International Telecommunication Union

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Radiocommunication Sector of ITU

# Recommendation ITU-R BT.2136-0

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# Assessing interference into digital terrestrial television broadcasting from other services by means of Monte Carlo simulation

BT Series
Broadcasting service
(television)

International Telecommunication Union

## Foreword

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

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Geneva, 2020

# RECOMMENDATION ITU-R BT.2136-0*

## Assessing interference into digital terrestrial television broadcasting from other services by means of Monte Carlo simulation

(2020)

### Scope

This Recommendation defines the methodology to be used to assess interference into digital terrestrial television broadcasting (DTTB) from other services, when Monte Carlo simulation is employed. It also provides guidance on how the results of such Monte Carlo simulation can be interpreted against guideline protection criteria given in Recommendation ITU-R BT.1895.

### Keywords

DTTB, Monte Carlo, Quality of Service, Time Window, Probability of Interference, Probability of Disruption

The ITU Radiocommunication Assembly,

*considering*

*a)* that Article 5 of the Radio Regulations (RR) allocates frequency bands to the terrestrial broadcasting service on a primary basis;

*b)* that the terrestrial broadcasting service is planned on a noise-limited basis, taking into account intrinsic receiver noise and external radio noise;

*c)* that broadcasting services may also be planned on an interference-limited basis;

*d)* that Recommendation ITU-R P.372 describes levels of external radio noise, which are applied to planning of broadcasting services;

*e)* that Recommendation ITU-R SM.1757 and Report ITU-R SM.2057 provide guidance on the protection requirements for the various radiocommunication services in respect of the aggregate emissions from devices using ultra-wideband technology;

*f)* that Recommendation ITU-R BT.1895 recognises the principles above and provides guidelines to ensure that total interference at the broadcasting receiver from all radiations and emissions from radiocommunication services and other sources of radio-frequency emissions should not exceed specific limits of the total receiving system noise power thus degrading the performance of terrestrial broadcasting systems beyond acceptable levels;

*g)* that protection criteria for intra-service broadcasting applications have been specified in ITU-R Recommendations (for example Recommendations ITU-R BT.1368, ITU-R BT.2033) and Regional Agreements, e.g. GE-06;

*h)* that two approaches, “deterministic” and “probabilistic” can be used to assess interference into DTTB. Deterministic approaches, while being simple, do not always provide a complete assessment of the interference scenarios that may arise;

*i)* that Monte Carlo simulation is increasingly being used within some services specifically to assess their compatibility with other radiocommunication systems;

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* Radiocommunication Study Group 6 made editorial amendments to this Recommendation in the year 2021 in accordance with Resolution ITU-R 1.

*j)* that the Monte Carlo simulation methodology, used to assess the compatibility between radiocommunications systems, provides the average probability of interference or the average loss of throughput, at any one instant in time, and does not account for interference that may occur within a time window due to changes with time, for example in the relative position and/or power of transmitters within the interfering network;

*k)* that unlike some radiocommunications systems, the broadcasting service cannot re-send data that has failed to be received and cannot adapt the bit rate to suit the state of the RF channel, so the quality of service (QoS) is therefore strongly dependent on the signal quality at the reception point;

*l)* that the criterion for satisfactory reception of DTTB is that the received service is Quasi-Error Free (QEF) and that the probability of disruption to a DTTB service derived by a Monte Carlo simulation is the probability that one or more interference events occur to the received signal (e.g. picture) in an hour;

*m)* that, for the above reasons (*j*, *k*, *l*), in the case of DTTB the outcome of Monte Carlo simulation may need to be post-processed to take into account state changes occurring in the interfering network within a time window;

*n)* that sharing and compatibility studies between radiocommunications services are usually required in cases where new allocations are being considered;

*o)* that in such studies values of technical system parameters for both services under study need to be supplied,

*recognizing*

the obligations incumbent on administrations through Articles 42 and 45 of the ITU Constitution (Nos. CS 193, CS 197, CS 198 and CS 199) to ensure the continued availability of the RF spectrum and guard against harmful interference,

*noting*

*a)* that Report ITU-R SM.2028 – Monte Carlo simulation methodology for the use in sharing and compatibility studies between different radio services or systems, describes a Monte Carlo radio simulation methodology;

