *N* for the listed frequency bands have been derived from the curves in Fig. 1 in Annex 1.

Attachment 4 to Annex 1

Example of adjacent channel field strength interference assessment thresholds for co-primary frequency allocations

In addition to co-channel interference, the broadcast receiving system is susceptible to interference from signals on adjacent and multiple adjacent channels as described in Attachment 2 to this Annex. Recommendation ITU-R BT.1368 describes the protection ratios for various digital terrestrial television services in the VHF and UHF bands. For example, the protection ratios for the ATSC digital television system under weak signal conditions near the noise threshold (as may be experienced at the outer limits or even within the coverage area) are tabulated in Tables 3 and 4 below.

TABLE 3

Adjacent channel protection ratios for a weak 6 MHz ATSC wanted signal on channel *N*

Type of interference	**Adjacent channel protection ratio (dB)**
Lower adjacent channel interference (N – 1)	−28
Upper adjacent channel interference (N + 1)	−26

TABLE 4

Multiple adjacent channels protection ratios, *N* ± 2 to *N* ± 15, for a weak 6 MHz ATSC wanted signal on channel *N*

Type of interference	Multiple adjacent channel protection ratio (dB)
N ± 2	−44
N ± 3	−48
N ± 4	−52
N ± 5	−56
N ± 6 to *N* ± 13	−57
N ± 14 and *N* ± 15	−50

The deterioration in the ATSC receiver sensitivity from adjacent-channel and multiple adjacent-channel interference is determined by the total power of the interfering signal within the adjacent channel. Consequently, for a single interfering signal from a radiocommunication service with a corresponding co-primary frequency allocation, the adjacent channel field-strength assessment thresholds can be determined from the ten per cent threshold requirement contained in Recommendation ITU-R BT.1895, the protection ratios contained in Recommendation ITU-R BT.1368, and the equivalent field strength of the total receiving system noise. In the UHF broadcast band (470-806 MHz), the total receiving system noise is dominated by the internal noise. Table 5 illustrates the resulting field-strength threshold for interference into multiple adjacent channels of the ATSC digital television system with a 6 MHz channel. It should be noted that Table 5 considers only a single interferer. Specific applications may need to consider the impact from multiple interferers.

TABLE 5

Adjacent-channel (*N* ± 1) and multiple adjacent channel (*N* ± 2 to *N* ± 15) co-primary interference field-strength assessment thresholds for the 6 MHz ATSC broadcast receiving system at various frequencies in the UHF band (dipole antenna in free space)

Type of interference	Interference field-strength threshold (dB(μV/m)		
	470 MHz	638 MHz	806 MHz
Lower adjacent channel interference (*N* – 1)	40.3	43.0	45.0
Upper adjacent channel interference (*N* + 1)	38.3	41.0	43.0
N ± 2	56.3	59.0	61.0
N ± 3	60.3	63.0	65.0
N ± 4	64.3	67.0	69.0
N ± 5	68.3	71.0	73.0
N ± 6 to *N* ± 13	69.3	72.0	74.0
N ± 14 and *N* ± 15	62.3	65.0	67.0

Attachment 5 to Annex 1

Method to assess co-channel and multiple-adjacent channel interference into the broadcasting service from all radiations and emissions without a corresponding frequency allocation in the bands allocated to broadcasting

This Attachment provides a methodology for assessment of co-channel and adjacent channel interference into the broadcasting service from all radiations and emissions without a corresponding frequency allocation in the bands allocated to broadcasting but nonetheless cause co-channel or multiple adjacent channel interference. It may assist administrations in the assessment of interference from these devices or systems without a frequency allocation while maintaining the performance of terrestrial broadcasting systems at acceptable levels.

1 Co-channel assessment threshold for the broadcasting service

With I/N = –20 dB according to *recommends* 2 of Recommendation ITU-R BT.1895, the corresponding co-channel field-strength assessment threshold for a dipole receive antenna located in free-space can be calculated for a dipole in free space from the power summation of the thermal noise and the environmental noise, and the I/N value of –20 dB. Table 6 below tabulates the assessment thresholds for each of the frequency bands allocated to the broadcasting service in terms of field-strength density (dB (μV/m/Hz)) at the broadcast receiving system without consideration for the location correction factor ($E_{I/N\_th} = E_N + I/N$), where E_N is derived from equation (9) of Annex 1.

TABLE 6

Co-channel interference field-strength density assessment thresholds for the broadcast frequency bands for an *I/N* of –20 dB and a dipole antenna (location correction factor is not taken into consideration)

Broadcast frequency band*	Interference field-strength density assessment thresholds (dB (μV/m/Hz))**			
	City	Residential	Rural	Quiet rural
148.5-283.5 kHz	–35.7	–40.0	–45.3	–58.2
525-1 705 kHz	–39.9	–44.2	–49.5	–62.9
2 300-2 498 kHz	–44.9	–49.2	–54.5	–68.4
3 200-3 400 kHz	–46.0	–50.3	–55.6	–69.6
3 900-4 000 kHz	–46.7	–51.0	–56.3	–70.4
4 750-4 995 kHz	–47.3	–51.6	–56.9	–71.1
5 005-5 060 kHz	–47.5	–51.8	–57.1	–71.3
5 900-6 200 kHz	–48.0	–52.3	–57.6	–71.9
7 200-7 450 kHz	–48.7	–53.0	–58.3	–72.7
9 400-9 900 kHz	–49.6	–53.9	–59.2	–73.7
11 600-12 100 kHz	–50.3	–54.6	–59.9	–74.5
13 570-13 870 kHz	–50.8	–55.1	–60.4	–75.0

TABLE 6 (*end*)

Broadcast frequency band*	Interference field-strength density assessment thresholds (dB (μV/m/Hz))**			
	City	Residential	Rural	Quiet rural
15 100-15 800 kHz	–51.2	–55.5	–60.8	–75.4
17 480-17 900 kHz	–51.7	–56.0	–61.3	–76.0
18 900-19 200 kHz	–51.9	–56.2	–61.5	–76.3
21 450-21 850 kHz	–52.4	–56.7	–62.0	–76.7
25 670-26 100 kHz	–53.0	–57.3	–62.6	–77.4
47-72 MHz	–55.0	–59.3	–64.6	–79.5
76-88 MHz	–56.6	–60.9	–66.2	–79.9
88-108 MHz	–57.1	–61.4	–66.7	–79.3
174-230 MHz	–59.3	–63.6	–68.8	–74.1
470-806 MHz	–62.1	–64.6	–65.4	–65.5
806-960 MHz	–60.4	–60.7	–60.8	–60.8
1 452-1 492 MHz	–55.6	–55.7	–55.7	–55.7

* Broadcast frequency bands do not include regional variations given in Article 5 of the Radio Regulations.

** The values of the total receiving noise level *N* for the listed frequency bands have been derived from the curves in Fig. 1 in Annex 1.

2 An example of adjacent and multiple-adjacent channel interference assessment thresholds from all radiations and emissions without a corresponding frequency allocation in the bands allocated to the broadcasting service

The broadcast receiving system is also susceptible to interference from signals on adjacent and multiple-adjacent channels. Recommendation ITU-R BT.1368 describes the protection ratios for various digital terrestrial television systems in the VHF and UHF bands. Attachment 3 to Annex 1 presents an example of the adjacent-channel assessment thresholds for the UHF TV band for those services with a corresponding co-primary frequency allocation. For the case of interference from services or application without a corresponding frequency allocation in the band allocated to the broadcasting service, the value of I/N = –20 dB applies. In the UHF broadcast band (470-806 MHz) the total receiving system noise is dominated by the internal noise. Table 7 illustrates the resulting field-strength threshold for interference into multiple adjacent channels of the ATSC digital television system with a 6 MHz channel. It should be noted that Table 7 considers only a single interferer. Specific applications may need to consider the impact from multiple interferers.

TABLE 7

Adjacent-channel (*N* ± 1) and multiple adjacent channel (*N* ± 2 to *N* ± 15) interference field-strength assessment thresholds for the 6 MHz ATSC broadcast receiving system from services or applications without a frequency allocation at various frequencies in the UHF band (dipole antenna in free space)

Type of interference	Interference field strength threshold (dB(μV/m)		
	470 MHz	638 MHz	806 MHz
Lower adjacent channel interference (*N* – 1)	30.3	33.0	35.0
Upper adjacent channel interference (*N* + 1)	28.3	31.0	33.0
N ± 2	46.3	49.0	51.0
N ± 3	50.3	53.0	55.0
N ± 4	54.3	57.0	59.0
N ± 5	58.3	61.0	63.0
N ± 6 to *N* ± 13	59.3	62.0	64.0
N ± 14 and *N* ± 15	52.3	55.0	57.0

Annex 2

Methodology for assessing degradation in DTTB reception location probability from interfering stations of other services/applications

A2.1 Introduction

In this Annex, a methodology is described, how the degradation to the DTTB reception location probability, (Δ_{RLP}) can be determined when the interfering stations (single or multiple) of other services/applications are implemented ("after") compared to the DTTB reception location probability when the interfering stations of other services/applications are not implemented ("before"). The calculation of the reception location probability and the degradation to the reception location probability is carried out using a Monte Carlo methodology.

A Monte Carlo methodology has been described which is suitable for determining the two cases of either co-channel or adjacent channel[10] interference of other service/application stations into DTTB by means of calculating the degradation of the DTTB reception location probability. The methodology takes into account the statistical variations of all the parameters. This includes:

– Statistical variation of the DTTB Wanted field strength and the other services/application interfering field strengths with locations within a small area referred to in this Report as "pixel"[11]

[10] Represents 1st, 2nd, …, *n*th adjacent channel.

[11] Pixel is a small area of typically about 100 m × 100 m where the percentage of covered receiving locations is indicated.

– Statistical variation of the DTTB Wanted field strength and the other services/application interfering field strengths with time.

The Monte Carlo methodology presented in this Annex applies only to the case of interference from fixed transmitters. The portable/mobile transmitters referred to later in this Annex are assumed to be stationary. A specific methodology is needed to deal with the case of moving sources of interference, e.g. Mobile terminals.

It is noted that broadcast planning is made for a specific reception location probability, which in this Report is defined as the percentage of locations within a small area, referred to in this Report as “pixel” , where the wanted signal is high enough to overcome noise and interference for a given percentage of time taking into account the temporal and spatial statistical variations of the relevant fields. It is noted that, to achieve sufficient stable results in Monte Carlo simulations, a sufficiently high number of simulations runs have to be executed, which requires an appropriate amount of computer capacity.

The coverage area[12] is, in digital terrestrial broadcasting, the area that comprises all pixels, where a given reference reception location probability (e.g. 95%) is reached or exceeded for a predetermined percentage of the time.

Attachment 1 to Annex 2 provides more elements regarding the definition of the reception location probability, as used in this Report.

The closer the assessed pixel is located to the transmitter, the higher the wanted field strength may be and thus the higher the actual reception location probability. If the interference impact should be limited by using this methodology, based on degradation of location probability (see § A2.2 indent c for the definition of the "degradation of reception location probability"), there could be at least two possible approaches to set a limit of the degradation to the reception location probability

1) the degradation to a specific reception location probability is limited to a value of *X*% calculated with respect to an actual reception location probability at different pixels within the coverage area. Consequently, the accepted degradation to the reception location probability (*X*%) does not change within the coverage area, including for those pixels within the coverage area where the actual reception location probability is higher than the planned reception location probability;

2) the degradation to the reception location probability is limited such that the planned reception location probability is fulfilled at all pixels within the coverage area. Consequently, the accepted degradation to the reception location probability could vary at different pixels within the coverage area.

