SEAMCAT®

User Documentation*

August 2001

* This document was amended in August 2001.

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1. Introduction

1.1. Background

The radio spectrum is a limited resource and can only be used optimally, if compatibility is assured between radio systems located in the same or adjacent frequency ranges. For example, an important criterion for radio compatibility is the difference in level between the wanted and unwanted signals in the victim receiver input. This parameter is used to derive a separation in the space or frequency domains for the different radio services. Considering only the adjacent bands, the most significant interferencing mechanisms are the unwanted emissions from the transmitters, and blocking and intermodulation in the victim receiver.

The classical approach for the estimation of these influences is the minimum coupling loss method. Within the frame of the CEPT Working Group Spectrum Engineering, a new statistical simulation model has been developed which is based on the Monte Carlo method. This model, SEAMCAT® (The Spectrum Engineering Advanced Monte Carlo Analysis Tool), allows the consideration of spatial and temporal distributions of the received signals, and therefore enables more efficient use of the spectrum.

1.2. About this documentation

The documentation covers the following points:

- Explaining the general architecture of the software,
- Explaining all the inputs in details and their function,
- Describing the principles and the key algorithms (signal level calculations + probability calculations) necessary for a good understanding.

In its first phase, the documentation will also identify the points where the authors do not have a full understanding.

This documentation complements the specification[1] ERO/1205MC and the ERC report 68.rev1 [2].

1.3. Interest of SEAMCAT

The Monte-Carlo simulation method is based upon the principle of taking samples of random variables from their defined probability density functions (also called distributions). The user inputs distributions of possible values of the parameters, and the software uses them to extract samples (also called trial or snapshot). Then, for each trial SEAMCAT calculates the strength of the interfering and the desired signal and stores them as arrays.

The software derives the probability of interference taking into account the quality of the receiver in a known environment, and the calculated signals.
The Monte Carlo method can address virtually all radio-interference scenarios, like e.g. sharing or compatibility studies. This flexibility is achieved by the way the system parameters are defined. Each random parameter (antenna pattern, radiated power, propagation path,…) is input as a statistical distribution function. It is therefore possible to model even very complex situations by relatively simple elementary functions. A number of diverse systems can be treated, such as

- broadcasting (terrestrial and satellite),
- mobile (terrestrial and satellite),
- point to point,
- point to multipoint.

This methodology is appropriate to be used to address the following issues in spectrum engineering:

- Sharing and compatibility studies between different radio systems operating in the same or adjacent frequency bands, respectively
- Evaluation of transmitter and receiver masks
- Evaluation of limits for parameters such as unwanted (spurious and out-of-band), blocking or intermodulation levels.

1.4. Architecture requirements

The architecture is composed in a sequential manner and consists of three processing engines:

Architecture of SEAMCAT

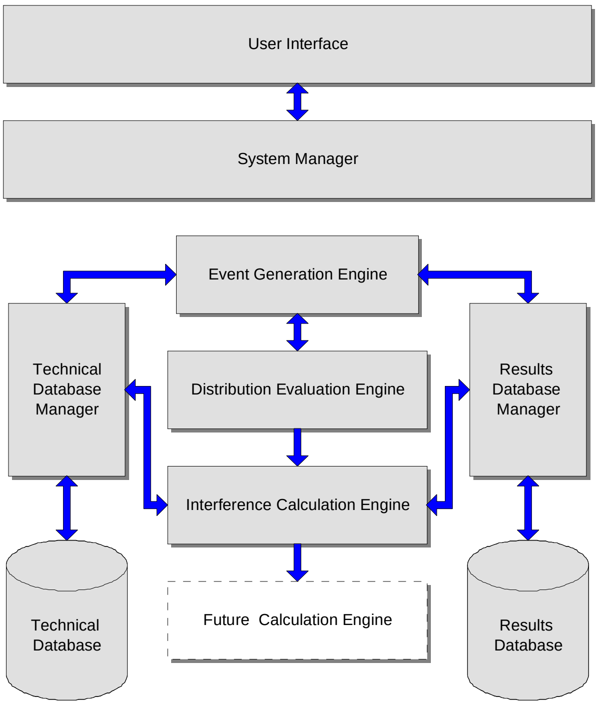

Figure 1, Architecture of SEAMCAT

1.4.1. Event Generation Engine (EGE)

This is the first stage after inputing all the parameters. The EGE generates random values, and processes them to calculate:

- the **d**esired **R**eceived **S**ignal **S**trength (***dRSS***), which is the strength of the desired signal received from the Wanted Transmitter (as if there was no interference at all),

- the **i**nterfering **R**eceived **S**ignal **S**trength (***iRSS***), which is the received signal strength from the Interfering Transmitter into the Victim Receiver. (See figure 2)

This process is repeated N times, where N is the number of trials. Generated samples of the desired and all interfering signals are stored in separate data arrays of length N.

There are three major mechanisms for generating interference:

- emissions of the interferer including unwanted emissions
- blocking of the victim receiver
- intermodulation between two interferers

More than one interfering system can be considered. For example, for intermodulation at least two different systems have to be taken into account.

Victim and interfering transceivers

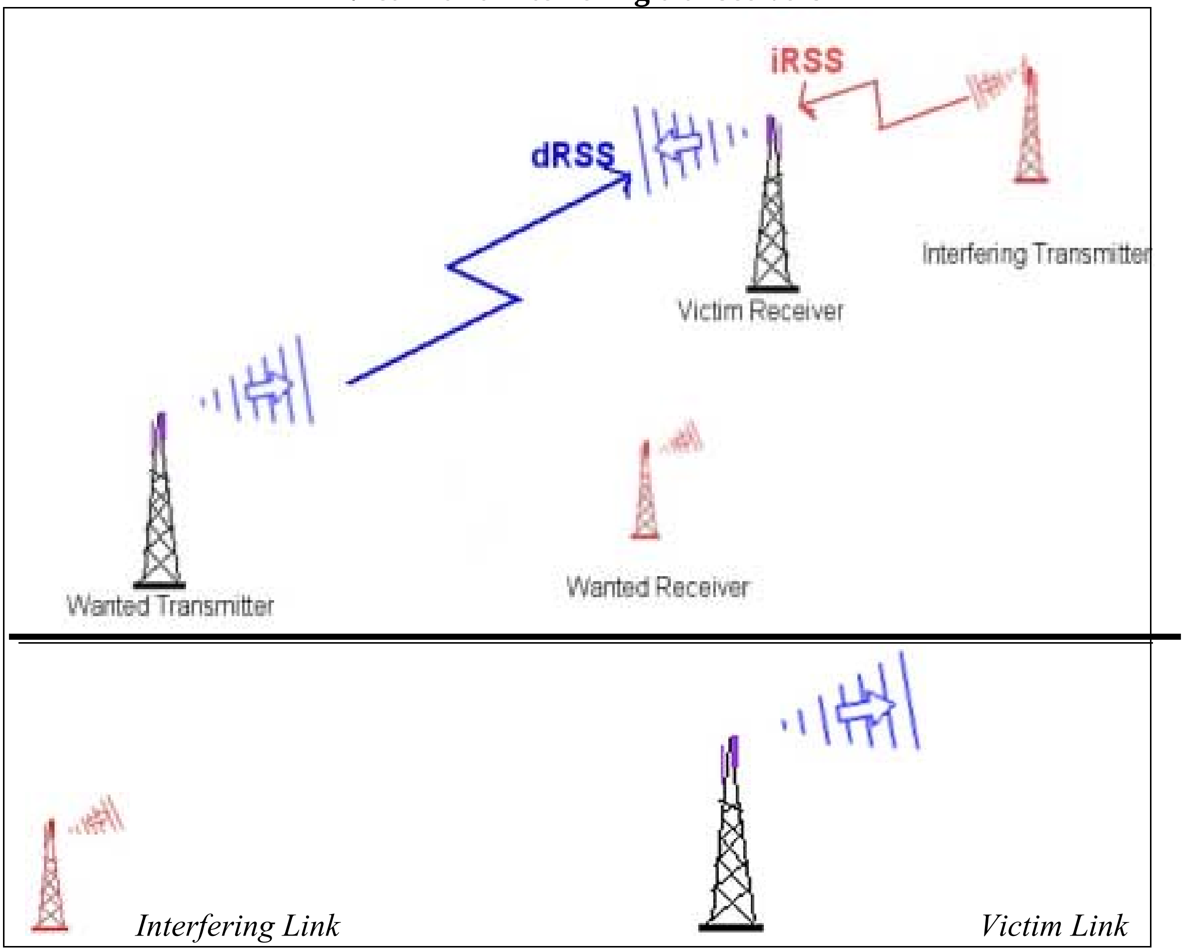

Figure 2, Victim and interfering transceivers

1.4.2. Distribution Evaluation Engine (DEE)

The Distribution Evaluation Engine (DEE) takes arrays generated by the EGE and processes the data in order to:

1) assess whether or not the number N of samples is sufficient to produce statistically stable results
2) calculate correlation (Annex 1) between
   - the **d**esired **R**eceived **S**ignal **S**trength (***dRSS***) and **i**nterfering **R**eceived **S**ignal **S**trength (***iRSS***) data
   - the different types of **i**nterfering **R**eceived **S**ignal **S**trength (***iRSS***) (e.g. blocking vs. Unwanted emissions)
3) turn the vector composed of the N samples into a known continuous distribution, if it is possible.