*b)* that Report ITU-R BT.2469 – Characteristics of digital terrestrial broadcasting systems in the frequency band 174-230 MHz, and Report ITU-R BT.2383 – Characteristics of digital terrestrial television broadcasting systems in the frequency band 470-862 MHz, contain parameters for the broadcasting service for the purpose of use in sharing and compatibility studies;

*c)* that Report ITU-R BT.2470 – Use of Monte Carlo simulation to model interference into DTTB, provides additional information and examples on the use of Monte Carlo simulation to model interference into DTTB reception for use in sharing and compatibility studies between DTTB systems and other radiocommunications services;

*d)* that Report ITU-R BT.2265 – Guidelines for the assessment of interference into the broadcasting service, outlines possible approaches for protecting broadcasting from interference originating from other services and interference originating from devices/applications without a corresponding frequency allocation and provides guidance to assist administrations in planning the use of the spectrum in an efficient manner;

*e)* that Recommendation ITU-R M.1634 – Interference protection of terrestrial mobile service systems using Monte Carlo simulation with application to frequency sharing, is a source of information on the use of the Monte Carlo method of analysis and recommends the use of a probabilistic approach when assessing potential interference;

*f)* that Recommendation ITU-R M.2101 – Modelling and simulation of IMT networks and systems for use in sharing and compatibility studies, contains the methodology for modelling and simulation of IMT networks for use in sharing and compatibility studies between IMT and other systems and/or applications. As such, it does not make any assumptions on the system parameters or modelling of these other systems and/or applications and is strictly limited to providing information for the IMT systems,

*recommends*

**1** that the methodology outlined in Annex 1 of this Recommendation should be used in studies, based on Monte Carlo simulation, that assess interference into DTTB from other services;

**2** that the parameters in Annex 2 concerning the broadcasting service should be used in such studies.

This Recommendation contains the following Annexes:

**Annex 1** – Methodology to be used in Monte Carlo simulation.

**Annex 2** – DTTB Parameters to be used in Monte Carlo simulation.

# Annex 1

# Methodology to be used in Monte Carlo simulation

## 1 Introduction

Monte Carlo simulation is a statistical method widely used to solve complex mathematical problems, to model physical phenomena or to understand complex real-life problems that cannot be easily modelled by analytical methods. Monte Carlo simulation is based on random sampling to generate a large number of events (experiments), according to the model implemented to describe a physical phenomenon.

Monte Carlo simulation is increasingly being used as the method for assessing interference in compatibility studies between mobile, fixed and broadcast services. The Monte Carlo simulation methods used to assess interference into and from bidirectional systems, provide information on the average probability of interference for any one moment in time. Usually, in bidirectional systems, this probability is mapped onto a loss of data throughput. Such simulations are ideal for assessing interference (blocking) in bidirectional systems that can re-send data not received. A method is required that suits assessing interference into broadcast systems of unidirectional design.

Modelling the probability of interference into DTTB using Monte Carlo simulation[1] poses some unique problems as quality of service is measured in a one hour time window and Monte Carlo simulation provides a probability of interference at one moment in time.

If the network being modelled does not change with time, i.e. the interferer position is fixed, and the transmitted power is constant, then there is a single event and the calculated probability of interference using a Monte Carlo simulation is valid for any time window. If, however, the network varies, in the

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[1] Report ITU-R SM.2028 provides background information on Monte Carlo simulation methodology for assessing compatibility between radio communication systems and their application in the Spectrum Engineering Advanced Monte Carlo Analysis Tool (SEAMCAT) software.

case of fixed interferers the power varies between off and fully on, or there is movement or change in position of the interferers in the network, then the calculated probability of interference is only valid for one moment in time or state of the network. To understand the probability of one or more interference events occurring in a one hour time window, further processing is needed as follows[2].

## 2 Method

In Monte Carlo simulation, depending on the interference scenario, a large number ($K$) of events (experiments) may need to be generated to obtain a reliable result. The events generated by Monte Carlo simulation are independent – the outcome of any one event having no effect on the probability of any other event.