[12] Recommendation ITU-R V.573 No. A51b defines “coverage area” as the “area associated with a transmitting station for a given service and a specified frequency within which, under specified technical conditions, radiocommunications may be established with one or several receiving stations. Note 4 explains that “the term “service area” should have the same technical basis as for “coverage area”, but also include administrative aspects”. Reference to the administrative aspects in the definition of service area is understood to mean that in that service area protection is required. For the case of broadcast services which are usually planned with multiple overlapping transmissions from different transmitter sites and it is usual to protect only the best coverage. Furthermore, spill over coverage into international neighbours or adjacent regions of a country do not usually form part of the intended service area and may not require protection.

A2.2 Methodology

The highlights of the methodology are the following:

a) It allows the analysis of the cumulative interference impact of interfering stations of other services/applications on DTTB transmissions both in co-channel and in adjacent channel situations.

b) It can be used for the calculation of protection of fixed roof top as well as mobile and portable DTTB reception.

c) The interfering impact is expressed in terms of the degradation, Δ_{RLP}, to the DTTB reception location probability when the interfering stations of other services/applications are implemented ("after") compared to the DTTB reception location probability when the interfering stations of other services/applications are not implemented ("before").

d) The degradation in the reception location probability, Δ_{RLP}, is calculated in specified pixels of the DTTB service area, either located at the coverage edge or within the coverage area.

e) More specifically, if within a given pixel within the DTTB service area, "P_{before}" is the DTTB reception location probability in the presence of noise and existing DTTB interferers, and "P_{after}" is the DTTB reception location probability in the presence of interferers from other services/applications, and noise, and existing DTTB interferers, then the degradation of the reception location probability is $\Delta_{RLP} = P_{before} - P_{after}$ %. Thus, if the protection criterion chosen is to specify an allowable degradation of x% of reception location probability, then protection would be considered to be achieved if, when introducing an additional interfering station, $\Delta_{RLP} \leq x$%, whereas protection would not be considered to be achieved if, when introducing an additional interfering station, $\Delta_{RLP} > x$%.

f) If networks of other services/applications are built up gradually, introducing interfering stations over a period of time, it is necessary to calculate the degradation of reception location probability due to the entire network as each new interferer is introduced.

g) The interference due to noise as well as all DTTB interferers is taken into account in the calculations, "before" and "after".

h) It should be noted that for the co-channel case, where the interfering stations of other services/applications can only be situated outside of any co-channel DTTB service area, the largest interference effects (single entry and cumulative) are likely to arise in the pixels located at the DTTB coverage edge, and the resulting degradations in reception location probability are also likely to be the highest in those pixels.

i) For the adjacent channel case the interfering stations of other services/applications may be situated anywhere inside of a DTTB service area. However, the DTTB reception cannot be protected in the immediate vicinity of an interfering station[13], because adjacent channel interference is strongest "locally", i.e. can cause blocking field strength values in the close proximity of the interfering transmitter.

---

[13] In the immediate vicinity of an interfering station of other services/applications, the field strength could be high enough to cause interference even when the out-of-channel protection ratio is very low; DTTB overload thresholds may also play a significant role in causing interference. For example the reception of a DTTB wanted field strength of 60 dBµV/m in the presence of an adjacent channel interfering field strength of 100 dBµV/m received from a nearby base station (few tens of meters away) with no antenna discrimination would require a protection ratio of -40 dB of the DTTB receiver. If this receiver has an adjacent channel protection ratio of -30 dB or more then it will be interfered with.

j) Assuming that the location of the interfering station of other services/applications can be chosen in a manner to avoid interference, then a specific minimum separation distance, "*D*" can be defined between the interfering station and test points to be protected. In § A2.3, "Parameters", 'test points' and suitable separations distances are defined at which the protection criterion is to be met.

k) The interference (single entry and cumulative) and the resulting reception location probabilities are calculated at the test points.

l) For cases where co-channel and adjacent channel interference are to be aggregated, a combination of calculations described in h) and i) is undertaken. Co-channel and adjacent channel interference may need to be considered when more than one mobile network is considered.

The following sections give more details about some of the parameters, some of the calculations, as well as describing the proposed Monte Carlo methodology.

A2.3 Parameters

The calculations are based on the following parameters[14]:

a) Protected sites:

– Pixels: a spatial resolution involves 100 m × 100 m; pixels within the DTTB service area[15] are relevant.

– Test points: The test points are defined as:

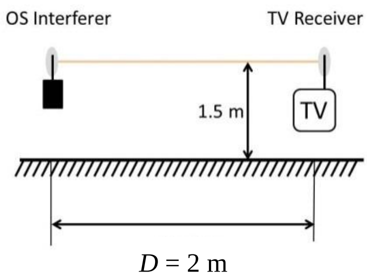
Case 1: Adjacent channel interference sources are located within a pixel inside the DTTB service area.

In this case, the interferers will be restricted by their interference effects at 'nearby' test points. Calculation of interference at these test points will use the following test geometries:

– For the case of handheld/mobile other-service transmitters and for portable or mobile DTTB reception, the test points are located at 1.5 m height, with 2 m lateral separation as shown in Fig. 4.

FIGURE 4

Handheld/mobile other-service transmitters and portable or mobile DTTB reception



For the case of fixed other-service transmitters and portable or mobile DTTB reception, the test points are located at 1.5 m height with up to 20 m lateral separation as shown in Fig. 5. See Note below on the range of "*D*".

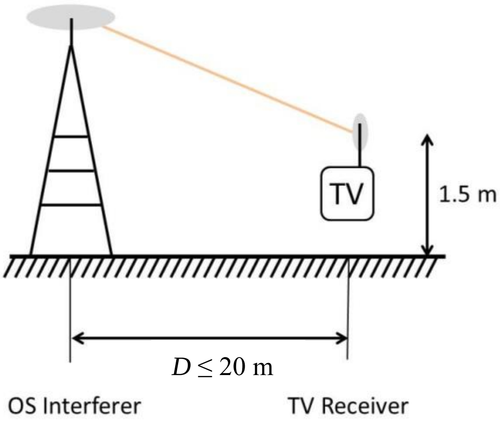
---

[14] The values of the parameters used here are widely used in European countries. However different values may be used in different countries.

[15] A practice within DTTB planning for many decades has been to assess coverage within a target area within an assessment area of 100 m × 100 m. This is regarded as a "pixel" within the total coverage within a target area – whatever the total coverage/service area might be.

FIGURE 5

Fixed other-service transmitters and portable or mobile DTTB reception

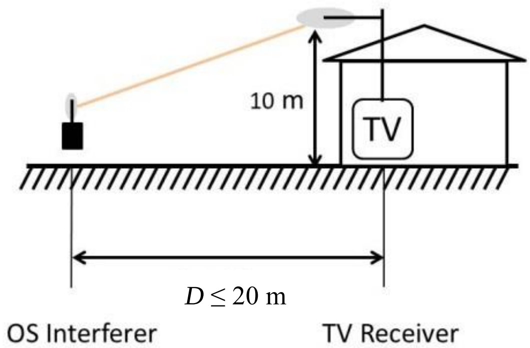


– For the case of handheld/mobile other-service transmitters and fixed DTTB reception the test points are located at 10 m height with a distance, *D*, ranging of up to 20 m of lateral separation.

These test points are positioned such that the other-service transmission falls in the front beam of the fixed DTTB receiving antenna as shown in Fig. 6.

FIGURE 6

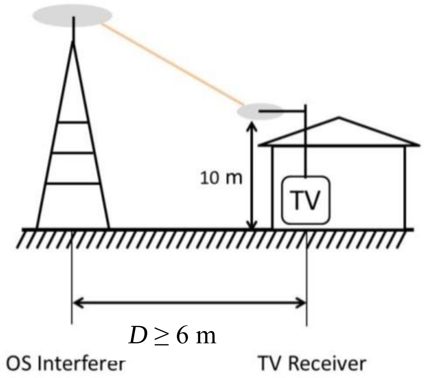
Handheld/mobile other-service transmitters and fixed DTTB reception



– For the case of fixed other-service transmitters and fixed DTTB reception, the test points are located at 10 m height with a distance, *D*, of at least 6 m of lateral separation as shown in Fig. 7. See Note below on the range of "*D*". These test points are positioned such that the other-service transmission falls in the front beam of the fixed DTTB receiving antenna.

FIGURE 7

Fixed other-service transmitters and fixed DTTB reception



NOTE – On the range of (D) – In practice the distance D may vary across the DTTB service areas, depending on fixed other-service transmitters to the DTTB receive antenna (depending on e.g. street width in urban or rural environment, availability of already existing sites or selection of sites which are outside residential areas).

The calculations dealing with reception location probability are to be carried out at those test points. The same test points will also be used when including the aggregate interference effects of other, more distant interferers.

Case 2: Interference sources (co-channel, adjacent channel) are located outside the DTTB service area.

In this case, the interferers are more distant from the DTTB receivers; in particular, they lie outside the DTTB service area. The calculations for the degradation in reception location probability are to be carried out at 10 m height for fixed DTTB reception, and 1.5 m height for portable or mobile DTTB reception. The same test points/pixels are used when calculating the effects of aggregate interference from a multitude of interferers. Depending on the situation involved, it may be necessary to do calculations at a large number of test points.

Case 3: Some Interference sources are located outside the DTTB service area and some other interference sources are located inside the DTTB service area.

In this case, interference calculations are carried out at test points which are selected according to Case 1 and also test points/pixels selected according to Case 2. The same test points are used when calculating the effects of aggregate interference from a multitude of interferers, inside and/or outside the DTTB service area.

b) The frequencies used by DTTB and the other services/applications.

c) The median field strength m_w and its standard deviation σ_w of the received DTTB signal for each pixel or test point. In the case of SFN, the set of wanted median field strengths and their respective standard deviations are required.

d) The median field strength m_i and its standard deviation σ_i of each of the existing DTTB interfering signals for each pixel or test point.

e) The permissible degradation, Δ_{RLP}, in the DTTB reception location probability when the new interfering signal is introduced.

f) The appropriate protection ratios for the DTTB service and overload thresholds of the DTTB receivers, co-channel and adjacent channel, for interference within DTTB, and for DTTB versus the other services/applications. The protection ratios for interference to DTTB by other services/applications can be found in Recommendation ITU-R BT.1368.

g) The e.i.r.p. of each interfering station of other services/applications:

g.1) Case 1: No TPC is used (e.g. as often assumed for base stations).

In this case, the e.i.r.p. of the station is constant and should be used in the interference calculations, together with the corresponding protection ratios and overload thresholds for the DTTB receivers.

g.2) Case 2: TPC is used (e.g. as often is true for mobile transmissions).

In this case, the appropriate TPC algorithms are used during Monte Carlo simulations to determine the appropriate interfering e.i.r.p. levels for the specific transmission paths; the corresponding protection ratios and overload thresholds for the DTTB receivers are to be used. These protection ratios are usually higher and overload thresholds are usually lower (i.e. more stringent) than for the non-TPC case. If required the assessment can be carried out for a range of signal levels from the interfering equipment.

h) An appropriate propagation prediction model, for DTTB and the other services/applications should be used (e.g. based on Recommendation ITU-R P.1546). The standard broadcast planning practice is to use 50% time curves for the wanted field strengths and 1% time curves for a single interfering field strength. A time value of about 1.75% has been indicated in Attachment 3 to Annex 2 for the aggregation of several interferers.

i) Terrain-based prediction methods could be used on an agreed basis for specific local interference situations. This could help improving the prediction in these situations.

j) The degradation in the reception location probability Δ_{RLP} is determined at (or within) the DTTB coverage edge in the following ways:

j.1) Co-channel case:

– Depending on the distance of the interfering station of other services/applications from the pixels on the corresponding "long distance" or "short distance" propagation model is used, or the interpolation between these two distances, as appropriate.

– The reception location probabilities, P_{before} and P_{after}, are calculated within the entire pixel:

j.1.1) The relevant propagation distances are those between the interfering station of other services/applications and the (randomly chosen) DTTB reception locations within the pixel.

j.1.2) The relevant receive antenna discriminations/polarization discriminations are determined by the relative geometry.

– In the case of two or more co-channel interferers, the cumulative interference within any given pixel (or at any test point) is calculated.