The first and third of the above points are achieved using a well known goodness-of-fit algorithms for general distributions such as Chi-squared test.

For the stability study (1), if the DEE detects unacceptable variations in discrete distribution estimated in two successive estimations using N and N-dN sample size, the EGE is instructed to generate another dN of additional samples. This test is repeated until a tolerable variation of the parameters is measured over the pre-defined number of successive tests.

Three different outputs are possible from the Distribution Evaluation Engine:

- data arrays of the ***dRSS and iRSS***. This is the output when a high degree of correlation is detected between the wanted and any of the interfering signals (no difference between the output of the EGE and the output of the DEE).
- discrete distributions of the ***dRSS and iRSS*** when
  - there is a weak correlation between the signals,
  - there is no correlation between the signals but no “continuous” distribution approximation with satisfactory accuracy is possible.
- continuous distribution functions of the ***dRSS and iRSS*** when signals are uncorrelated and discrete distributions are successfully approximated with continuous distribution functions.

1.4.3. Interference Calculation Engine (ICE)

The Interference Calculation Engine (ICE) is the heart of the proposed architecture. Here, information gathered by the EGE and processed by DEE is used to calculate the probability of interference.

The ICE generates new samples from the arrays or the distributions output by the DEE, and evaluates for each sample whether the victim receiver suffers interference or not.

This probability can be calculated for three different interference types as a function of the interference criteria, e.g. C/(N+I) *(wanted signal-to-interferer+noise)*:

- unwanted emission level for each transmitter of each interfering link,
- victim receiver response for blocking interference,
- victim receiver rejection for intermodulation interference.

Two applications can be foreseen for the ICE module:

- COMPATIBILITY: It calculates the probability, considering all the fixed input parameters
- TRANSLATION:
  - It calculates the probability of interference as a function of one of the 3 following parameters:
    - Power supplied by the Interfering transmitter for the unwanted,
    - Blocking response level of the Victim receiver for the Blocking,
    - Intermodulation rejection level for the Victim receiver.
  - In this case, all the following parameters must be frequency independent: Receiver blocking response mask, Receiver intermodulation rejection mask, power distribution of interfering transmitter, Unwanted emission floor mask. This must be verified because the calculation of the EGE has already been done considering fixed input parameters. SEAMCAT would have to re-run EGE algorithm in order to take frequency variable parameters into account.

ICE uses 3 exclusive algorithms depending on the situation (See figure 3)

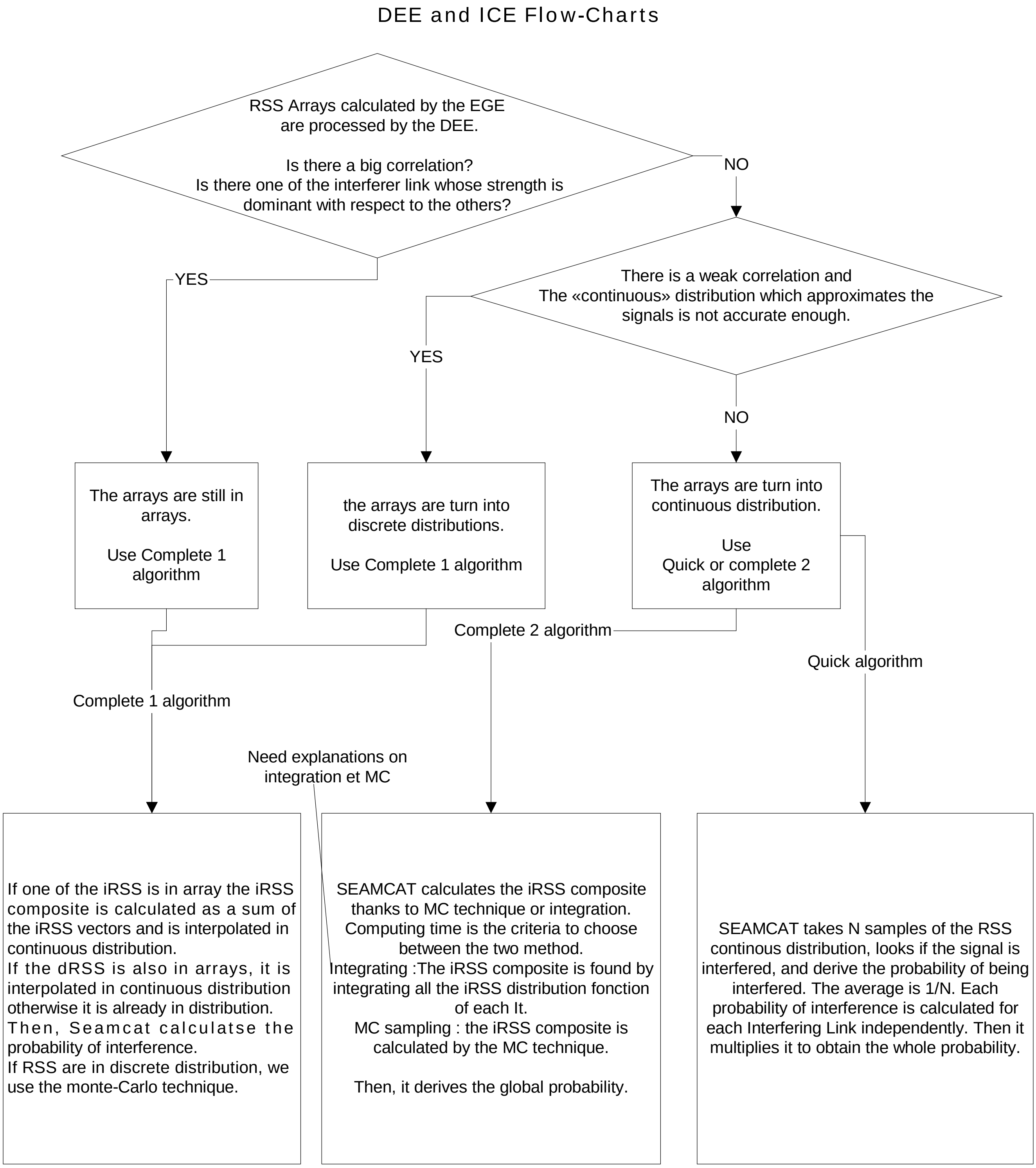

Figure 3, DEE and ICE flow-chart

2. EGE Input parameters

This part is aimed to list all the input parameters available in the user-interface. It also explains the impact of these parameters in the calculations.

Fundamental abbreviations and terminologies used in the following tables (See figure 4):

Victim link: Studied link,
Victim receiver(Vr): Receiver within the considered Victim Link,
Wanted transmitter(Wt): Transmitter within the considered Victim Link,

Interfering link: Link which interferes the Victim receiver,
Interfering transmitter (It): Transmitter within the considered Interfering Link,
Wanted receiver (Wr): Receiver within the considered Interfering Link,

dRSS = desired Received Signal Strength,
$iRSS_{spur}$ = interfering Received Signal Strength due to unwanted emissions,
$iRSS_{block}$ = interfering Received Signal Strength within the interferer bandwidth and attenuated by the receiver mask (called blocking interference),
$iRSS_{intermod}$ = interfering Received Signal Strength due to intermodulation.