The probability of interference ($p_I$) is calculated from the generated data arrays of received useful and interfering signal levels, *DRSS* and *IRSS*, based on a given interference criterion threshold ($C/I$, $C/(I+N)$, $I/N$ or $(N+I)/I$). The probability of interference calculated for $K$ events is expressed as:

$$p_I = 1 - p_{NI} \tag{1}$$

where $p_{NI}$ is the probability of non-interference of the receiver. This probability can be calculated for different interference types (unwanted emissions, blocking, overloading and intermodulation) or combinations of them.

The interference criterion $C/(I+N)$ should be used for assessing the impact of the interfering transmitters on DTTB reception, where $C/(I+N)$ is equal to the DTTB system $C/N$. For a constant interferer transmit power $p_{NI}$ can be calculated as follows:

$$\begin{aligned} p_{NI} &= P\left(\frac{DRSS}{IRSS_{composite}+N} \geq \frac{C}{I+N}\right), for\ DRSS > Rx_{sens} \\ &= \frac{\sum_{i=1}^{M} 1\left\{\frac{DRSS(i)}{IRSS_{composite}(i)+N} \geq \frac{C}{I+N}\right\}}{M} \end{aligned} \tag{2}$$

where:

$$1\{condition\} = \begin{Bmatrix} 1, & if\ condition\ is\ satisfied \\ 0, & else \end{Bmatrix}$$

$$IRSS_{composite}(i) = \sum_{j=1}^{L} IRSS_{(j)}^{(i)}$$

| | |
|---|---|
| *DRSS* : | received useful signal level |
| *IRSS* : | received interfering signal level |
| $Rx_{sens}$: | Receiver sensitivity |
| $M$ : | number of events where $DRSS > Rx_{sens}$. Note that in most cases $M < K$ (number of events generated) |
| $L$ : | number of interfering transmitters |

Note that $\frac{DRSS}{IRSS_{composite}+N} \geq \frac{C}{I+N}$ condition checks if the sum of the interfering signals received from different fixed interferes causes interference into DTTB receiver, at a time instance.

The degradation of DTTB reception in the presence of interfering signals can easily be calculated as follows:

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[2] Report ITU-R BT.2470 provides further information on the Monte Carlo method described in this Recommendation along with example calculations.

$$\Delta p_I = P_I\,(N{+}I) - P_I\,(N) \tag{3}$$

where:

$P_I\,(N)$: $p_I$ in the presence of noise only

$P_I\,(N{+}I)$: $p_I$ in the presence of noise and interference.

From equation (2), it is obvious that $P_I\,(N) = 0$. Then, the following can be written:

$$\begin{aligned}\Delta p_I &= P_I\,(N{+}I)\\ &= p_I \end{aligned} \tag{4}$$

From equation (4) it can be concluded that the degradation of DTTB reception in the presence of interfering signals is simply $p_I$ calculated in Monte Carlo simulation as described by equations (1) and (2).

It should be noted that the $p_I$, being an average probability over all samples across the area of the simulation, will be significantly influenced by the interference scenario being modelled. For example, the $p_I$ calculated in a 100 m × 100 m pixel at the edge of the DTTB coverage area will be, because of low wanted signal levels, much higher than a $p_I$ calculated across the overall DTTB coverage area.

It is also important to bear in mind that the $p_I$ is invariant in time. If the occurrence of interference ($I$) and non-occurrence of interference ($NI$) are considered as the two values of a Bernoulli random variable $X$ that represents the state of interference, then it is possible to write:

$$P(X{=}I) = p_I$$

$$P(X{=}NI) = 1 - p_I$$

The degradation of the reception location probability ($\Delta p_{RL}$) of DTTB can be calculated as follows:

$$\begin{aligned}\Delta p_{RL} &= p_{RL} - (p_{RL} - p_I)\\ &= p_I \end{aligned} \tag{5}$$

where:

$p_{RL}$: target reception location probability

$p_I = 1 - p_{NI}$: which is the probability of interference calculated using Monte Carlo simulation.

## 2.1 Fixed interferer

In the case of fixed interferers, that is if the source or sources of interference do not move (e.g. mobile base station), the impact of the interference on the DTTB coverage area most often appears as holes (or areas) where the required QoS can no longer be ensured due to the interference. Such holes are often near the interfering transmitters.