– For all other pixels, the actual distance between the interfering station and the centre of the pixel is used for the calculation.

j.2) Adjacent channel case:

– Adjacent channel interfering fixed or handheld/mobile stations of other services/applications could be situated within any pixel of fixed or portable/mobile DTTB coverage area. The interference analysis is carried out for the pixel where the interferer is located. This pixel can be located at the edge of the broadcast coverage area or anywhere inside of it. The interference from such a station or stations (single entry and cumulative) and the resulting locations probabilities are calculated at test points as defined in a) above. These results are related to the pixel in which the interfering station is located.

– Where the adjacent channel interfering station is a fixed station of other services, the test geometry will also be applied to the eight pixels surrounding the pixel where the interfering station is. The pixel approach allows for a minimum resolution of for example 100 m only. In order to cover uncertainties with regard to the exact locations of the interferer and the victim, the adjacent pixels are analyzed as well. For each pixel, the actual wanted and existing interfering signals applicable to an individual pixel will be used for the calculation of reception location probabilities before the additional interference is considered.

– For all other pixels, the actual distance between the interfering station and the centre of the pixel is used for the calculation.
– In the case of two or more interfering adjacent channel stations of another service/application, the cumulative interference and the degradation in the reception location probability, Δ_{RLP}, are calculated at test points within the pixels in which the interfering stations are located[16], at the specific distance "*D*" from each respective interfering station. Note that this may also require the use of the "long distance" propagation models for the larger distances involved with respect to the interfering stations of other services/applications not lying within the pixel under consideration.

A2.4 Nuisance fields and power summation

If, at a given point, the wanted DTTB field strength is E_w and a (single) interfering DTTB field strength is E_{dtt_1}, then the wanted DTTB reception is "acceptable" (in the absence of noise) if:

$$E_w > E_{dtt\_1} + PR(\Delta f) - POL - DIR, \text{ and} \tag{24}$$

$$E_{dtt\_1} < E_{Oth\_dtt\_1} - POL - DIR \tag{24a}$$

where $PR(\Delta f)$ is the required protection ratio for a given frequency offset (carrier centre to carrier centre), Δf, *POL* is the polarization discrimination when relevant, and *DIR* is the receive antenna discrimination, vis-à-vis the interfering signal of other services/applications, when relevant. $E_{Oth\_dtt\_1}$ is the relevant overload field-strength threshold for the frequency offset, Δf. It is derived from the relevant overload threshold, O_{th_dtt}, in dBm taking into account the antenna gain (G_R) in dBi including the feeder loss.

$$E_{Oth\_dtt\_1} = O_{th\_dtt} + 20 \log f \text{ MHz} + 77.2 - G_R \tag{24b}$$

Values for *POL* and *DIR* are specified in Recommendation ITU-R BT.419-3. In the case of portable/mobile DTTB reception, no antenna directivity or polarization discrimination need to be considered.

E_w is the wanted field strength. In the case of an SFN, this would be the power sum of the wanted signals received from the SFN transmitters.

E_{dtt_1}, is the interfering DTTB field strength.

We define the "nuisance field", NU_{dtt_1}, corresponding to the interfering field E_{dtt_1} to be:

$$NU_{dtt\_1} = E_{dtt\_1} + PR(\Delta f) - POL - DIR \tag{25}$$

The nuisance field, NU_N, for the noise, N, is[17]:

$$NU_N = N + C/N$$

where N is the noise equivalent field strength, and C/N is the required DTT carrier-to-noise ratio to ensure acceptable DTT reception in the presence of noise only.

---

[16] NOTE – This means that the wanted DTTB field strength increases as the pixel approaches the DTTB transmitter.

[17] Sometimes the nuisance field for the noise is called the "minimum field", E_{min}.

If we take noise and a single interferer into account, then the requirement for an acceptable reception is:

$$E_W > 10\log\left(10^{\frac{NU_{dtt\_1}}{10}} + 10^{\frac{NU_N}{10}}\right)$$

NU_{dtt_1} is calculated for 1% time, E_W is calculated for 50% time.

If there are K interfering DTTB signals, E_{dtt_1}, E_{dtt_2}, ..., E_{dtt_K}, then the summed nuisance field for all of the interfering signals (including noise) is:

$$10\log\left(10^{\frac{NU_{dtt\_1}}{10}} + 10^{\frac{NU_{dtt\_2}}{10}} + \ldots + 10^{\frac{NU_{dtt\_K}}{10}} + 10^{\frac{NU_N}{10}}\right)$$

In the case of two or more interferers, although the aggregate power exceeded at 1% time is to be calculated, the individual path loss calculations are made using a 'corrected time percentage' which reflects the de-correlation between interference paths.

Based on the limited empirical data available (see Attachment 3 to Annex 2), a 'corrected time percentage' of 1.75% should be used to give an estimate of aggregate power at 1.0% time. This is a simple method to calculate the cumulative field strength at 1% time.

A 'General method' is also described in Attachment 3 to Annex 2 which is applicable at any desired percentage-time value.

For an acceptable DTTB reception:

$$E_W > 10\log\left(10^{\frac{NU_{dtt\_1}}{10}} + 10^{\frac{NU_{dtt\_2}}{10}} + \ldots + 10^{\frac{NU_{dtt\_K}}{10}} + 10^{\frac{NU_N}{10}}\right) \tag{26}$$

Similarly, the nuisance field for a single interferer of other services/applications, producing a field strength E_{os_1} at the DTTB receiver, would be:

$$NU_{os\_1} = E_{os\_1} + PR(\Delta f) - POL - DIR \tag{27}$$

If there are L interfering other service/application signals, E_{os_1}, E_{os_2}, ..., E_{os_L}, then the power summed other service/application nuisance field is:

$$NU_{OS} = 10\log\left(10^{\frac{NU_{os\_1}}{10}} + 10^{\frac{NU_{os\_2}}{10}} + \ldots + 10^{\frac{NU_{os\_L}}{10}}\right) \tag{28}$$

In the case of two or more interferers, although the aggregate power exceeded at 1% time is to be calculated, the individual path loss calculations are made using a 'corrected time percentage' which reflects the de-correlation between interference paths.

Based on the limited empirical data available (see Attachment 3 to Annex 2), a 'corrected time percentage' of 1.75% should be used to give an estimate of aggregate power at 1.0% time. This is a simple method to calculate the cumulative field strength at 1% time.

A 'General method' is also described in Attachment 3 to Annex 2 which is applicable at any desired percentage-time value.

If DTTB and other service/application interference are included together, then for an acceptable DTTB reception:

$$E_W > 10\log\left\{\left(10^{\frac{NU_{dtt\_1}}{10}} + 10^{\frac{NU_{dtt\_2}}{10}} + \ldots + 10^{\frac{NU_{dtt\_K}}{10}}\right) + \left(10^{\frac{NU_{os\_1}}{10}} + 10^{\frac{NU_{os\_2}}{10}} + \ldots + 10^{\frac{NU_{os\_L}}{10}}\right) + 10^{\frac{NU_N}{10}}\right\} \qquad (29)$$

At any given frequency offset, Δf_j, no interfering field $E_i(\Delta f_j)$ (either $E_{dtt}(\Delta f_j)$ or $E_{os}(\Delta f_j)$), should exceed the relevant overload threshold for that frequency offset, $E_{Oth}(\Delta f_j)$ (either $E_{Oth\_dtt}(\Delta f_j)$ or $E_{Oth\_OS}(\Delta f_j)$):

$$E_i(\Delta f_j) > E_{Oth}(\Delta f_j) \qquad (30)$$

leads to overload for any individual interfering field with frequency offset Δf_j.

$E_{Oth}(\Delta f_j)$ is the relevant overload field strength threshold for the frequency offset, Δf_j. It is derived from the relevant overload threshold, $O_{th}(\Delta f_j)$ in dBm, taking into account the antenna gain, G_R, in dBi including the feeder loss.

$$E_{Oth}(\Delta f_j) = O_{th}(\Delta f_j) + 20 \log f \text{ MHz} + 77.2 - G_R \qquad (30a)$$

If there are two or more interfering fields, $E_{i\_1}(\Delta f_j)$, $E_{i\_2}(\Delta f_j)$, ... with a frequency offset Δf_j, then the power sum of these fields, $E_{PS}(\Delta f_j)$, should not exceed the overload threshold for that frequency offset, $E_{Oth}(\Delta f_j)$:

$$E_{PS}(\Delta f_j) = 10\log\left(10^{\frac{E_{i\_1}(\Delta f_j)}{10}} + 10^{\frac{E_{i\_2}(\Delta f_j)}{10}} + \ldots + 10^{\frac{E_{i\_M}(\Delta f_j)}{10}}\right) > E_{Oth}(\Delta f_j) \qquad (31)$$

leads to overload for all interfering field with frequency offset Δf_j.

If there are two or more interfering fields, $E_{i\_1}(\Delta f_j)$, $E_{i\_2}(\Delta f_k)$, ..., with frequency offsets Δf_j, Δf_k, ..., then none of the individual interfering fields and none of the power sums of these fields, $E_{PS}(\Delta f_i)$, $E_{PS}(\Delta f_j)$, …, for each frequency offset should exceed the overload threshold for that frequency offset, $E_{Oth}(\Delta f_j)$:

$$E_{PS}(\Delta f_j) > E_{Oth}(\Delta f_j) \qquad (32)$$

for any frequency offset, Δf_j, leads to overload.

A methodology to calculate the overall (‘cumulative’) effect of all interferers taken together, with respect to overloading, is still subject to further study.

A2.5 Monte Carlo simulation

In a Monte Carlo simulation, the statistical variations of the signals are taken into account. To this end, the following values for the relevant parameters are assumed:

a) The median wanted DTTB field strength E_{W_med} and the i^{th} median interfering DTTB field strength $E_{dtt\_i\_med}$, are calculated using the wanted DTTB test point coordinates, the wanted and interfering DTTB transmitter coordinates, ERPs, transmit and receive antenna patterns, etc. The standard deviations for wanted σ_W and interfering fields σ_{dtt_i} depend on the propagation prediction model. Typical values are σ_W = 5.5 dB, σ_{dtt_i} = 5.5 dB.

b) The median other service/application interfering field strengths $E_{os\_i\_med}$ for the other service/application interferers are calculated using the wanted DTTB test point coordinates, the other service/application interfering transmitter coordinates, e.i.r.p.s, transmit and receive antenna patterns, etc. The standard deviations σ_{os_i} depend on the propagation prediction model.

c) If some of the interfering stations of other services/applications are already implemented, with agreed transmission parameters, these are the parameter values that are used to determine the relevant statistical field strength values.

For the other stations where the suitable technical characteristics are to be determined, initial parameter values can be assumed and varied, and used to determine the resulting degradation of the DTTB reception location probability Δ_{RLP}.

d) The appropriate protection ratios corresponding to the relevant Δf (frequency offset) have to be used, see Recommendation ITU-R BT.1368.

e) Polarization discrimination POL and receive antenna discrimination DIR (see Recommendation ITU-R BT.419-3), for DTTB to DTTB and other service/application to DTTB interference, if applicable and depending on the network configurations, have to be considered.

A Monte Carlo simulation will be required for each test point/pixel to be protected in the DTTB service area. For example, in the adjacent channel case when a new other service/application station is proposed inside of a DTTB service area, the test points within the pixel in which the new station is to be situated and also in the neighbouring pixels must be investigated. Because Monte Carlo simulations can often involve a very large number of calculations, the relationship between I/N and the degradation of reception location probability is explained in Attachment 1, and an example is given in Attachment 2 whereby a large amount of calculation iteration time can be saved.

A2.6 Conclusion

An example methodology has been described which is suitable for determining the two cases of either co-channel or adjacent channel interference of other service/application stations into DTTB by means of calculating the degradation of the DTTB reception location probability. In this methodology, no approximations are made with respect to the treatment of the statistical variables relating to reception location probability, in the calculation of the statistical distributions of the wanted and interfering fields as well as their cumulative interference effects.