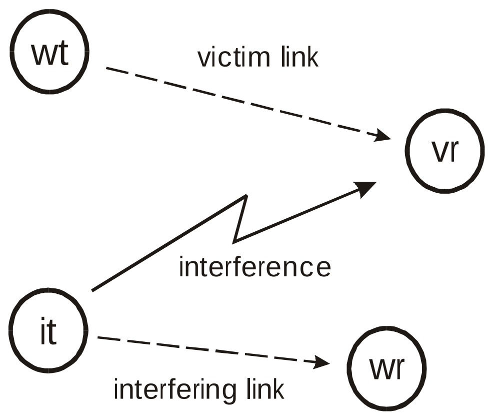

Figure 4, Notation used in SEAMCAT

The following notations are used in the description of the software:

S means a scalar,
D means a distribution (The way to input a distribution is explained in Annex 2),
F means a function (The way to input a function is explained in Annex 3).

2.1. Windows Victim link/General

Description	Notation	Type	Unit	Comments
Name: name of the victim link				
Description: comments on the link				
Victim receiver: choose in the menu a receiver already defined in the library				Call a receiver already defined in the Library, otherwise type the inputs directly.
Wanted transmitter: choose a transmitter already defined in the library				If **Wanted transmitter** is checked: • Call a transmitter already defined in the Library otherwise type the input directly. • dRSS is calculated taking into account all the Victim link parameters.
User defined dRSS: define a distribution of the desired Received Signal Strength	DRSS	D or S (if constant)	dBm/Vr reception bandwidth	If **User-defined dRSS** is checked: • the user defines the dRSS distribution. tabsheets “Wanted transmitter” and “Wt to Vr Path” disappear. The **Power control max threshold** option is not available in this case in the “Victim receiver” tabsheet.
Frequency	f_{wt}	S	MHz	enter frequency of the victim link

Table 1: Victim link/General

2.2. *Windows Victim link/Victim receiver*

Two tabsheets are available:

- general
- antenna

2.2.1. Tabsheet Victim link/Victim receiver/General

Description	Notation	Type	Unit	Comments
Name: name of the victim receiver				
Description: comments on the receiver				
Antenna height	h	D or S	m	
Antenna azimuth: Antenna alignment horizontal tolerance	δ^H	D or S	degree	This is the horizontal angle range between the Vr main beam and the aligned direction. (e.g. if antenna azimuth=0, the Vr and Wt antennas are strictly aligned in the horizontal plane). (Annex 4)
Antenna elevation: Antenna alignment vertical tolerance	δ^V	D or S	degree	This is the vertical angle range between the Vr main beam and the aligned direction. (e.g. if antenna elevation=0, the Vr and Wt antennas are strictly aligned in the vertical plane). (Annex 4)
Noise floor: define a distribution of the noise floor	N	D or S	DBm/MHz	Distribution of the strength of the noise floor. This parameters is used for the probability calculation when the criteria is C/(N+I) or (N+I)/N.
Blocking response: Receiver frequency response (receiver blocking performance)	blocking	F(MHz)	dBm or dB depending on the chosen Blocking attenuation mode, see below.	Receiver mask attenuation (positive or negative values depending on the chosen Blocking attenuation mode, see below) versus frequency shift. (Annex 5)

Blocking attenuation mode				Calculation mode of the of the receiver attenuation. (Annex 5) • **User-defined**: the attenuation due to the receiver selectivity is the blocking mask. In this case, the blocking response is in dB (so input positive values). • **Protection ratio**: the attenuation of the receiver is 3+C/(N+I)+Blocking mask. In this case, the blocking response is in dB (So input positive values). • **Sensitivity**: the user inputs the Blocking mask in dBm (absolute value) which is the maximum acceptable interfering power (dBm).The attenuation of the receiver is C/(N+I)+Blocking mask (dBm)-Sensitivity.
Intermodulation rejection: Inter-modulation response (inter-modulation interference)	intermod	F(MHz)	dB	Receiver mask at the intermodulation frequency. (Annex 14, calculation 2.3.)
Power control max threshold: Power control maximum increase	Pc_{max}	S	dB reception bandwidth	Maximum power that the receiver can receive. If the resulting dRSS exceeds Pc_{max} + sens, the dRSS is set to this value.[1]
Sensitivity	sens	S	dBm	Sensitivity of the receiver.
Reception bandwidth: Operating bandwidth	*B*	S	kHz	Bandwidth of the receiver.
Interference criteria: C/I or C/(N+I) or (N+I)/N: Protection Ratio	C/I or C/(N+I) or (N+I)/N	S	dB	The user defines at least one of these three criteria. (C/I, C/(N+I), (N+I)/N). Then, the user will choose one of these criteria for each interference probability calculation.

Table 2: Victim link/Victim receiver

2.2.2. Tabsheet Victim link/Victim receiver/Antenna

(See Annex 6)

[1] It should be noted that there is a mistake in the On Line Help File since the Power control max threshold is given in dBm and not in dB.

2.3. Windows Victim link/ wanted transmitter

Two tabsheets are available:

- general
- antenna

2.3.1. Tabsheet Victim link/ wanted transmitter/General

Description	Notation	Type	Unit	Comments
Name: name of the victim link				
Description: comments on the link				
Power distribution: Power supplied	P	S or D	dBm/Vr reception bandwidth	
Antenna height	h_{wt}	S or D	m	
Antenna azimuth: Antenna alignment horizontal tolerance	δ^{H}_{wt}	S or D	degree	This is the horizontal angle range between the Wt main beam and the aligned direction. (e.g. if antenna azimuth=0, the Vr and Wt antennas are strictly aligned in the horizontal plane). (Annex 4)
Antenna elevation: Antenna alignment vertical tolerance	δ^{V}_{wt}	S or D	degree	This is the vertical angle range between the Wt main beam and the aligned direction. (e.g. if antenna elevation=0, the Vr and Wt antennas are strictly aligned in the vertical plane). (Annex 4)

Table 3: Victim Link/Wanted transmitter

2.3.2. Tabsheet Victim link/ wanted transmitter/Antenna

(See Annex 6)

2.4. Windows Victim link/WT VR path

Two tabsheets are available:

- relative location
- propagation model

2.4.1. Tabsheet Victim link/WT VR path/Relative location

- Correlation case: position between the receiver and the transceiver is defined using cartesian coordinates.

Description	Notation	Type	Unit	Comments
Correlation distance				Checked
Delta X, delta Y	X Y	S	km	distance between the transmitter and receiver in the Victim link.

Table 4: Victim Link/WT VR correlation case

- Uncorrelated case: A coverage radius is calculated. Three different modes are available for calculating the maximum radius R_{max}^{wt} (Annex 14, calculation 1.1). The Wanted transmitter will be randomly deployed within the area centered on the Victim receiver and delimited by the maximum radius R_{max}^{wt}.

Description	Notation	Type	Unit	Comments
Correlation distance				unchecked
Path azimuth		D or S	Degrees	Distribution of the horizontal angle range for the location of the Wt respect to the Vr. If constant, the Wt location will be on a straight line. If not, the location of the Wt will be on an angular area. (Annex 19)
Path distance factor		D or S		Distribution of the distance between the Wt and the Vr. This factor will be multiplied by R_{max}^{wt} to obtain the coverage area. Therefore, the real distance between Wt and Vr is R_{max}^{wt} *Path factor. If the path factor is constant, the Wt will be located on a circle around the Vr.
Coverage radius calculation mode				Three different modes of calculation of the coverage radius R_{max}^{wt} of a given transceiver: • **User-defined coverage radius**: (Annex 7) • **Noise-limited network**: (Annex 8) • **Traffic limited network**: (Annex 9) (Annex 14, calculation 1.1.) The user should check the consistency of this value with the sensitivity, so that if a receiver is placed at given distance such as the maximum coverage radius, the received power is higher than the Sensitivity for a reasonable percentage of time (availability).
User-defined coverage radius /**coverage radius**		S	km	Coverage radius, and fix it constant or make it vary with the path loss distribution.

Table 5: Victim Link/WT Vr/Uncorrelated case

2.4.2. Tabsheet Victim link/WT VR path/Propagation Model

- The second tabsheet is the propagation model: Choose a propagation model between HATA (See annex 10 and section 2.10), Spherical diffraction (See annex 11 and section 2.10), User-defined (See annex 12 and section 2.10). For User-defined, the user has to implement the propagation model.