### 2.1.1 Calculation of the probability of interference into DTTB reception in the case of fixed interferers with constant transmit power

In the case of fixed interferers with constant (invariant in time) transmit power then there is a single event and the calculated probability of interference using a Monte Carlo simulation is valid for any time window.

### 2.1.2 Calculation of the probability of interference into DTTB reception in the case of fixed interferers with varying transmit power

If the transmitted power of the interferer varies in time according to a duty cycle or a given probability distribution, the $p_{NI}$ cannot be appropriately calculated from equation (2), because DTTB quality of service is assessed in a one-hour time window (*TW*). Equation (2) can only be used if the interferer transmit power is constant § 2.1.1.

For example, if a DTTB receiver at a given location is interfered with by a fixed interfering transmitter transmitting at constant power for 100% of the time, then the $p_I$ calculated from equations (1) and (2) will be 1 (100%). Now, if the same transmitter had a 50% duty cycle, i.e. is off for 50% of the time and on for the rest 50% of the time, the calculated $p_I$ would be 0.5 (50%). If the duty cycle was 10% then the calculated $p_I$ would be 0.1 (10%), etc. However, from the viewer's point of view, the DTTB reception is systematically interfered with by the interfering transmitter, that is $p_I = 1$ (100%) in all the cases. In fact, in a one-hour *TW*, whether the DTTB reception is disrupted during 100% or for only 10% of time does not change the perception of the viewer who experiences an unacceptable QoS in both cases.

This duty cycle is also often modelled as an effective reduction in the base station transmitted power. A 50% duty cycle corresponds to a 50% activity factor which is modelled as a 3 dB reduction in power and a consequent reduction in a calculated $p_I$ compared with that when the base station transmits at maximum power. This approach is not valid for studies involving DTTB, as with such a method the transmitter is never modelled at its maximum power in a one-hour time window.

In the interference scenario considered above, a similar problem will occur when the interferer transmit power varies in time according to a given probability distribution. From the point of view of actual interference into DTTB, information is required as to whether or not the interferer operates at full power at some point within the one-hour *TW*. If it does then the $p_I$ that a DTTB receiver will be subject to one or more interference events from a single source of interference can be estimated by assuming that the interferer operates at maximum power. This is valid for the case of a single interferer. If however, there is more than one interferer, all operating at full power, this would, because of the power sum ($IRSS_{composite}$), overestimate the probability of interference. In such a case the actual $p_I$ would lie between that if there was one interferer and that if all interferers operated at full power ($p_{I\,single} < p_I < p_{I\,multiple}$).

Based on the above observations, equation (2) is modified to take into account the variation of the interferer transmit power in time, while taking into account the fact that a given interfering transmitter operates at maximum power at some point within the one-hour *TW*.

Consequently, when assessing the interference from radio services or systems to DTTB in the presence of fixed interferers $p_{NI}$ is calculated including the logical checks required as follows:

$$p_{NI} = P\left(\left(\frac{DRSS}{IRSS_{composite}+N} \geq \frac{C}{I+N}\right) \wedge (PMAX_{check} = L)\right), for\ DRSS > Rx_{sens}$$

$$= \frac{\sum_{i=1}^{M} 1\left\{\left(\frac{DRSS(i)}{IRSS_{composite}(i)+N} \geq \frac{C}{I+N}\right) \wedge (PMAX_{check}(i) = L)\right\}}{M} \qquad (6)$$

where:

$$1\{condition\} = \begin{Bmatrix} 1, & if\ condition\ is\ satisfied \\ 0, & else \end{Bmatrix}$$

$$IRSS_{composite}(i) = \sum_{j=1}^{L} IRSS_{(j)}^{(i)}$$

$$PMAX_{check}(i) = \sum_{j=1}^{L} \mathbf{1}\left\{\frac{DRSS(i)}{IRSS_{PMAX_{(j)}^{(i)}}+N} \geq \frac{C}{I+N}\right\}$$

$M$ = number of events where $DRSS > Rx_{sens}$. Note that in most cases $M < K$

$L$ = number of interfering transmitters

$IRSS_{PMAX}$: received interfering signal level for the maximum transmit power invariant in time.