This methodology is applicable for the assessment of interference into fixed roof top as well as mobile and portable DTTB reception in the presence of fixed stations of other service/application. It is advised to use characteristics of broadcasting and mobile service deployments in order to apply this methodology.

Attachment 1 to Annex 2

Example calculations of relationship between I/N and Δ_{RLP}

1 Introduction

The limits of the broadcasting coverage area may be defined as the point at which the reception location probability is reduced to a specified value. The reception location probability is usually taken to be 95%, but sometimes 90% or even 70% is used.

If a specific value of *I/N* is chosen as a protection criterion, it is of interest to know the value of the corresponding degradation to the reception location probability, Δ_{RLP}.

Calculations to determine the relationship between *I/N* and Δ_{RLP} can be carried out using Monte Carlo simulations.

2 Relationship between *I/N* and degradation of the reception location probability

The Monte Carlo calculations are carried out using the following model:

– A pixel of a given area is taken within the area of interest.

– It takes the median wanted field strength of the pixel.

– The reception location probability within the pixel in the presence of noise only, RLP_N, is taken to be RLP_N = 95%, RLP_N = 90%, or RLP_N = 70%.

– An interference, *I*, is taken which has a strength given as $I_{med}/N = -X$ dB; that is, the median interfering field, I_{med}, is *X* dB less than the noise field, $I_{med} = N - X$.

– The standard deviation of the wanted and interfering fields is 5.5 dB; noise is assumed to have 0 dB standard deviation.

The Monte Carlo simulations were performed with the following parameters:

N: noise value (expressed as an equivalent field strength)

$(C/N)_{ref}$: reference required wanted carrier-to-noise value for acceptable reception

PR: required protection ratio

σ: standard deviation of the wanted field

μ_x: statistical factor corresponding to *x*% location probability; e.g. $\mu_{95} = 1.645$, $\mu_{90} = 1.28$, $\mu_{70} = 0.52$

E_{w_med}: median wanted field strength for the required location probability in the presence of noise only

$$E_{w\_med} = N + (C/N)_{ref} + \mu_x * \sigma$$

$I_{med} = N - \delta$: median interfering field strength (δ to be varied from 0 dB to 24 dB)

In a Monte Carlo simulation, a large number of 'trials' are calculated (in order to give a statistically meaningful result).

In each ‘trial’ the following is done:

– The value of the received wanted signal is calculated: $E_w = E_{w\_med} + SV_r*\sigma$, where SV_r is a randomly generated ‘statistical value’ corresponding to a Gaussian distribution.

– The value of the received interfering signal is calculated: $E_I = I_{med} + SV_r*\sigma$, where SV_r is a randomly generated ‘statistical value’ corresponding to a Gaussian distribution.

– The values SV_r are generated randomly for each field value as it is calculated.

– The noise nuisance field, $N_{nuis} = N + (C/N)_{ref}$, is constant (0 standard deviation).

– The interference nuisance field is $I_{nuis} = E_i + PR$.

– The total interference nuisance field is $T_{nuis} = (E_i + PR) \oplus (N + (C/N)_{ref})$, where $\oplus$ represents power summing.

A) In the case of noise only (i.e. no other interference source)

A comparison is made:

if $E_w \geq N_{nuis}$, then the ‘trial’ is noted as being ‘acceptable reception’

if $E_w < N_{nuis}$, then the ‘trial’ is noted as being ‘unacceptable reception’.

B) In the case of noise and interference

A comparison is made:

if $E_w \geq T_{nuis}$, then the ‘trial’ is noted as being ‘acceptable reception’

if $E_w < T_{nuis}$, then the ‘trial’ is noted as being ‘unacceptable reception’.

After the large number of trials has been carried out (for case A when noise only is being considered, for case B when noise and interference are both being considered) the total number of ‘acceptable reception’ trials is divided by the total number of trials to determine the location probability, RLP_N for case A and $RLP_{N \oplus I}$ for case B.

The overall results, for X ranging from X = 0 dB to X = 24 dB are shown in Fig. 8. The results for RLP_N = 95%, RLP_N = 90%, RLP_N = 70%, respectively, are superposed on Fig. 8. The horizontal axis (the ‘I/N’ axis) represents the median I/N values; the vertical axis (the ‘Δ_{RLP}’ axis) represents the corresponding degradation to the reception location probability.

A closer view of the results is given in Fig. 9, for X ranging from X = 10 dB to X = 24 dB.

A still closer view of the results is given in Fig. 10, for X ranging from X = 18 dB to X = 24 dB.

FIGURE 8

$\Delta_{RLP} = f(I/N)$ (= $RLP_N - RLP_{N \oplus I}$)

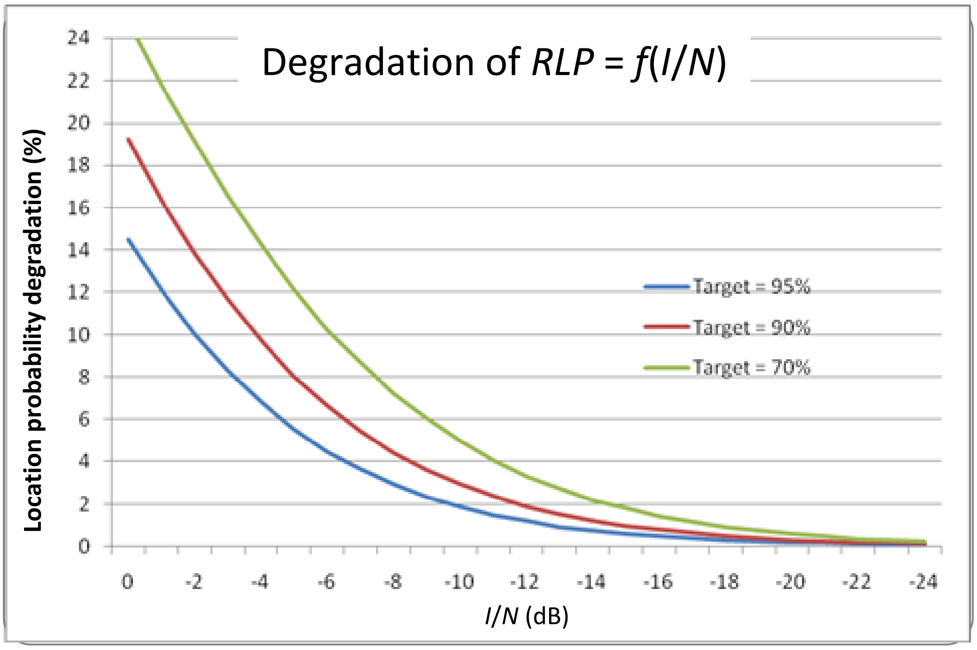


FIGURE 9

$\Delta_{RLP} = f(I/N)$ (= $RLP_N - RLP_{N \oplus I}$)

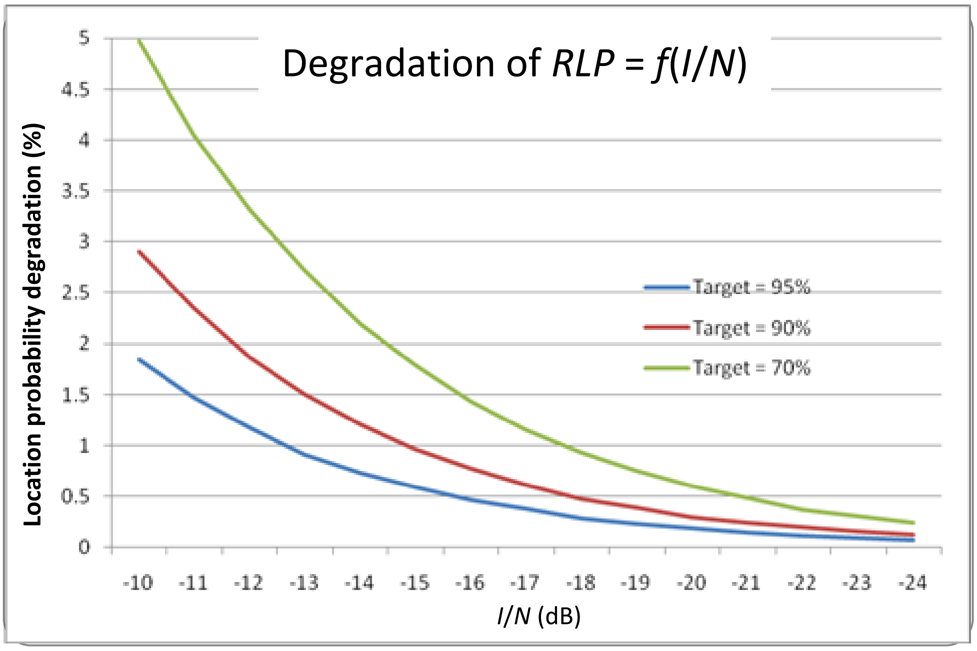
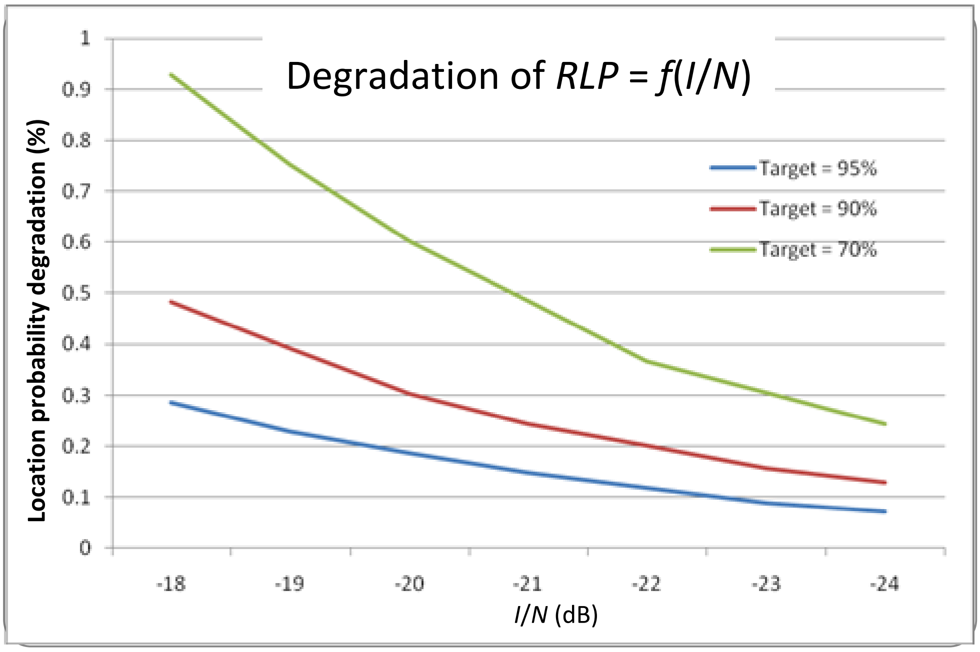


FIGURE 10

$\Delta_{RLP} = f(I/N)$ (= $RLP_N - RLP_{N \oplus I}$)



The individual results are given in Table 8 (for RLP_N = 95%), Table 9 (for RLP_N = 90%), and Table 10 (for RLP_N = 70%). The relationships between I/N and Δ_{RLP} are seen in Fig. 8.