2.5. Windows Interfering Link/General

Description	Notation	Type	Unit	Comments
Name: name of the interfering link				
Description: comments on the link				
Interfering transmitter: choose in the menu a transmitter already defined in the library				Call a transmitter already defined in the Library, otherwise type the inputs directly.
Wanted receiver: choose in the menu a receiver already define in the library				Call a receiver already defined in the Library, otherwise type the inputs directly.
Frequency: Distribution of the frequency of the interfering link		D or S	MHz	Distribution of the center frequency of the interferer bandwidth.

Table 6: Interfering link/general

2.6. *Windows Interfering Link/Interfering transmitter*

Two tabsheets are available:

- general
- antenna

2.6.1. Tabsheet Interfering link/Interfering transmitter/general

Description	Notation	Type	Unit	Comments
Name: name of the interfering transceiver				
Description: comments on the transceiver				
Antenna height	h	S or D	m	
Antenna azimuth: Antenna alignment horizontal tolerance	δ^H	D or S	degree	This is the horizontal angle range between the It main beam and the aligned direction. (e.g. if antenna azimuth=0, the It and Wr antennas are strictly aligned in the horizontal plane) (Annex 4)
Antenna elevation: Antenna alignment vertical tolerance	δ^V	D or S	degree	This is the vertical angle range between the It main beam and the aligned direction. (e.g. if antenna elevation=0, the It and Wr antennas are strictly aligned in the vertical plane). (Annex 4)
Power: define a distribution of the power send by the transmitter.		D or S	dBm/It emission bandwidth	Power supplied by the IT. (Annex 15)
Unwanted emission mask: Unwanted signal level (Transmitting mask)	unwanted (f)	F(MHz)	dBc/reference bandwidth	Define the mask of the transmitter, in the bandwidth and out of the bandwidth. The values in the relative mask should be chosen in that way that the integration over the emission bandwidth results is the total emitted power. (Annex 15). If constant mask, there is no emission outside of the bandwidth.
Unwanted emissions floor: Noise floor signal level	unwanted (f)	F(MHz)	dBm/MHz	Define the minimum strength of the unwanted emissions. So the unwanted emission are equaled to Max(Pit + Pcontrol + Unwanted emission, Unwanted emissions floor) (See Annex 14)

Emission bandwidth		S	kHz	This band is the reference bandwidth for the transmitting power.
Reference bandwidth		S	kHz	This is the reference bandwidth for the interfering power.
Power control				If Power control is checked, the 3 following parameters have to be defined. This Power control is used to limit the output power of the transmitter. (Annex 18)
Power control/**Power control step size**	Pc^{st_rg}	S	dB	
Power control/**Min received power**	Pc_{min}	S	dBm/ emission bandwidth	
Power control/**max received power**	Pc_{max}	S	dBm/ emission bandwidth	

Table 7: Interfering link/Interfering transmitter

2.6.2. Tabsheet Interfering link/Interfering transmitter/Antenna

(See Annex 6)

2.7. *Windows Interfering Link/Wanted receiver*

Two tabsheets are available:

- general
- antenna

2.7.1. Tabsheet Interfering link/Wanted receiver/general

Description	Notation	Type	Unit	Comments
Name: name of the wanted receiver				
Description: comments on the receiver				
Antenna height	h_{wt}	S or D	m	
Antenna azimuth: Antenna alignment horizontal tolerance	δ^{H}_{wt}	S or D	degree	This is the horizontal angle range between the Wr main beam and the aligned direction. (e.g. if antenna azimuth=0, the Wr and It antennas are strictly aligned in the horizontal plane). (Annex 4)
Antenna elevation: Antenna alignment vertical tolerance	δ^{V}_{wt}	S	degree	This is the vertical angle range between the Wr main beam and the aligned direction. (e.g. if antenna elevation=0, the Wr and It antennas are strictly aligned in the vertical plane). (Annex 4)

Table 8: Interfering Link/wanted receiver

2.7.2. Tabsheet Interfering link/Wanted receiver/Antenna

(See Annex 6)

2.8. *IT towards WR path*

Two tabsheets are available:

- relative location
- propagation model

2.8.1. Tabsheet Interfering link/IT WR/Relative location

- Correlation case: position between the receiver and the transceiver is defined using cartesian coordinates.

Description	Notation	Type	Unit	Comments
Correlation distance				Checked
Delta X, delta Y	X Y	S	km	distance between the transmitter and receiver in the interfering link.

Table 9: Interfering Link/IT WR correlation case

- Uncorrelated case: A coverage radius is calculated. Three different modes are available for calculating the maximum radius $R^{it}_{\max}$ (Annex 14, calculation 1.1. same algorithm as the calculation of R^{wt}_{max}). The Interfering transmitter will be randomly deployed within the area centered on the Wanted receiver and limited by the maximum radius $R^{it}_{\max}$.

Description	Notation	Type	Unit	Comments
Correlation distance				unchecked
Path azimuth		D or S	Degrees	Distribution of the horizontal angle range for the location of the It respect to the Wr. If constant, the It location will be on a straight line. If not, the location of the It will be on an angular area. (Annex 19)
Path distance factor		D or S		Distribution of the distance between the It and the Wr. This factor will be multiplied by $R^{it}_{\max}$ to obtain the coverage area. Therefore, the real distance between It and Wr is $R^{it}_{\max}$ *Path factor. If the path factor is constant, the It will be located on a circle around the Wr.
Coverage radius calculation mode				Three different modes of calculation of the coverage radius $R^{it}_{\max}$ of a given transceiver: • User-defined coverage radius: (Annex 7) • Noise-limited network: (Annex 8) • Traffic limited network: (Annex 9) (Annex 14, calculation 1.1.)

Table 10: Interfering link/IT WR Uncorrelated case

2.8.2. Tabsheet Interfering link/IT WR path/Propagation Model

The second tabsheet is the propagation model: Choose a propagation model between HATA (See annex 10 and section 2.10), Spherical diffraction (See annex 11 and section 2.10), User-defined (See annex 12 and section 2.10). For User-defined, the user has to implement the propagation model.

2.9. *IT towards VR path*

Two tabsheets are available:

- relative location
- propagation model

2.9.1. Tabsheet Interfering link/IT VR path/Relative location

- Correlation case: position between two transceivers is defined using cartesian coordinates: Choose which correlation:
  - (IT-VR)
  - (IT-WT)
  - (WR-WT)
  - (WR-VR)

Description	Notation	Type	Unit	Comments
Correlation distance				(IT-VR), (IT-WT), (WR-WT) or (WR-VR)
Delta X, delta Y	X Y	S	km	distance between the two transceivers. The reference depends on the choice of correlation.

Table 11: Interfering Link/IT VR correlation case

Uncorrelated case:

<table>
<tr><th>Description</th><th>Notation</th><th>Type</th><th>Unit</th><th colspan="2">Comments</th></tr>
<tr><td>Correlation distance</td><td></td><td></td><td></td><td colspan="2">none</td></tr>
<tr><td>Path azimuth</td><td></td><td>D or S</td><td>Degrees</td><td colspan="2">Distribution of the horizontal angle range for the location of the It respect to the Vr.
If constant, the It location will be on a straight line.
If not, the location of the It will be on an angular area.
(Annex 19)</td></tr>
<tr><td>Path distance factor</td><td></td><td>D or S</td><td><u>IMPORTANT</u></td><td colspan="2">Distribution of the distance between the It and the Vr.
This factor will be multiplied by R_{simu} to obtain the simulation area. Therefore, the max distance between It and Vr is R_{simu} *Path factor.
If the path factor is constant, the It will be located on a circle around the Vr which means that the distance between the It and Vr won't change</td></tr>
<tr><td>Number of active transmitter</td><td>n^{active}</td><td>S</td><td></td><td></td><td rowspan="5">Use all these parameters to calculate R_{simu} (Annex 13)

(Annex 14, calculation 2.1.)</td></tr>
<tr><td>Density of active transmitters</td><td>$dens_{active}$</td><td>S</td><td>1/km^2</td><td>Maximum number of active transceivers per km^2</td></tr>
<tr><td>Probability of transmission</td><td>P_{trans}</td><td>S</td><td></td><td></td></tr>
<tr><td>Activity</td><td>activity</td><td>F</td><td>1/h</td><td>Activity function of the time of the day</td></tr>
<tr><td>Time</td><td>time</td><td>S</td><td>hh/mm/ss</td><td></td></tr>
</table>

Table 12: Interfering Link/IT VR Uncorrelated case

2.9.2. Tabsheet Interfering link/IT VR path/Propagation Model

The second tab sheet is the propagation model: Choose a propagation model between HATA (See annex 10 and section 2.10), Spherical diffraction (See annex 11 and section 2.10), User-defined (See annex 12 and section 2.10). For User-defined, the user has to implement the propagation model.