Note that:

$\frac{DRSS}{IRSS_{composite}+N} \geq \frac{C}{I+N}$ checks if the sum of the interfering signals received from different fixed interferes causes interference into DTTB receiver, at a time instance $T_X$.

$\frac{DRSS(i)}{IRSS_{PMAX}{}_{(j)}^{(i)}+N} \geq \frac{C}{I+N}$ checks if transmitter (j) operating at maximum power causes interference into DTTB receiver within a time window.

Note also that for a given time instance $i$, the $L$ $iRSS_{PMAX}{}^{i}{}_{j}$ are independent variables, where the index $j$ corresponds to the $j$-th interfering signal received by the victim receiver. Therefore, one of these $L$ $iRSS_{PMAX}$ interfering signals is always predominant with respect to all the others. The predominant $iRSS_{PMAX}$ level is called $iRSS\_PMAX_{max}$.

For a given time instance $i$:

– if $\frac{dRSS(i)}{iRSS\_PMAX_{max}(i)+N} \geq \frac{C}{I+N}$, then $PMAX_{check}(i) = \mathrm{L}$

– if $\frac{dRSS(i)}{iRSS\_PMAX_{max}(i)+N} < \frac{C}{I+N}$, then $PMAX_{check}(i) = 0$

Consequently,

$$PMAX_{check}(i) = \sum_{j=1}^{L} \mathbf{1}\left\{\frac{DRSS(i)}{IRSS_{PMAX}{}_{(j)}^{(i)} + N} \geq \frac{C}{I+N}\right\}$$
$$= \mathbf{1}\left\{\frac{DRSS(i)}{IRSS\_PMAX_{max}(i) + N} \geq \frac{C}{I+N}\right\}$$

Then, equation (6) can be rewritten including the logical checks required as:

$$p_{NI} = \frac{\sum_{i=1}^{M} 1\left\{\left(\frac{DRSS(i)}{IRSS_{composite}(i)+N} \geq \frac{C}{I+N}\right) \wedge \left(\frac{DRSS(i)}{IRSS\_PMAX_{max}(i)+N} \geq \frac{C}{I+N}\right)\right\}}{M} \qquad (7)$$

### 2.1.3 Relationship between probability of interference and *I*/*N*

The result of Monte Carlo simulation provides a probability of interference $p_i$. Recommendation ITU-R BT.1895 provides guideline information on the permissible increase in interference (10% or 1%) depending on whether the interferer is co-primary or not. The percentages provided in BT.1895 equate to $I/N$ of −10 dB and −20 dB respectively and have equivalent probability of interference, for 95% locations served at the edge of DTTB coverage, as shown in Table 1.

TABLE 1

**Required probability of interference in a 100 m × 100 m pixel at the edge of DTTB coverage**

| **Required probability of interference ($p_I$) for 95% locations equivalent to the protection in a 100 m × 100 m pixel at the edge of DTTB coverage provided in Rec. ITU-R BT.1895** | | | |
|---|---|---|---|
| **$p_I = \Delta p_{RL}$ (%) (95% locations)** | 0.086 | 0.869 | 2.22 |
| **Equivalent $I/N$ (dB)** | −20 | −10 | −6 |

*Note* 1: The $I/N$ of −20 and −10 dB are equivalent to guideline values provided in Rec. ITU-R BT.1895. The $I/N$ of −6 dB is a further value beyond BT.1895 that is often used in compatibility studies within some regions.

*Note* 2: 95% locations served at cell edge is equivalent to $99.4 \leq X \leq 99.6$ (see Report ITU-R BT.2470) by cell area[3].