TABLE 8

Reception location probability degradation (Δ_{RLP}) as a function of median I/N: RLP target = 95%

***I/N* (50%)**	**–6 dB**	**–10 dB**	**–19.05 dB**[18]	**–20 dB**	**–22.77 dB**[19]
$C/N \geq$ PR	95.00%	95.00%	95.00%	95.00%	95.00%
$C/(I \oplus N) \geq$ PR	90.53%	93.16%	94.77%	94.81%	94.90%
Δ_{RLP}	**4.47%**	**1.84%**	**0.23%**	**0.18%**	**0.10%**

TABLE 9

Reception location probability degradation (Δ_{RLP}) as a function of median I/N: RLP target = 90%

***I/N* (50%)**	**–6 dB**	**–10 dB**	**–19.05 dB**	**–20 dB**	**–22.77 dB**
$C/N \geq$ PR	90.00%	90.00%	90.00%	90.00%	90.00%
$C/(I \oplus N) \geq$ PR	83.36%	87.11%	89.62%	89.69%	89.83%
Δ_{RLP}	**6.64%**	**2.89%**	**0.38%**	**0.31%**	**0.17%**

[18] I/N = –19.05 dB at 50% of the locations corresponds to $I/N \geq$ –10 dB at 5% of the locations.

[19] I/N = –22.77 dB at 50% of the locations corresponds to $I/N \geq$ –10 dB at 1% of the locations.

TABLE 10

Reception location probability degradation (Δ_{RLP}) as a function of median *I/N*: RLP target = 70%

I/N (50%)	–6 dB	–10 dB	–19.05 dB	–20 dB	–22.77 dB
$C/N \geq$ PR	70.00%	70.00%	70.00%	70.00%	70.00%
$C/(I \oplus N) \geq$ PR	59.72%	65.03%	69.27%	69.40%	69.69%
RLP degradation	**10.28%**	**4.97%**	**0.73%**	**0.60%**	**0.31%**

3 Summary

It is seen in Fig. 8 that a permitted median *I/N* level greater than –10 dB will lead to large RLP degradations, i.e. RLP degradations greater than 1.5% to 4% for a median value of *I/N* = –10 dB, and RLP degradations greater than 4% to 10% for a median value of *I/N* = –6 dB.

For a median value of *I/N* = –20 dB (see Fig. 9), the *RLP* degradation for *RLP* = 95% is 0.2%, for *RLP* = 90% is 0.3%, and for *RLP* = 70% is 0.6%.

For a median value of *I/N* = –23 dB (see Fig. 10), the *RLP* degradation for *RLP* = 95% is 0.1%, for *RLP* = 90% is 0.15%, and for *RLP* = 70% is 0.3%.

This demonstrates that there is a relationship between the *I/N* criterion and criteria based on a corresponding degradation to the reception location probability. The statistical nature of some of these variables leads to the use of Monte Carlo simulations as a possible method to assess the degradation of reception.

Attachment 2 to Annex 2

Example Monte Carlo simulation with calculation saving methods

In a Monte Carlo simulation, a large number of "trials" are considered in which, for each trial, random values for the fields of interest are selected, according to the relevant statistical distributions; and on the basis of the statistics of the results of the trials, the relevant probabilities (in this case, reception location probabilities) can be calculated.

For each trial the following calculations are carried out and the results are stored in a table, such as the table shown below:

– a random wanted DTTB field strength is calculated using:

$$E_W = E_{W\_med} + \text{random (Gaussian, } \sigma_W \text{) variation}$$

– random interfering DTTB field strengths are calculated using:

$$E_{dtt\_i} = E_{dtt\_i\_med} + \text{random (Gaussian, } \sigma_{dtt\_i} \text{) variation}$$

The corresponding nuisance fields, NU_{dtt_i}, are calculated using equation (25) above and the relevant protection ratios, *POL*, *DIR*, etc.:

– random interfering other service/application field strengths are calculated using:

$$E_{os\_i} = E_{os\_med\_i} + \text{random (Gaussian, } \sigma_{os\_i} \text{) variation}$$

The corresponding total other service nuisance field, NU_{os}, is calculated using equation (28) above and the relevant protection ratios, *POL*, *DIR*, etc.; the power sums for the NU_{dtt_i} and NU_N are carried out for each trial, leading to a value NU_{before}, which is compared to the trial value of E_w.

The ratio of the number of trials where $E_W > NU_{before}$, to the total number of trials, gives the reception location probability, RLP_{before}, for acceptable DTTB reception in the presence of the interfering DTTB signals and the noise.

For each trial, the power sum of NU_{before} and NU_{os} is carried out leading to a value NU_{after}.

The ratio of the number of trials where $E_W > NU_{after}$, to the total number of trials, gives the reception location probability, RLP_{after}, in the presence of the interfering DTTB signals, the noise, and the other service interference.

If $RLP_{before} - RLP_{after} \leq x\%$, we are done: the assumed other service/application transmission characteristics are acceptable.

If $x\%$ is exceeded, another set of calculations may be carried out after introducing modifications to the interfering stations of other services/applications.

If $RLP_{before} - RLP_{after} > x\%$, the other service/application technical characteristics must be altered (e.g. e.i.r.p.s decreased, transmit antenna patterns modified, separation distance increased, etc.), until the overall degradation to the DTTB reception location probability in the pixels of interest has been reduced to an acceptable level. This involves iterative calculations which can be time consuming.

A method which requires less calculation time (but more computer storage) can proceed as follows:

The calculated values are stored in a table (see the shaded columns in the Table below)[20]. It is only necessary to iterate on the values of NU_{os_i}, which were derived from the "initial variable" parameter assumptions.

If changes in these initially assumed parameters lead to changes in the respective initial median field strength values, $E_{med\_os\_i\_\alpha}$, = $E_{med\_os\_i} + \delta_i$, the corresponding changes are to be made to the initial nuisance fields, to yield $NU_{med\_os\_i\_\alpha}$, = $NU_{med\_os\_i} + \delta_i$, without going through additional Monte Carlo simulations, and then the corresponding overall values, NU_{os_α}, can be calculated. Then the modified power sums can be carried out to determine $NU_{after\_\alpha} = NU_{before} \oplus NU_{os\_\alpha}$, as before. With a few such iterations the appropriate other service/application parameters can be found for the interfering stations under consideration (i.e. when $RLP_{before} - RLP_{after} \leq x\%$).

Using this procedure, only one Monte Carlo simulation is necessary, and the iteration needed for finding acceptable other service/application transmission characteristics is reduced to a simple iteration involving analytic calculations based on previously stored quantities only.

NOTE – A Monte Carlo simulation, involving 30 000 trials, and 20 iterations takes less than 0.1 second calculation time on a personal computer.

[20] NOTE – Depending on the details of the Monte Carlo simulation, it may also be necessary to store the coordinates used for each transmitter and receiver site used in each trial, in order to recalculate the relevant median field strengths for modified other service/application technical characteristics.

Trial #	E_W	NU_{dtt_1}	...	NU_{dtt_K}	NU_N	$NU_{before} = \sum_{i=1}^{k} \oplus NU_{dtt\_i} \oplus NU_N$	NU_{os_1}	...	NU_{os_L}	$NU_{OS} = \sum_{i=1}^{L} \oplus NU_{OS\_i}$	$NU_{after} = NU_{before} \oplus NU_{OS}$
1											
2											
3											
...											
30000											

NOTE – The shaded columns are to be stored during the Monte Carlo simulation, in order to rapidly calculate NU_{after} for each iteration on e.i.r.p.$_{os}$.

In the case where adjacent channel interference to DTTB reception is being calculated, similar simulations to those just described are required (applying the same method), except that the simulation distances between interfering stations of the other services/applications and affected DTTB receive antenna are taken to be those described in Annex 2, § A2.3, indent a) Case 2.

Attachment 3 to Annex 2

Methods for the aggregation of short-term interfering signals

Introduction

This Attachment describes the methods recommended by WP 3K for use in the studies being conducted by WP 6A concerning potential interference to UHF television services.

A general method is specified that could be used in any Monte-Carlo simulations, and is applicable at any desired percentage-time value; a simple alternative is provided only for cases where computational complexity must be avoided.

1 Proposed methods

Two methods for the computation of aggregate interference from multiple transmitters where individual path losses are temporally variable are recommended.

The first approach ("general method") is based on a rigorous mathematical treatment of the joint variability of multiple paths, and can be used to estimate the aggregate received power at any percentage-time. The method uses Monte Carlo simulation involving multiple calculations for each path of interest, and would be appropriate for use in a situation where numerically-intensive computer simulation is already envisaged.

Recognising that this approach may not always be appropriate (e.g. where a quick estimate is required without an iterative computer simulation), a simple alternative is also proposed ("simple method"). This method is currently only defined for the case where the aggregate power is to be estimated at 1% time, although it could be readily extended for use at other percentage-times.

2 General method

Mutual correlation

The intention of the algorithm given in the description of the "general" method is that one set of random numbers is used as a "reference" from which all the other random variables (used to "drive" the propagation models for the various paths) are derived using the copula function. The reference variable is not, itself, used as the input to a propagation model.

The method is described in the following pseudo-code (where RV is a "random variable", CDF the "cumulative distribution function", and α is a constant, discussed below):

FOR *trial k = 1, 2, ... N (where N is the number of trials)*

{

  set power sum for this trial, P_{trial_k}, to zero

  get initial RV, μ_{0_k}, from uniform distribution in range 0-1

  FOR *signal i = 1, 2, ... T (where T is the number of contributing signals)*

  {

    get RV, ν_{i_k}, from uniform distribution in range 0-1)

    derive new RV, $\mu_{i\_k} = \mu_{0\_k}\left(\nu_{i\_k}^{-\alpha/(\alpha+1)} - 1 + \mu_{0\_k}^{\alpha}\right)^{-1/\alpha}$

    get received power, $P_{n\_i\_k}$, from signal *i* at %-time = μ_{i_k} * 100

    add $P_{n\_i\_k}$ to power sum, P_{trial_k}

  }

  Add P_{trial_k} to *result_array*

}

Make CDF of *result_array*

Find 0.01 probability point on CDF (corresponds to 1% aggregate power)

The constant α determines the degree of 'correlation' between loss values on the different paths. On the basis of the limited empirical data available a value of 1.0 should be used.

Careful attention must be paid to the choice of *number_of_trials*. The number of trials must be sufficient to give a confidence interval appropriate for the scenario under investigation.

Note that although the pseudo-code is couched in terms of received power the results may need to be expressed as an aggregate field strength for use in the simulations described in this Annex 2.

Application of the "general" method when complete temporal distributions are not known (e.g. Recommendation ITU-R P.1546)

All propagation models will have a finite range of percentage-times for which they are valid; for Recommendation ITU-R P.1546, for example, the limits are 1% to 50%. The "general" method, on the other hand, requires that complete temporal distributions (0%-100%) are available as an input document. This is clearly impossible, if only because no measurement data can be available at the extremes. For practical purposes, however, it is only necessary (i) that the propagation model does not return an error for any percentage-time input and (ii) that the results are 'acceptably accurate' in the region of the distribution close to the percentage time of interest.

The latter judgment can only be made by the user in a particular application, but in the specific case of Recommendation ITU-R P.1546 at 1% time, acceptable performance seems to be given by clamping the output above 50% to the 50% value and to allow the model to extrapolate below 1% time as explained below.

Propagation model

In line 9 of the pseudo-code, the received power from a single transmitter is calculated, and this calculation will need to take into account transmitter EIRP, transmitter and receiver antenna directivity, receive antenna gain and the basic transmission loss.

The latter can be determined using any appropriate propagation model that takes percentage time as an input parameter.

Unfortunately the majority of ITU-R models (e.g. Recommendation ITU-R P.1546) are not directly suitable for use in Monte Carlo simulation of temporal behaviour, as they are only defined for use over a limited temporal range (e.g. 1%-50% for Recommendation ITU-R P.1546). The only exception is Recommendation ITU-R P.2001, which is designed for use in precisely the type of simulation discussed here.

Should it be required to use Recommendation ITU-R P.1546 to perform these simulations, the following changes will be required:

- For any time greater than 50%, the model should return the loss value for 50.0%.
- The model should be allowed to return loss values for arbitrarily small percentage times by allowing the existing log-normal interpolation function to extrapolate below 1%. The only change required to Recommendation ITU-R P.1546 should be the removal of the 1% limit.