2.10 Propagation models

2.10.1 Hata model, outdoor-outdoor

$f_{propag}(f, h_1, h_2, d, env) = L + T(G(\sigma))$

where

L = median propagation loss (in dB)

σ = standard deviation of the slow fading distribution (in dB)

f = frequency (in MHz)

$H_m = \min\{h_1, h_2\}$

$H_b = \max\{h_1, h_2\}$

d = distance (in km), preferably less than 100 km.

env = (outdoor/outdoor), (rural, urban or suburban), (propagation above or below roof)

If H_m and/or H_b are below 1 m, a value of 1 m should be used instead. Antenna heights above 200 m might also lead to significant errors. Propagation below roof means that both H_m and H_b are above the height of roofs. Propagation is above roof in other cases (H_b above the height of roofs).

2.10.1.1 Calculation of the median path loss *L* :

Case 1: $d \le 0.04$ km

$$L = 32.4 + 20\log(f) + 10\log(d^2 + (H_b - H_m)^2 / 10^6)$$

Case 2: $d \ge 0.1$ km

$$a(H_m) = (1.1\log(f) - 0.7)\min\{10, H_m\} - (1.56\log(f) - 0.8) + \max\{0, 20\log(H_m/10)\}$$

$$b(H_b) = \min\{0, 20\log(H_b/30)\}$$

$$\alpha = \begin{cases} \alpha = 1 & d \le 20 \text{ km} \\ \alpha = 1 + \left(0.14 + 0.000187\, f + 0.00107\, H_b\right)\left(\log\dfrac{d}{20}\right)^{0.8} & 20 \text{ km} < d \le 100 \text{ km} \end{cases}$$

Sub-case 1: Urban

- 30 MHz < f ≤ 150 MHz

$$L = 69.6 + 26.2\log(150) - 20\log(150/f) - 13.82\log(\max\{30, H_b\}) + \alpha\left[44.9 - 6.55\log(\max\{30, H_b\})\right]\log(d) - a(H_m) - b(H_b)$$

- 150 MHz < f ≤ 1500 MHz

$$L = 69.6 + 26.2\log(f) - 13.82\log(\max\{30, H_b\}) + \alpha[44.9 - 6.55\log(\max\{30, H_b\})]\log(d) - a(H_m) - b(H_b)$$

- 1500 MHz < f ≤ 2000 MHz

$$L = 46.3 + 33.9\log(f) - 13.82\log(\max\{30, H_b\}) + \alpha[44.9 - 6.55\log(\max\{30, H_b\})]\log(d) - a(H_m) - b(H_b)$$

- 2000 MHz < f ≤ 3000 MHz

$$L = 46.3 + 33.9\log(2000) + 10\log(f/2000) - 13.82\log(\max\{30, H_b\}) + \alpha[44.9 - 6.55\log(\max\{30, H_b\})]\log(d) - a(H_m) - b(H_b)$$

<u>Sub-case 2:</u> Suburban

$$L = L(\text{urban}) - 2\{\log[(\min\{\max\{150, f\}, 2000\})/28]\}^2 - 5.4$$

<u>Sub-case 3:</u> Open area

$$L = L(\text{urban}) - 4.78\{\log[\min\{\max\{150, f\}, 2000\}]\}^2 + 18.33\log[\min\{\max\{150, f\}, 2000\}] - 40.94$$

<u>Case 3:</u> 0.040 km < d < 0.1 km

$$L = L(0.04) + \frac{[\log(d) - \log(0.04)]}{[\log(0.1) - \log(0.04)]}[L(0.1) - L(0.04)]$$

When L is below the free space attenuation for the same distance, the free space attenuation should be used instead.

2.10.1.2 Assessment of the standard deviation for the lognormal distribution

<u>Case 1:</u> $d \le 0.04$ km

$$\sigma = 3.5 \text{ dB}$$

<u>Case 2:</u> 0.040 km < d ≤ 0.1 km

$$\sigma = 3.5 + \frac{(12 - 3.5)}{(0.1 - 0.04)}(d - 0.04) \text{ dB}$$ for propagation above the roofs

$$\sigma = 3.5 + \frac{(17 - 3.5)}{(0.1 - 0.04)}(d - 0.04) \text{ dB}$$ for propagation below the roofs

<u>Case 3:</u> 0.1 km < d ≤ 0.2 km

$\sigma = 12$ dB for propagation above the roofs

$\sigma = 17$ dB for propagation below the roofs

<u>Case 4:</u> 0.2 km < d ≤ 0.6 km

$$\sigma = 12 + \frac{(9-12)}{(0.6-0.2)}(d-0.2) \quad \text{dB} \qquad \text{for propagation above the roofs}$$

$$\sigma = 17 + \frac{(9-17)}{(0.6-0.2)}(d-0.2) \quad \text{dB} \qquad \text{for propagation below the roofs}$$

Case 5: 0.6 km < d

$\sigma = 9$ dB

2.10.2 Spherical model, outdoor-outdoor

A spherical propagation model based on various ITU-R Recommendations P.452, P.676 and P.526[2] is applied in SEAMCAT for larger distances and higher frequencies. In the following the spherical diffraction model is derived including default values for Europe and additional boundary conditions.

2.10.2.1 Spherical diffraction model

According to ITU-R Rec. P.452 the median loss between transceiver and receiver is given by the following equation:

$$L_{bd}(p) = 92.5 + 20\log f + 20\log d + L_d(p) + A_g$$

where

$L_{bd}(p)$	is the basic loss in dB as function of the time percentage p in %
f	is the frequency in GHz
d	is the distance in km
$L_d(p)$	is the diffraction loss in dB as function of the time percentage p in %
A_g	is the attenuation due to atmospheric gas and water in dB

2.10.2.2 Attenuation due to atmosphere

Attenuation due to atmosphere is given by

$$A_g = [\gamma_O(f) + \gamma_w(\rho, f)]\, d$$

where

$\gamma_O(f)$	linear attenuation due to dry air (oxygen) in dB/km
$\gamma_w(\rho, f)$	linear attenuation in dB/km due to water as function of the water concentration ρ in g/m³, *default value: 3 g/m³*

2 The used documentation is based on documents published in 1990-1994. In the meantime newer Recommendations are available. Unfortunately, some of the useful information were shifted to Reports or other Recommendations.

Both terms can be approximated by the following equations according to ITU-R Rec. 676:

- Attenuation due to water:

$$\gamma_w(\rho, f) = \left[0.050 + 0.0021\rho + \frac{3.6}{(f-22.2)^2 + 8.5} + \frac{10.6}{(f-183.3)^2 + 9} + \frac{8.9}{(f-325.4)^2 + 26.3}\right] f^2 \rho 10^{-4}$$

for f < 350 GHz

Attenuation due to oxygen:

$$\gamma_O(f) = \left[7.19 \cdot 10^{-3} + \frac{6.09}{f^2 + 0.227} + \frac{4.81}{(f-57)^2 + 1.50}\right] f^2\, 10^{-3} \qquad f \le 57 \text{ GHz}$$

$$\gamma_O(f) = 10.5 + 1.5\,(f-57) \qquad 57 < f \le 60 \text{ GHz}$$

$$\gamma_O(f) = 15 - 1.2\,(f-60) \qquad 60 < f \le 63 \text{ GHz}$$

$$\gamma_O(f) = \left[3.79 \cdot 10^{-7} f + \frac{0.265}{(f-63)^2 + 1.59} + \frac{0.028}{(f-118)^2 + 1.47}\right](f+198)^2\, 10^{-3} \qquad f > 63 \text{ GHz}$$

Note: For simplification a linear interpolation between 57 and 63 GHz is used. The maximum is 15 dB/km for 60 GHz.