## 2.2 Moving interferer

A moving interferer may change its:

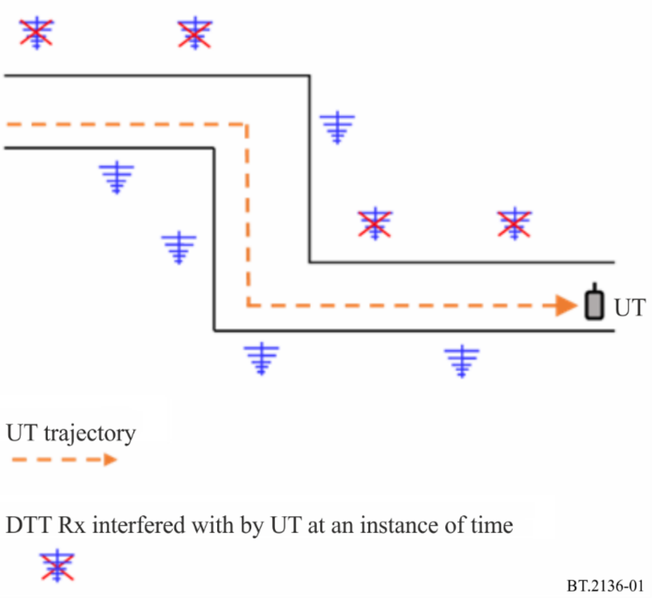
- power in time according to a power control scheme;
- position and location in time.

Change in position or location may cause interference successively to different DTTB receivers or may bring it into range of a particular receiver as shown in Fig. 1.

Obviously, the impact of such interferers on the DTTB coverage area does not appear as holes (or areas) where the required QoS cannot be ensured. Consequently, in the case of moving interferers (e.g. mobile user terminals), the impact of the interference on the reception location probability ($P_{RL}$) cannot be estimated as described in equation (5).

FIGURE 1

**Impact of a moving interferer (user terminal) on DTTB reception**



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[3] An estimate of the relationship between cell edge and area coverage is provided by Jakes, Microwave Mobile Communications, section 2.5.3, p. 126, IEEE press 1993.

Therefore, with moving interferers, when assessing their impact on DTTB reception, the problem becomes more complicated as their movement in time needs to be taken into account. It should be clear that the $p_I$ calculated in Monte Carlo simulation, as described by equations (1) and (2) or equations (1) and (6), cannot be directly used to assess the impact of moving interferers on DTTB reception due to the fact that $p_I$ does not provide information on the probability that a DTTB receiver will be subject to one or more interference events within a given *TW*.

### 2.2.1 Probability of disruption

As explained in the previous section, in the case of moving interferers the continuity in time should be taken into account by converting the $p_I$ calculated in the Monte Carlo simulation into a probability which would better reflect the impact of interference on DTTB reception. This probability is called "probability of disruption". The method used to calculate this probability is described below.

The $p_I$ derived from Monte Carlo simulation, by using equations (1) and (2) or equations (1) and (6), provides information on the probability that a DTTB receiver would be subject to interference at any instant (moment) in time. It does not give the probability that a DTTB receiver will be subject to one or more interference events within a given time window. Thus, it is necessary to extend the result of Monte Carlo simulation to take account of the period in time over which DTTB QoS is assessed, one hour.

The probability of interference ($p_I$) is invariant in time (constant). If the occurrence of interference (*I*) and non-occurrence of interference (*NI*) are considered as the two values of a Bernoulli random variable *X* that represents the state of interference, then it is possible to write:

$$P(X=I) = p_I$$

$$P(X=NI) = 1 - p_I$$

where:

*I*: interference

*NI*: non-interference.

Now let us split a one-hour *TW* in "*n*" time intervals. If the value of *n* is appropriately chosen each time interval can be considered as a Bernoulli trial (a random experiment) with outcomes "*I*" and "*NI*" [7]. These outcomes are called "Interference events". Within the one-hour *TW* it can be considered that "*n*" repeated Bernoulli trials occur, here it is obviously assumed that each trial is independent, then the probability that a DTTB receiver is subject to *k* interference events within the *TW* is expressed as follows:

$$P(X = k) = \binom{n}{k} p_I^k (1 - p_I)^{n-k} \tag{8}$$

where:

$p_I$: probability of interference calculated in Monte Carlo simulation as described by equations (1) and (2)

$n$: number of independent trials

$k$: number of trials resulting in interference events.