It should be emphasised that the values returned by the model at >50% and <1% are not valid in themselves; these modifications are simply required to allow the use of Recommendation ITU-R P.1546 in a Monte Carlo framework and any errors introduced in the estimation of aggregate power between 1% and 50% time are expected to be insignificant.

3 Choice of the copula parameter, α

For the specific case of estimating aggregate interference at 1% time over long (>50 km) paths at UHF, the value of $\alpha = 1.0$ was suggested, based on limited empirical evidence. A different value of this parameter may be appropriate for the evaluation of interference at different percentage times.

Computational issues

The implementation indicated above is only the most simple, and several tactics to make the code faster could be implemented.

For example, most computation time will be expended in line 9, the call to the propagation model. As the (*number_of_tx*) transmission paths do not change in the course of the computation, it would be worthwhile pre-computing the distribution of path loss with time for each path, and storing this as a look-up table or polynomial fit.

It may be possible to combine the modelling of temporal variability with that of location variability in a computationally-efficient manner; this issue has not been studied by the correspondence group, but may form the basis of further work.

Simple method

In this approach, the calculation of aggregate power is made by simply taking the power sum of the individual interferers (i.e. assuming full correlation between paths).

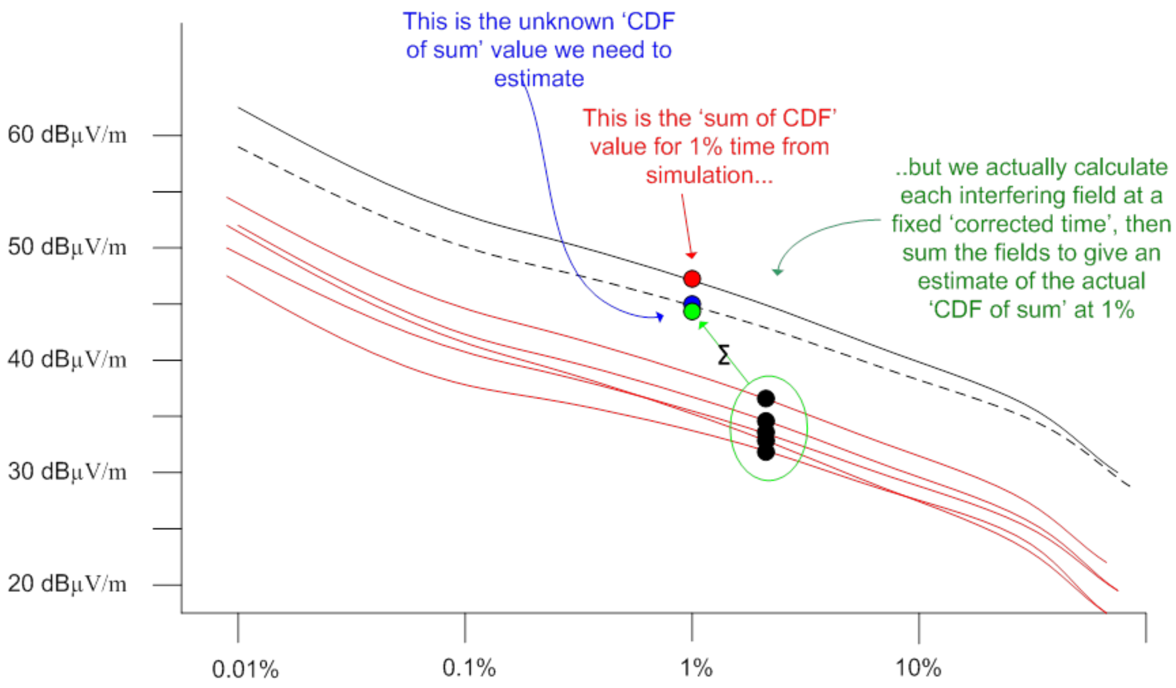
However, although the aggregate power exceeded at 1% time is to be calculated, the individual path loss calculations are made at a 'corrected time' which reflects the de-correlation between interference paths.

Based on the limited empirical data available, a 'corrected time' of 1.75% should be used to give an estimate of aggregate power at 1.0 % time.

The procedure of the simple method is sketched below.

FIGURE 1

The 'simple method'



Comparison of methods

Simulations using the 'general' model have been made for three simple cases, as set out in Table 1.

TABLE 1

Test scenarios

Name	Number of tx	Path lengths	Effective tx heights
'longer paths'	42	50 km – 134 km	30 m (fixed)
'shorter paths'	100	20 km – 70 km	10 m – 60 m
'large spread'	200	100 km – 300 km	50 m – 450 m

In all cases the frequency assumed was 500 MHz and the receive height 3 m.

The overall results for the three cases are shown in Figs 2-4 below. The dependence of the aggregate field on the assumed value of α (i.e. the degree of mutual correlation between paths) is clearly seen.

FIGURE 2

'Longer paths' case

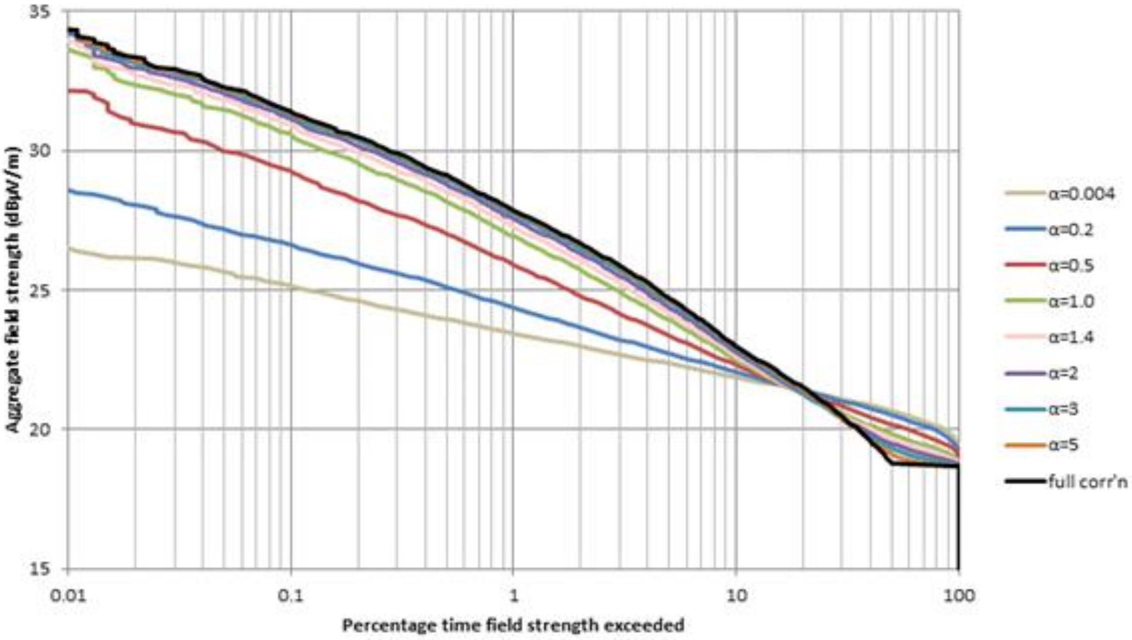


FIGURE 3

'Shorter paths' case

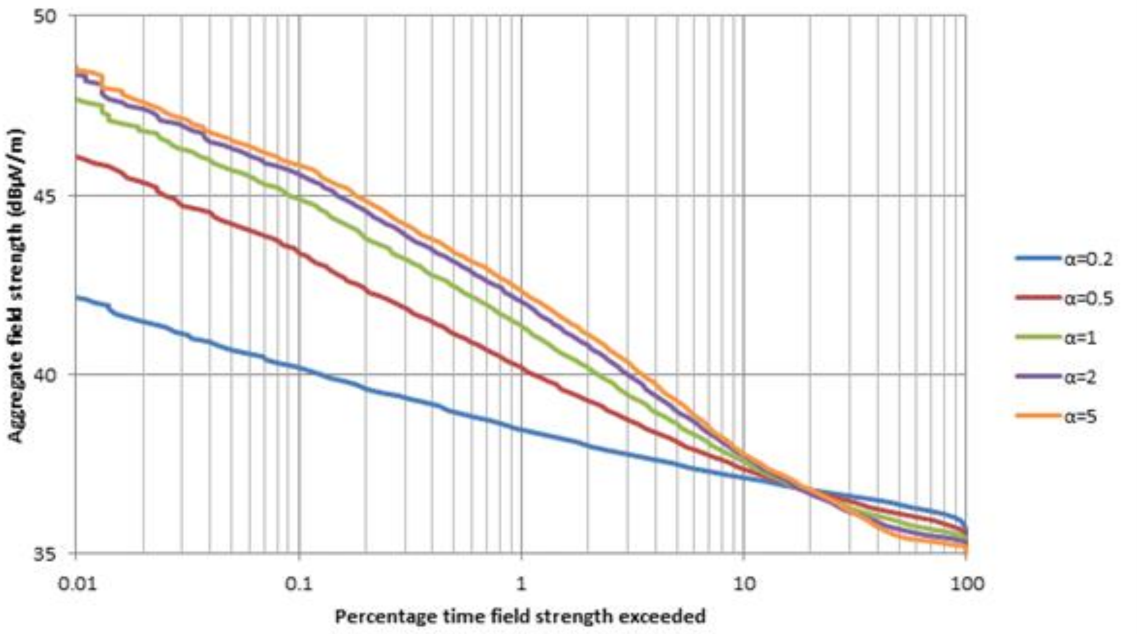
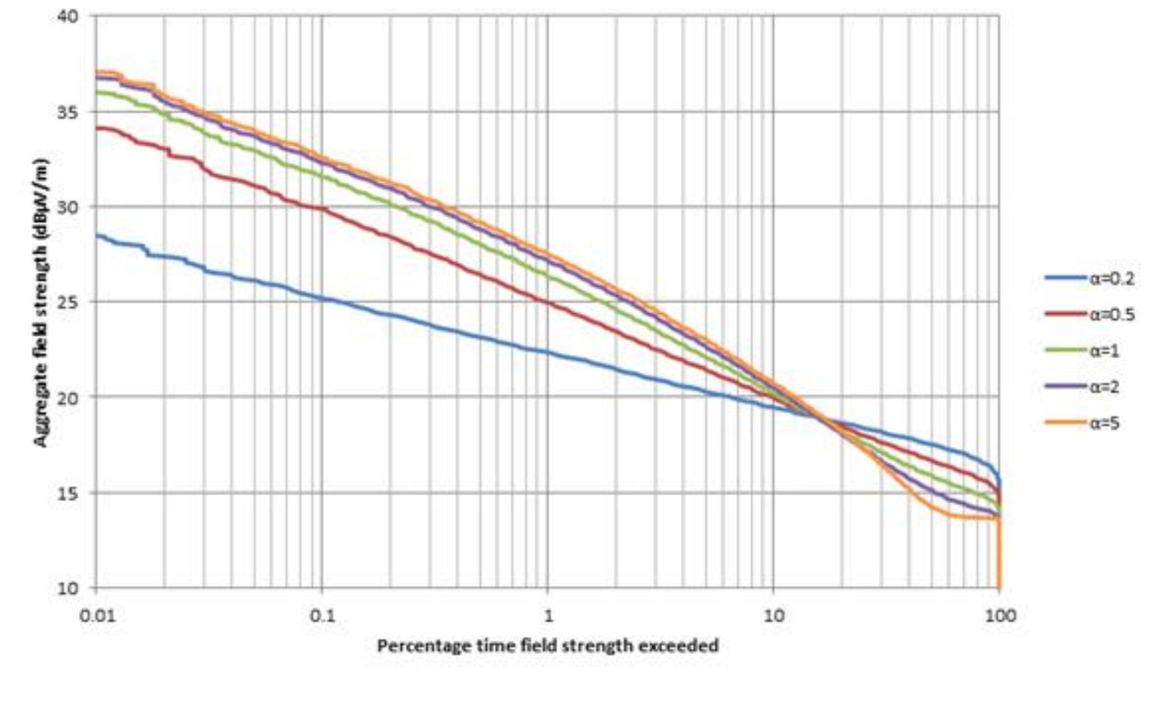


FIGURE 4

'Large spread' case



In the following figures, details of the above plots are reproduced, with additional data points representing the simple aggregate power sum from all transmitters, taken at fixed percentage-times (i.e. the fully-correlated assumption).