2.10.2.3 Attenuation due to diffraction

According to ITU-R Rec. P.526, the diffraction loss $L_d(p)$ can be derived by the received field strength E referred to the free space E_0 :

$$-L_d(p) = 20 \log \frac{E}{E_0} = F(X) + G(Y_1) + G(Y_2)$$

where

X is the normalized radio path between transmitter and receiver
Y_1 is the normalized antenna height of the transmitter
Y_2 is the normalized antenna height of the receiver

$$X = 2.2\beta\, f^{\frac{1}{3}}\, a_e^{\frac{-2}{3}}\, d$$

$$Y = 9.6 \cdot 10^{-3} \beta\, f^{\frac{2}{3}}\, a_e^{\frac{-1}{3}}\, h_i$$

where

β is a parameter derived from the earth admittance factor K: β = 1 for f > 20 MHz.
f is the frequency in MHz
a_e is the equivalent earth radius in km (definition see below)
d is the distance in km

h_i is the antenna height above ground in m with i =1 or 2 for the transmitter or receiver, respectively

The distance-dependent term $F(X)$ is given by the semi-empirical formula:

$$F(X) = 11 + 10\log(X) - 17.6X$$

The antenna height gain $G(Y)$ is given by the formula set:

$$G(Y) = 17.6(Y - 1.1)^{\frac{1}{2}} - 5\log(Y - 1.1) - 8 \qquad \text{for } Y > 2$$
$$G(Y) = 20\log(Y + 0.1Y^3) \qquad \text{for } 10K < Y < 2$$
$$G(Y) = 2 + 20\log K + 9\log(Y/K)\left[\log(Y/K) + 1\right] \qquad \text{for } K/10 < Y < 10K$$
$$G(Y) = 2 + 20\log K \qquad \text{for } Y < K/10$$

where

K is the normalized earth surface admittance factor (see ITU-R Rec. 526), *default value:* 10^{-5}

Note: All frequencies used in section 2.10.2.3 have the unit MHz in contrast to the sections 2.10.2.1 and 2.10.2.2 where GHz is applied.

2.10.2.4 Time dependent variation in path loss

This variation in path loss is provided through the variability of the equivalent earth radius a_e (unit: km) which is considered to be dependent on the time percentage p :

$$a_e(p) = 6375\,k(p)$$

with the earth radius factor $k(p)$ expressed as:

$$k(p) = k_{50} + (5 - k_{50})\frac{(1.7 - \log p)}{(1.7 - \log \beta_0)} \qquad \text{for } p < 50\%$$

$$k(p) = k_{50} \qquad \text{for } p > 50\%$$

and $$k_{50} = \frac{157}{157 - \Delta N}$$

where

ΔN is the mean gradient of the radio refraction profile over a 1 km layer of the atmosphere from the surface. The *default value* is *40 units/km* for Europe (standard atmosphere). This value yields to $k_{50} \approx 4/3$ and a_e = 8500 km. Note: The mean gradient is positive!

β_0 is the existence probability (in %) of the super-refractive layer ($\Delta N >$ 100 units/km) in the low atmosphere. *Default value: 1 % for Europe*.

Note: The probabilities p and β_0 are denoted in %, i.e. a range of variety: 0...100 %.

Note: In SEAMCAT, $p = 50\%$ is currently implemented, i.e. the median with respect to time is computed. Later versions may allow to choose a certain time percentage.

2.10.2.5 Range of application

- The frequency range should be larger than 3 GHz, with caution lower frequencies may be used but not below 300 MHz due to the surface admittance and polarisation effects.
- The model was developed for open (rural) area. Therefore, the additional attenuation due to obstacles like buildings found in suburban or urban environment is not included.
- The loss due to rain is not covered.
- This model is applicable only for terrestrial radio paths.

2.10.3 Combination of indoor and outdoor propagation models

Most of the propagation models published in the open literature are derived either for outdoor or indoor application. But in the "real world" a combination of both types is required.

In SEAMCAT, the classical outdoor models, Hata (SE21 version) and spherical diffraction model (ITU-R Recs. P.452, P.526 and P.676) are combined with an indoor model (COST231). An illustrative description is given in the following where between the different cases outdoor-outdoor, indoor-outdoor, outdoor-indoor and indoor-indoor is distinguished.

COMBINATION OF DIFFERENT PROPAGATION SCENARIOS

The path loss p_L consists of median path loss L and the Gaussian variation $T(G(\sigma))$ where σ is the standard deviation:

$$p_L(f, h_1, h_2, d, env) = L + T(G(\sigma))$$

where

f is the frequency in MHz,
h_1 is the antenna height of the transmitter antenna in m,
h_2 is the antenna height of the receiver antenna in m,
d is the distance in km,
env is a parameter for the environments of the transmitter and receiver.

2.10.3.2 Outdoor-outdoor

- Scenario: transmitter and receiver are both outdoor
- Modified Hata model:

Median: $L(outdoor - outdoor) = L_{Hata}(outdoor - outdoor)$

Variation: intrinsic variation, $\sigma(outdoor - outdoor) = \sigma_{Hata}$

- Spherical diffraction model
  Median: $L(outdoor - outdoor) = L_{spherical}$
  Variation: no variation possible, $\sigma(outdoor - outdoor) = 0$

2.10.3.3 Indoor-outdoor or outdoor-indoor

- Scenario: transmitter is indoor and receiver is outdoor, or vice versa
- Modified Hata model:
  Median: $L(indoor - outdoor) = L_{Hata}(outdoor - outdoor) + L_{we}$
  where L_{we} is the attenuation due to external walls (*default value = 10 dB*)
  Variation: $\sigma(indoor - outdoor) = \sqrt{\sigma_{Hata}^2 + \sigma_{add}^2}$
  where σ_{add} is the additional standard deviation of the signal (*default value: 5 dB*).
  The standard deviation of the lognormal distribution is increased, compared to the outdoor-outdoor scenario due to additional uncertainty on materials and relative location in the building.
- Spherical diffraction model
  Median: $L(indoor - outdoor) = L_{spherical} + L_{we}$
  Variation: $\sigma(indoor - outdoor) = \sigma_{add}$
  The lognormal distribution is determined by the additional variation is due to the variation in building materials, only, because for the spherical diffraction model no variation is considered.

2.10.3.4 Indoor-indoor

There are two different scenarios possible: The transmitter and receiver are in the same or in different buildings. Which scenario is used by SEAMCAT is randomly selected.

2.10.3.4.1 Selection of the scenario

The first step is to determine whether the indoor-indoor scenario corresponds to transmitter and receiver in the same building or not. This is done by the calculation of the random variable SB (Same Building).

Trial of the condition SB (Same Building):

- *d* < 0.020 km (20 m):
  SB = Yes => $P(\text{Yes}) = 1$
- 0.020 km < *d* < 0.050 km (50 m):
  SB = Yes *P*(Yes) = (0.050-*d*)/0.030
  SB = No *P*(No) = 1- *P*(Yes) = (*d*-0.020)/0.030
- *d* > 0.050 km (50 m):
  SB = Yes => $P(\text{Yes}) = 0$

2.10.3.4.2 Indoor-indoor, different buildings

- Scenario: transmitter and receiver in different buildings: *P*(Yes)=0 or *P*(No)=1
- Modified Hata model:
  Median: $L(indoor - indoor) = L_{Hata}(outdoor - outdoor) + 2L_{we}$
  It is to remark that the loss due to 2 external walls is to add.
  Variation: $\sigma(indoor - indoor) = \sqrt{\sigma_{Hata}^2 + 2\sigma_{add}^2}$
- Spherical diffraction model
  Median: $L(indoor - indoor) = L_{spherical} + 2L_{we}$
  Variation: $\sigma(indoor - indoor) = \sqrt{2}\sigma_{add}$
  The lognormal distribution is determined by the additional variation is due to the variation in building materials, only, because for the spherical diffraction model no variation is considered. The variation is increased to the second external wall.