The probability that a DTTB receiver is not subject to any interference events is given by setting $k = 0$ in equation (8):

$$P(X = 0) = (1 - p_I)^n$$

And finally, the probability that a DTTB receiver is subject to at least one interference event can be calculated from:

$$P(X > 0) = 1 - (1 - p_I)^n$$

This probability is called probability of disruption ($p_d$) and is expressed as follows:

$$p_d = 1 - (1 - p_I)^n \tag{9}$$

Such a probability $p_d$ could be understood as the probability of having one or more uncorrelated disruptions to the DTTB service during a given time window. The time window should reflect what is used to assess the QoS for DTTB which is, in turn, considered acceptable for the TV viewer (one hour).

### 2.2.2 Derivation of independent events

Independent events can be generated by either movement of interferers (user terminals) or by switching between different interfering sources (user terminals).

#### 2.2.2.1 Independent network configurations generated by moving user terminals

For a given *TW* and the distribution of UT velocity, the proportion of UT moving a certain distance can be readily calculated. From the distance UT move and the decorrelation distance, the number of uncorrelated states "*n*" generated in a *TW* by UT can be derived as follows:

$$n = TW * \sum_i^k \frac{P_i V_i}{D_i} \tag{10}$$

where:

*D*: decorrelation distance in metres

*V*: velocity in metres/second of UT

*P*: proportion of UT moving at velocity *V*

*k*: number of velocity values

*TW*: time window in seconds (for DTTB *TW* = 3 600 seconds).

#### 2.2.2.2 Independent network configurations generated by the scheduler in OFDMA/SC-FDMA based mobile networks

Allocation of physical resource blocks (PRB) for uplink transmission is initiated at the request of UT and made per UT by the uplink scheduler. The allocation of PRB by the scheduler to a UT is independent of the previous requests of the UT and consequently it can be considered as an independent state.

The number of independent states generated in a *TW* by the scheduler as it cycles through UT registered in the cell is given by:

$$n = \frac{M}{A} \tag{11}$$

where:

*M*: maximum number of active UT per sector (or cell) in *TW*

*A*: average number of active UT per sector (or cell) in the Monte-Carlo simulation.

### 2.2.3 Determination of the number of independent network configurations in the specified TW

As explained in the previous two sections, the number of independent state changes *n* within the specified TW depends on the number of active interferers and the distance an interferer needs to move before an interference event caused by the interferer becomes independent relative to a previous event. The number of uncorrelated events "*n*" generated in a *TW* by UT can be calculated using equations (10) and (11):

$$n = \frac{M}{A} + TW * \sum_{i}^{k} \frac{P_i V_i}{D_i} \quad (12)$$

$M$: maximum number of active UT per sector (or cell) in $TW$

$A$: average number of active UT per sector (or cell) in the Monte-Carlo simulation

$D$: decorrelation distance in metres

$V$: velocity in metres/second of UT

$P$: proportion of UT moving at velocity $V$

$k$: number of velocity values

$TW$: time window in seconds (for DTTB $TW$ = 3 600 seconds).

If there is no movement of UT in *TW*, either because UT are fixed, or the *TW* is very short – for example 1 ms, the summation term will be zero, or very close to zero, and the number of events will be provided by *M*/*A*. Consequently, *M*/*A* will vary between 1 and the number of UT active in *TW* – in some case this may be the same.

For example, if the state of UT changes every 1 ms and *TW* is short 1 ms, then $M = A = 1 = n$ and from equation (9) $p_d$ will equal $p_I$.

If *TW* is long relative to the time the network changes state, for example *TW* is one hour (3 600 seconds), a large number of UT could be expected to be active. Within the one-hour *TW*, UT in the cell may remain stationary, some will move within the cell, others will move and leave the cell and some will enter the cell. The interest is the number of these UT that transmit at least once during *TW*. Every UT that transmits in *TW*, the number being *M*, generates or contributes to at least one event. It also needs to be considered how many UT, the number being *A*, are considered in the Monte Carlo simulations. In the case that only one UT is considered, there would be *M* events. If more than one UT is considered as active at any one time in the Monte Carlo simulations, then it needs to be considered in the number of events generated, hence *M/A*. M and A should be appropriate for the systems and environment being considered in sharing and compatibility studies.