FIGURE 5

'Longer paths' case (detail)

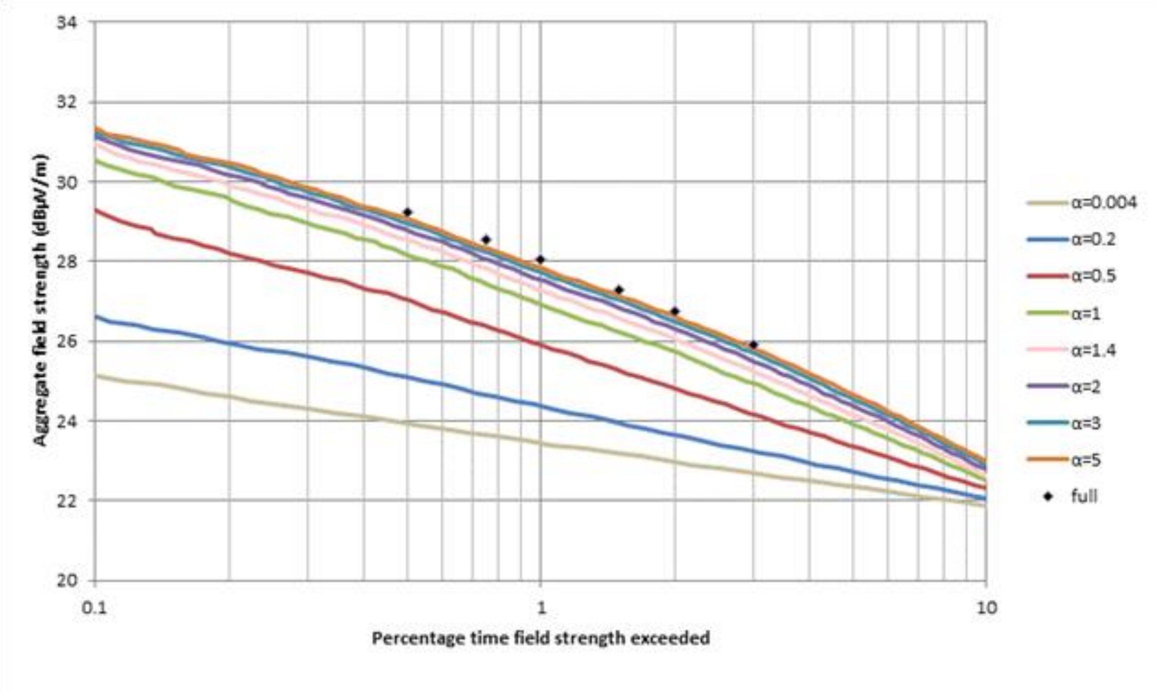


FIGURE 6

'Shorter paths' case (detail)

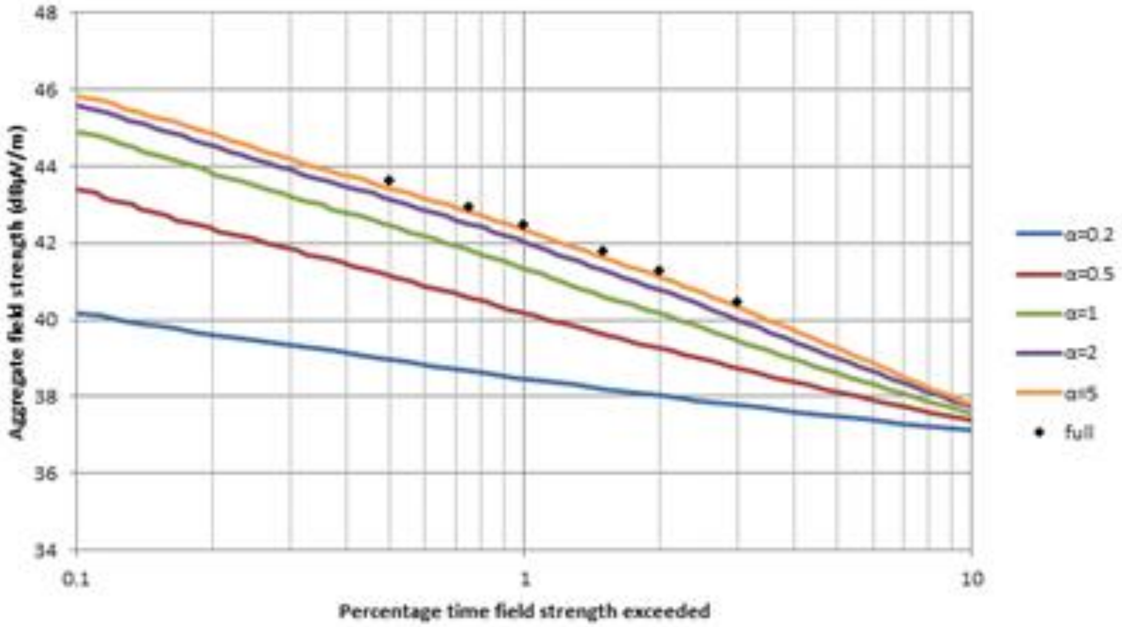
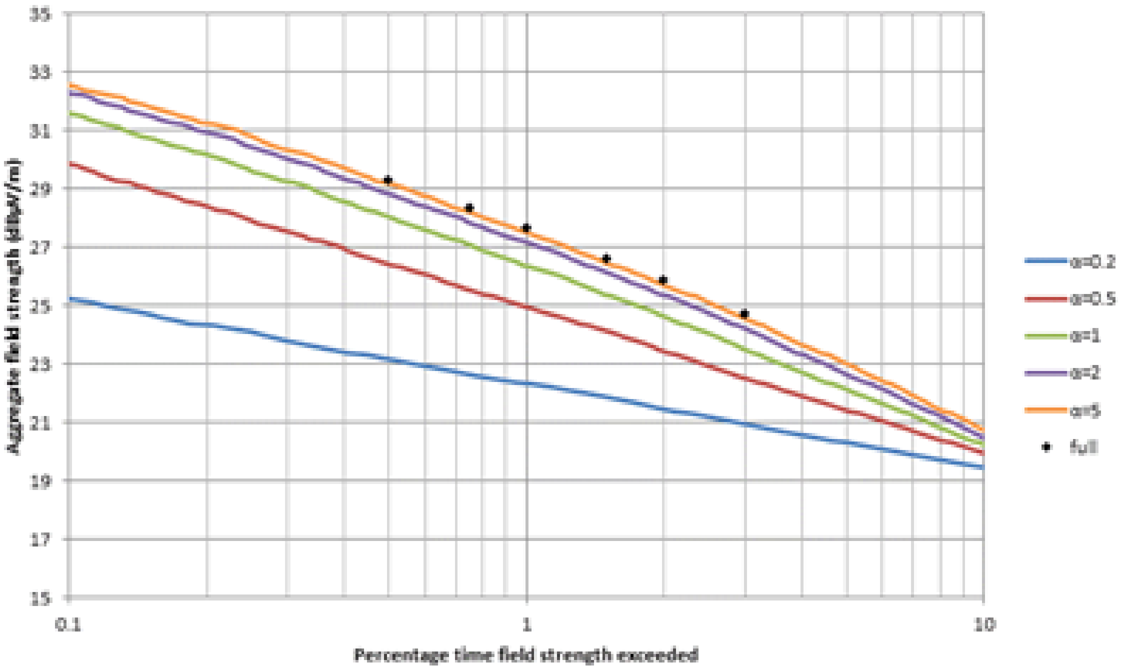


FIGURE 7

'Large spread' case (detail)



As would be expected, the new points are very close to the trace representing the highest value[21] of α.

---

[21] This value corresponds to a 'correlation' of 0.9.

TABLE 2

‘General method’ results

Scenario	Aggregate (full correlation)	Aggregate (General method, α=1.0)	Δ_{wrt} full correlation
‘Longer paths’	28.0 dBμV/m	27.0 dBμV/m	–1.1 dB
‘Shorter paths’	42.5 dBμV/m	41.4 dBμV/m	–1.1 dB
‘Large spread’	27.6 dBμV/m	26.4 dBμV/m	–1.3 dB

TABLE 3

‘Simple method’ results

Scenario	Aggregate (full correlation)	Aggregate (‘simple’ at 1.75%)	Δ_{wrt} full correlation
‘Longer paths’	28.0 dBμV/m	27.0 dBμV/m	–1.0 dB
‘Shorter paths’	42.5 dBμV/m	41.5 dBμV/m	–1.0 dB
‘Large spread’	27.6 dBμV/m	26.2 dBμV/m	–1.4 dB

If the ‘general method’ is used with α=1.0 (green trace), the ‘simple method’ gives the same field strength for a ‘corrected time’ of around 1.75%.

TABLE 4

Comparison of methods (corrected time=1.75%)

Scenario	General method, α=1.0	‘simple method’ corrected time = 1.75%	Δ (‘simple’ wrt ‘general’)
‘Longer paths’	27.0 dBμV/m	27.0 dBμV/m	+0.0 dB
‘Shorter paths’	41.4 dBμV/m	41.5 dBμV/m	+0.1 dB
‘Large spread’	26.4 dBμV/m	26.2 dBμV/m	–0.2 dB

Annex 3

Methodology for assessing degradation in DTTB reception from interfering stations of mobile service

1 Introduction

This Annex describes an example methodology for the assessment of interference into the digital broadcasting service from a single main interferer in an interfering network. This analysis based on *C/I* and *C/(N+I)* criteria, takes into account the statistics of distribution of the wanted (*C*) and interfering (*I*) signals.

It contains in the Attachment an example of application of this methodology using actual information on planned broadcasting and mobile service areas. For this, the actual deployments of both broadcasting and mobile networks are used combined with the use of a digital terrain model and the use of adequate propagation models.

The characteristics, assumptions, description and applications of this methodology are further described in the following sections.

2 Description of the methodology – Evaluation of the probability of interference in terms of population, considering a statistical variation of *C* and *I* signals

The important points of the methodology are the following:

a) This methodology can be used for the calculation of protection of fixed rooftop reception and on portable reception. In case of mobile DTT reception a result in terms of area coverage might be more convenient.

b) The interfering impact is expressed in terms of a percentage of population for which a given protection ratio is not fulfilled by the analysis of the statistics of *C/I* over a DTT cell. A result in terms of population will directly provide estimation on the number of people and/or households for which mitigation measures are required on a local basis.

c) The percentage of impacted population mentioned in b) can be calculated within a given pixel, in an area containing several pixels, or in the whole DTTB coverage area by calculating the impact in each pixel thereof.

d) This methodology assumes the identification of a single main interferer in each DTT reception pixel. The aggregate effect of multiple interferers (other than the main) on top of the effect of the main interferer is assumed to be negligible and is not considered.

e) This methodology allows the analysis of the interference impact of a single main interfering station from the interfering network on DTTB reception both in co-channel and in out-of-channel situations:

   i) for the co-channel case, the interfering stations (from which the main interferer is selected) are situated outside of a DTTB coverage area.

   ii) for the out-of-channel case, the interfering stations can be located inside of a DTTB coverage area.

f) Actual deployment of mobile networks: digital terrain model (DTM) (e.g. with a 100 m step) and building clutter data should be used, if available, in order to provide more accuracy in the results.

The method calculates the probability that a pixel served by DTT (i.e. $C \geq Sens$[22]) has $C/I < PR$[23] , taking into account the statistical variations of wanted and interfering signals.