2.10.3.4.3 Indoor-indoor, same building

- Scenario: transmitter and receiver in the same building: *P*(Yes)=1 or *P*(No)=0
- Indoor propagation model:
  Median:

$$L(\text{indoor} - \text{indoor}) = -27.6 + 20\log(1000d) + 20\log(f) + \text{fix}\left(\frac{1000d}{d_{room}}\right)L_{wi} + k_f^{\left[\frac{k_f+2}{k_f+1} - b\right]}L_f$$

with

$$k_f = \text{fix}\left(\frac{|h_2 - h_1|}{h_{floor}}\right)$$

L_{wi}	= loss of internal wall (in dB)	(*default value = 5 dB*)
L_f	= loss between adjacent floor (in dB)	(*default value = 18.3 dB*)
b	= empirical parameter	(*default value = 0.46*)
d_{room}	= size of the room (in m)	(*default value = 4 m*)
h_{floor}	= height of each floor (in m)	(*default value = 3 m*)

Note: The path length d *uses the unit km and the frequency the unit MHz*

Variation: $\sigma(indoor - indoor) = \sigma_{in}$

The lognormal distribution trial is made using a standard deviation entered by the user and covering the variation, internal in the building, due to building design, in furniture of the rooms, etc.. The *default value is* $\sigma_{in} = 10\ dB$.

2.11 Simulation control

Description	Notation	Type	Unit	Comments
Number of events	N	S		The number of trials: this is the number of different random configurations of WT, VR, IT, WR that the software generates to calculate the iRSS and the dRSS. Then, in the DEE, SEAMCAT calculates distributions based on the arrays of dRSS and iRSS. (0 < N < 500,000)
Termination condition				• **Number of events**: simulation to stop after a certain number of samples. So, the **Significance level for stability estimation,** the **Add number of events** and the **Significant level for distribution identification** are not useful**.** ***Pbl***: No stability evaluation, the user can make a simulation with only 2 events. • **DEE driven**: The software asks the EGE to generate more samples if the number of samples is considered as insufficient to ensure the probability stability. • **Expected duration**: The simulation to stop after a certain duration. . So, the **Significance level for stability estimation,** the **Add number of events** and the **Significant level for distribution identification** are not useful**.** ***Pbl***: No stability evaluation.
Time left		S	min	If **Expected duration** was chosen.
Significance level for stability estimation		S		Value used for Chi-squared test. In order to check if the distribution obtained with N-dN samples and the one obtained with N samples respect this comparison threshold. If the user increase this value, the stability increase. The maximum number of samples is 2*N. ***Pbl***: SEAMCAT allows values more than 1.
Add number of events	dN	S		Number of trials to add. If DEE detects unacceptable variations in discrete distribution resulted from the EGE and estimated in two successive estimations using N and N+dN sample size, the EGE is instructed to generate another dN of additional samples. This test is repeated until a tolerable variation of the parameters is measured over the pre-defined number of successive tests.

Significant level for distribution identification		S		Value used for the Chi-squared test. In order to check if signal issued by the EGE compared to a known continuous distribution respect this comparison threshold. Use for the interpolation in distributions of the array vectors output by the EGE. ***Pbl***: SEAMCAT allows values more than 1.
Correlation threshold	ε	S		Annex 1 for the algorithm. ***Pbl***: This value must be included between 0 and 1 however SEAMCAT allows any positive values.

Table 13: Parameters to calculation of the iRSS and dRSS

3. EGE/DEE Simulation

During the EGE/DEE simulation , the EGE (each iRSS, dRSS)and the DEE (stability and correlation) are calculated . Then, in order to have probability results, use the Windows simulation/interfering calculation.

Description	Notation	Type	Unit	Comments
Calculation mode/**Compatibility**: The result is a probability.				Compatibility: Give the probability of being interfered by the Blocking interference and/or by the Unwanted interference and/or by intermodulation interference.
Calculation mode/**Translations**: the result is a graph. In this case all the following parameters are independent from frequencies: Receiver blocking response mask, Receiver intermodulation rejection mask, power distribution of interfering transmitter, Unwanted emission floor mask.				Calculation of the probability of interference as a function of the reference parameters: • Power supplied by the It for the unwanted, • Blocking response level of the Vr for the Blocking, • And intermodulation rejection level for the Vr. Useful when there is more than 2 interfering transmitter at f1 and f2, iRSS intermodulation ½ fo=2f2-f1 or 2/1 2f1-f2 and fo must be in the Vr bandwidth. These parameters are varying on user-defined definition domain defined by the number of points where the software has to calculate the probability. (Annex 16)
Signal type				Choose the interference studied: Unwanted and/or Blocking and/or Intermodulation.
algorithm				Choose the appropriate algorithm.
algorithm/**Quick**:				• Interfering signals (N) issued by EGE for each of the interfering links (n) involved in the interfering scenario are statistically independent (non correlation). • One of the interfering links have an iRSS which is dominant with respect to all the other interfering signals. See Figure 2
algorithm/**Complete 1**:				See Figure 2

algorithm/**Complete 2**:				See Figure 2
Samples				Number of samples from the distribution calculated by the DEE, it represents the number of events to calculate the probability. The accuracy of the probability results derives from this parameters..
Interference criterion				(C/I, C/(N+I), (N+I)/N)
Translation parameters: If translation was chosen				Number of points between the min and max, where the software will calculate the probability.
Calculation control				Delete a result, and see the last results
Result/Compatibility				Gives the probability of interference (1 always interfered, 0 never interfered)
Result/Translation				Gives the graph, with the parameters chosen in the translation parameters in abscissa and the probability not to be interfered in orderly. The average of the graph depends of the number of points, but the higher the number is, the longer the calculations are.

Table 14: Parameters to calculate the probability

4 SEAMCAT example

Spectrum Engineering Advanced Monte Carlo Analysis Tool

How to use SEAMCAT

**Example: SRDs operating at 165 MHz interfere
FM broadcasting operating at 100 MHz**

- **Define workspace**
- **Define wanted radio system (victim link)**
- **Define interfering radio systems (interfering links)**
- **Compute iRSS and dRSS by simulation (event generation)**
- **Calculate probability of interference**

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Slide 2

SEAMCAT

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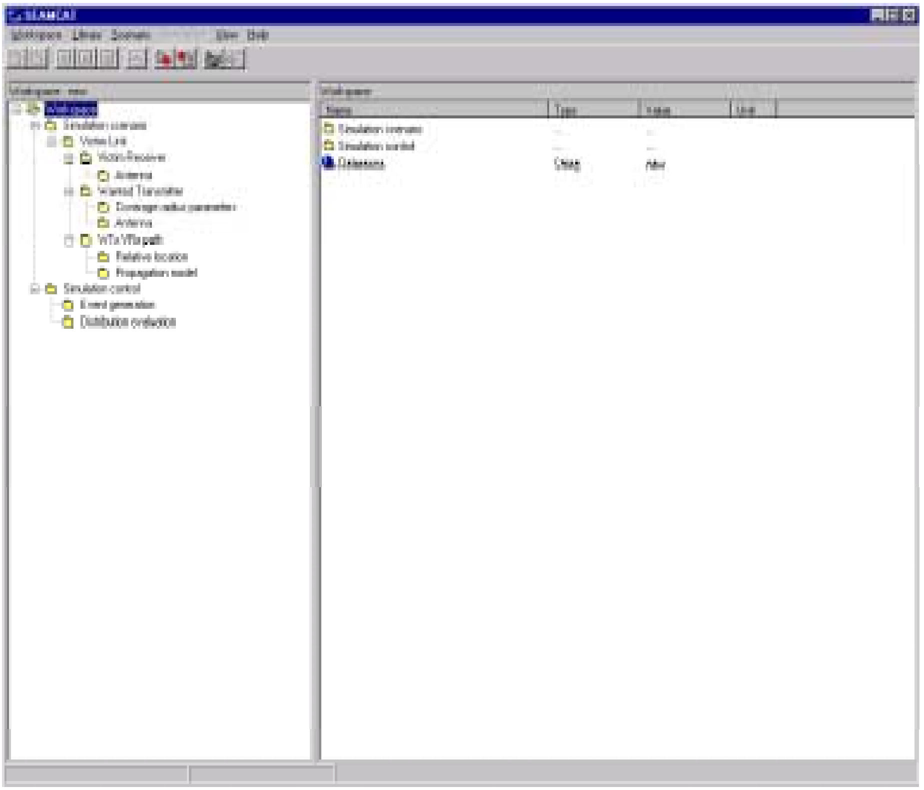
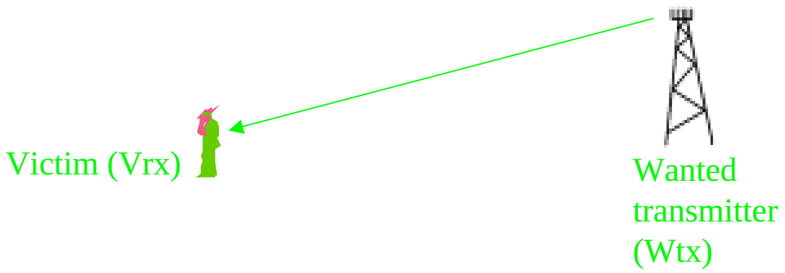