### 2.2.4 Probability of disruption and impact on DTTB coverage

In the case of fixed interferers, as demonstrated in § 2, the $p_I$ calculated by Monte Carlo simulation is an estimation of the degradation of the reception location probability ($\Delta p_{RL}$). That is a $p_I$ of 2% calculated in a pixel of 100 m × 100 m means that in the 2% of the area of the pixel all the DTTB receivers may be interfered with by the fixed interferers. The interfered areas appear as fixed holes (or areas) where the required QoS cannot be ensured, which shows directly the impact of the interference on DTTB coverage.

In the case of moving interferers, the $p_I$ calculated by Monte Carlo simulation cannot be directly used to assess the impact of interference on the DTTB coverage as the impact of such interferers on the DTTB coverage area does not appear as fixed holes (or areas) where the required QoS cannot be ensured. This is the reason why the $p_d$ was introduced in § 2.2.1, which is the probability that at least one interference event occurs to the received signal (e.g. picture) in a time window (*TW).* In other words, the $p_d$ is the probability that the required QoS cannot be ensured in the *TW*.

Nevertheless, it is possible to show that there is an equivalence between the $p_d$ and the $\Delta p_{RL}$ for $p_d$ values lower than 1% and up to a $p_d$ of 3% there is good correlation with $\Delta p_{RL}$ (see Report ITU-R BT.2470). For higher $p_d$ values the high divergence between the $p_d$ and the $\Delta p_{RL}$ prevents their direct comparison for the benefit of $p_d$.

However, when comparing the $p_I$ calculated in the case of fixed interferers and the $p_d$ calculated in the case of moving interferers, it is important to remember that in the latter case the interfered areas do not appear as fixed areas. These interfered areas are small areas appearing and disappearing anywhere in a given DTTB coverage area. Such behaviour prevents identifying the interfered areas and implementing an adequate mitigation technique to solve or minimize the interference into DTTB.

# Annex 2

# DTTB parameters to be used in Monte Carlo simulation

TABLE 2

**DTTB parameters**

**a) DTTB system independent (1)**

| **Parameters (2)** | **Unit** | **Simulation requirement** |
|---|---|---|
| e.i.r.p. | dBm | Required |
| Transmitter antenna height | m | Required |
| Receiver antenna height | m | Required |
| Center frequency | MHz | Required |
| Channel BW | MHz | Required for the determination of the effective BW |
| Noise figure (F) | dB | Required |
| Noise power (Pn) | dBm | Required |
| Cell edge location probability (LP) | % | Required for the calculation of the coverage radius |
| Coverage-area location probability | % | Required for the deteremination of the acceptable/permissible probability of interference |
| Gaussian confidence factor for cell edge coverage probability of 95% ($\mu_{95\%}$) | % | Required for the calculation of the log normal fading margin (lm) for 95% |
| Shadowing loss standard deviation ($\sigma$) | dB | Required |
| Log normal fading margin ($L_m$) for 95% | dB | Required for the calculation of the Pmean for LP=95% |
| Pmean for LP = 95% | dBm | Required for the calculation of the coverage radius |
| Cable loss (Lcable) | dB | Required |
| Receiver antenna gain (Giso) | dBi | Required |
| Coverage radius calculated by ITU-R P.1546 propagation model (Beam tilts = 1° and 1.6°) | km | Required |
| Adjacent channel selectivity (ACS) | dB | Required |
| Boltzmann's constant (k) | J/K | Required for the calculation of the noise power |
| Absolute temperature (T) | K | Required for the calculation of the noise power |

(1) Different parameter values may be used for different DTTB systems and by individual countries/regions according to their requirements and planning scenarios.

(2) Parameters for DTTB systems can be found in Report ITU-R BT.2383.

### b) DTTB system dependent (3)

| Parameters | Unit | Simulation requirement |
|---|---|---|
| Effective BW | MHz | Required |
| Carrier to noise ratio ($C/N$) at cell edge | dB | Required for the calculation of the coverage radius |
| Protection criterion ($C/(N+I)$) (4) | dB | Required |
| Receiver sensitivity ($P_{min}$) | dBm | Required |

(3) Different parameter values may be used by individual countries/regions according to their requirements and planning scenarios.

(4) Other protection criterion (e.g. $C/I$ or $I/N$) may be chosen by individual countries/regions.