In order to take into account the statistical variation of the wanted and interfering signals from their median values following a log-normal distribution, it is necessary:

– to calculate, for each pixel, the values of the median wanted (*C*) and interfering (*I*) field strengths with regard to location. The appropriate time percentage of time for each signal should be used;

– to apply the antenna discrimination and the polarization attenuations to the values of *I*;

– that the probability be calculated as follows, and represented by the factor *F*:

$$F(c_m, I_m) = \int_{\hat{c}=S_{ens}=N+PR}^{+\infty} p_c(\hat{c}, c_m) \left\{ \int_{\hat{I}=\hat{c}-PR}^{+\infty} p_I(\hat{I}, I_m) d\hat{I} \right\} d\hat{c} \qquad (1)$$

where:

C_m : median wanted field strength of the pixel

N : noise level in field strength units

I_m : median interfering field strength in the pixel considered (including discriminations)

p_c : lognormal random variable with standard deviation[24] of 5.5 dB and mean of C_m

p_I : lognormal random variable with standard deviation[24] of 5.5 dB and mean of I_m

S_{ens} : sensitivity of the DTT receiver (in field strength units), $S_{ens} = Noise + PR = N + PR$

PR: protection ratio criteria, sometimes noted $(C/I)_{threshold}$.

Formula 1 does not consider the effect of the power sum of noise and interference. Nevertheless, it is possible to take into account this effect, knowing that a DTT pixel is interfered when the following condition applies:

$$\frac{C}{N+I} < PR \qquad (2)$$

Therefore, modifying the factor *F* as follows, the effect of power sum of noise and interference can be taken into account:

$$F(c_m, I_m) = \int_{\hat{c}=S_{ens}=N+PR}^{+\infty} p_c(\hat{c}, c_m) \left\{ \int_{\hat{I}=10Log\left[10^{\frac{\hat{c}-PR}{10}} - 10^{\frac{N}{10}}\right]}^{+\infty} p_I(\hat{I}, I_m) d\hat{I} \right\} d\hat{c} \qquad (3)$$

Regarding the intra-service interference (interference into DTT reception from DTT transmitters different than the wanted one), it could be necessary to consider its impact before taking into account the other services interference. As this formula (3) does not allow to consider more than one statistical interfering signal, a way to consider an existing interference level is to assume that it is static (i.e. it is constant all through the pixel) and it increases the existing Noise level by a margin corresponding to the median level of the existing DTT interferer. This is done by applying the formula (4) below.

---

22 *Sens*: sensitivity of the receiver, expressed in field strength.

23 *PR*: Protection ratio.

24 According to different models, this standard deviation can vary for closer distances.

$$F(c_m, I_m) = \int_{\hat{c}=S'_{ens}=10Log\left[10^{\frac{N}{10}}+10^{\frac{I_{Dm}}{10}}\right]+PR}^{+\infty} p_c(\hat{c}, c_m)\left\{\int_{\hat{I}=10Log\left[10^{\frac{\hat{c}-PR}{10}}-10^{\frac{N}{10}}-10^{\frac{I_{Dm}}{10}}\right]}^{+\infty} p_I(\hat{I}, I_m)\,d\hat{I}\right\}d\hat{c} \tag{4}$$

where I_{Dm} is the median DTT interference field strength received in the pixel (different than the wanted DTT signal).

In order to take the statistical variation of the DTT interfering signal with location inside the Pixel the following formula (5) should be used:

$$F(c_m, I_{\text{Im}}, I_{Dm}) = \int_{\hat{c}=S_{ens}=N+PR}^{+\infty} p_c(\hat{c}, c_m)\left\{\int_{\hat{I}_D=10Log\left[10^{\frac{\hat{c}-PR}{10}}-10^{\frac{N}{10}}\right]}^{+\infty} p_D(\hat{I}_D, I_{Dm})\left\langle\int_{\hat{I}_I=10Log\left[10^{\frac{\hat{c}-PR}{10}}-10^{\frac{N}{10}}-10^{\frac{\hat{I}_D}{10}}\right]}^{+\infty} p_I(\hat{I}_I, I_{\text{Im}})\,d\hat{I}_I\right\rangle d\hat{I}_D\right\}d\hat{c} \tag{5}$$

where:

p_D : lognormal random variable with standard deviation[25] of 5.5 dB and mean of I_{Dm} related to the existing DTT interfering signal;

p_I: lognormal random variable with standard deviation[25] of 5.5 dB and mean of I_{Im} related to the other service interfering signal.

The probability calculated using equations (1), (3), (4) or (5) can be translated in terms of impacted population in a pixel, an area containing several pixels, or the entire DTT service area. In order to make this translation, it is required to know the population of each pixel ($\text{Pop}_{\text{pixel}}$). This can be obtained, for example, using a layer in the simulation software, corresponding to the type of area where the considered pixel is located.

In a given pixel, the total amount of interfered population, $\text{Pop}_{\text{int\_pixel}}$, is then obtained by multiplying the amount of population in that pixel, $\text{Pop}_{\text{pixel}}$, by the factor F calculated above in equations (1), (3), (4) or (5).

$$Pop_{\text{int}\_pixel} = Pop_{pixel} \cdot F \tag{6}$$

This is the end of the process if the only objective is to obtain an assessment of the interfered population in a single pixel.

In order to assess the amount of interfered population in an area (that could be the whole DTT service area), $\text{Pop}_{\text{int\_area}}$, it is necessary to sum the information obtained for each pixel that is contained in that area, as follows:

$$Pop_{\text{int}\_area} = \sum_{pixels} Pop_{\text{int}\_pixel} \tag{7}$$

3 Conclusions

The methodology described above allows the evaluation of the amount of population that could be impacted by the introduction of mobile networks operated in adjacent bands into the DTT reception.

This method can be used taking into account the actual implementation of mobile networks, the actual DTT planning configuration and a digital terrain model. Digital terrain models, building clutter data

---

[25] According to different models, this standard deviation can vary for closer distances.

and appropriate propagation models should be used to improve the accuracy of the results. This would allow administrations to determine more precisely where mitigation measures might be required in order to protect DTTB reception, and assist them to determine the potential costs of these measures.

Some assumptions are made in order to simplify calculations, like the fact of considering a single main interferer. This simplification is valid in cases where the contribution of a main interferer is dominant compared to secondary interferers.

Attachment to Annex 3

Example of application

1 Introduction

In the following example, the methodology described in Annex 3 is applied to assess the amount of population potentially interfered with by an LTE network situated in the area of Laval (France), limited to the area of La Mayenne. Channel 60 is used in the DTT network.

FIGURE 1

Mayenne Area in France where channel 60 will be used for DTT

FIGURE 2

Coverage of Mayenne area with the main DTT transmitter (Mont-Rochard) and secondary ones

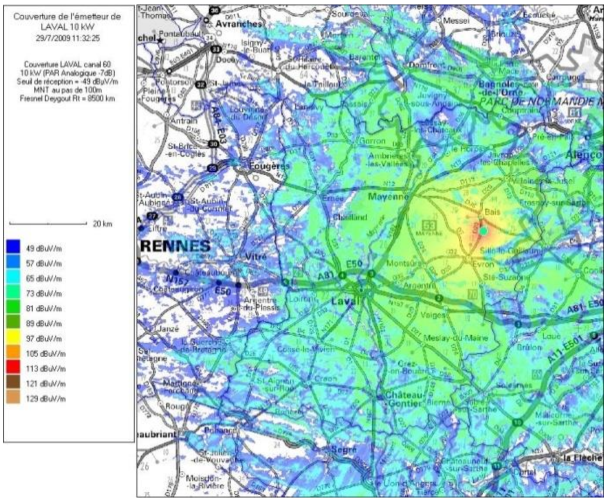
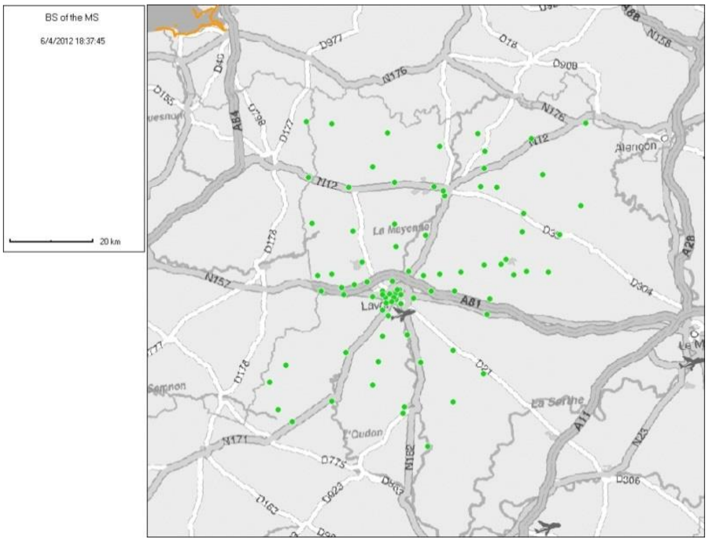


FIGURE 3

Example of one LTE network based on a GSM 900 network



Three LTE networks have been simulated, as using the three 10 MHz blocks of the downlink band plan of LTE in the 800 MHz band (791-801 MHz, 801-811 MHz, 811-821 MHz), based on the GSM 900 networks, with in-block e.i.r.p. of 64 dBm and ACLR of 64 dB.

The selected interferer is the transmitter whose field strength has the highest impact at the DTT receiver frequency, taking into account the PR (thus ACLR) as well as the antennas directivity and polarization discriminations.

2 Characteristics of the mobile network

The methodology described in Annex 3 is used for the case of an actual deployment of mobile base stations.

In this example base stations of GSM 900 networks are used to approximate the results expected by simulating a LTE network in UHF band.

The parameters used for the deployment of the mobile network include geographic coordinates, antenna height, antenna tilt and power levels. The power levels could be set depending on the environment (i.e. different power levels, or set at a fixed level, i.e. 59 dBm or 64 dBm). In this example, an e.i.r.p. of 64 dBm is used.

It has to be noted, that antenna tilt can be adjusted mechanically or electronically. Therefore, this parameter is subject to variations. Also, depending on the transmission mode, the power levels can vary.

If known, the exact antenna diagrams of base stations should be used in order to obtain accurate results. Otherwise, it can be considered that base stations use tri sectorial antennas or omnidirectional antenna in the horizontal plane. In the vertical plane, antenna diagrams according to Recommendation ITU-R F.1336-2 might be used. Nevertheless, the degree of uncertainty in the calculations increases by not using the exact antenna diagrams.

In this example the propagation model used for the interfering signal from mobile base stations is based on the Okumura-Hata propagation model and takes into account digital terrain model (DTM) with a 100 m step and building clutter data.

3 Characteristics of the broadcasting network

The methodology described in Annex 3 (Equation 1) above is used for the case of actual deployment of DTT transmitters, including the antenna diagrams in the horizontal and vertical planes.

Protection ratios and overloading thresholds are taken from Recommendation ITU-R BT.1368.

Directivity discrimination of antennas in the reception of DTT broadcasting used are in accordance with Recommendation ITU-R BT.419.

Depending on the reception mode used, polarization discrimination is taken into account according to the polarization of the wanted and the interfered signal, i.e. 0 dB for same polarizations, 16 dB for orthogonal polarizations or 3 dB for slant polarization.

Antenna and polarization discriminations are calculated using the location of the best server (DTT transmitter giving the best wanted signal) and the location of the base stations considered to cause the strongest interfering signal.

4 Results

In this example, the percentage of population that might suffer from interference in the considered area according to the methodology described in Annex 3 is about 4.8% using a PR for 50% of the receivers and about 7.81% for PR for 90% of the receivers. These protection ratios are taken from Recommendation ITU-R BT.1368.

This methodology can also be applied in the cases of DTT portable outdoor and mobile reception. In the case of DTT portable indoor reception, wall loss and its statistical variation as well as variation of wanted signals in an indoor propagation environment should be taken into account.