Slide 3

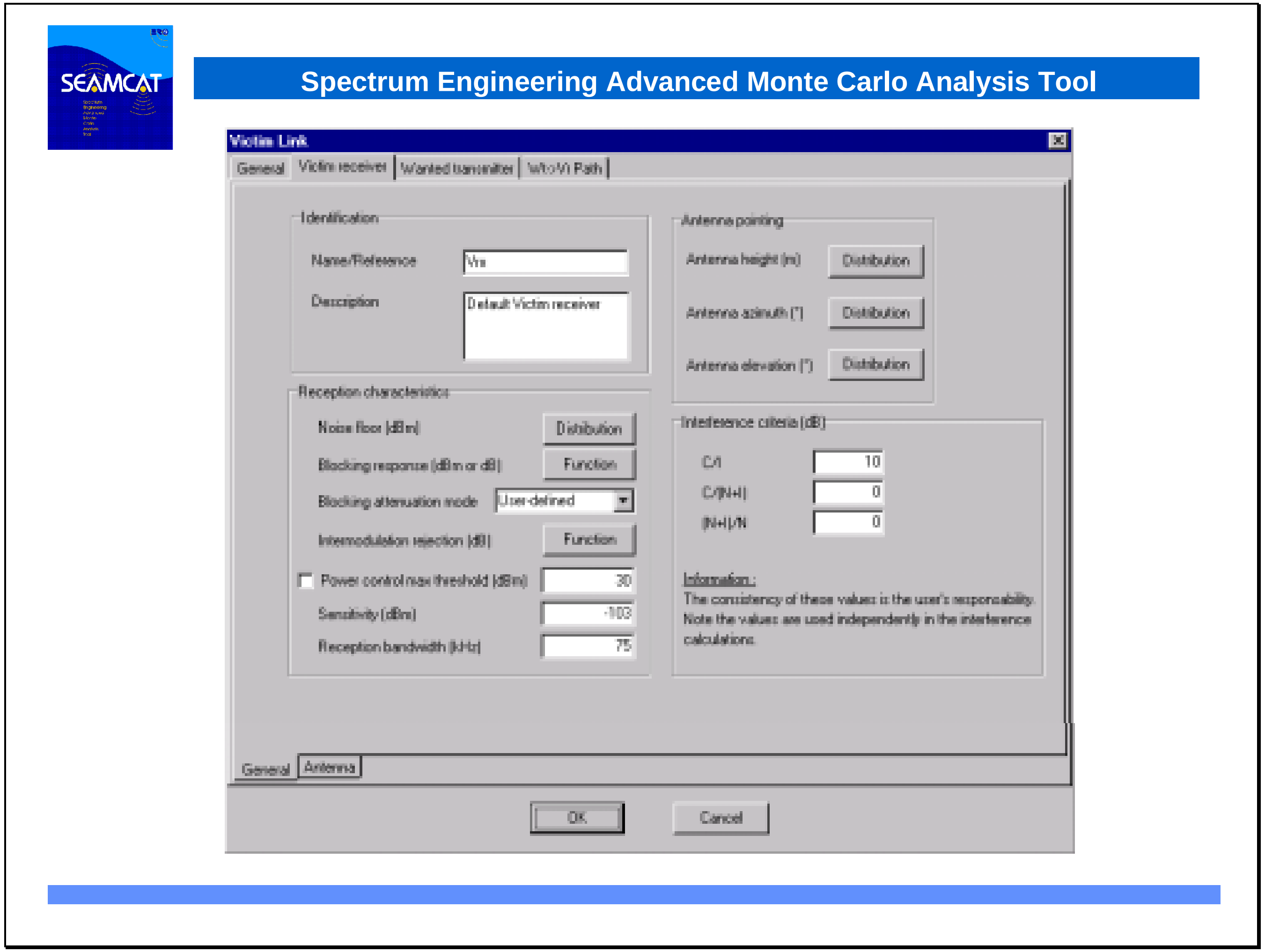
Spectrum Engineering Advanced Monte Carlo Analysis Tool

1. Define Victim link

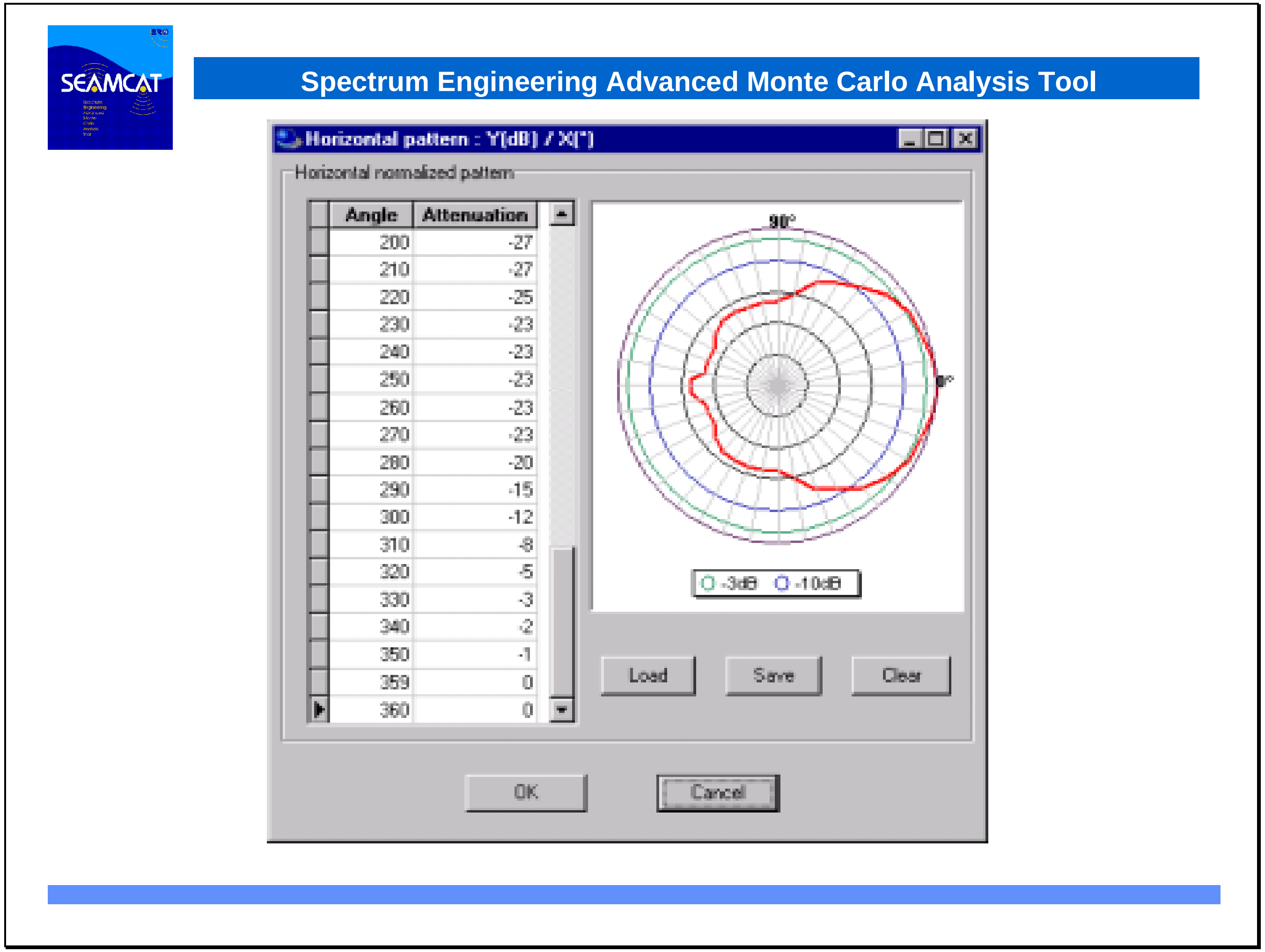
- FM Broadcast transmitter: 100 MHz, 1 kW
- Mobile receiver characteristics: C/I, Blocking, Sensitivity



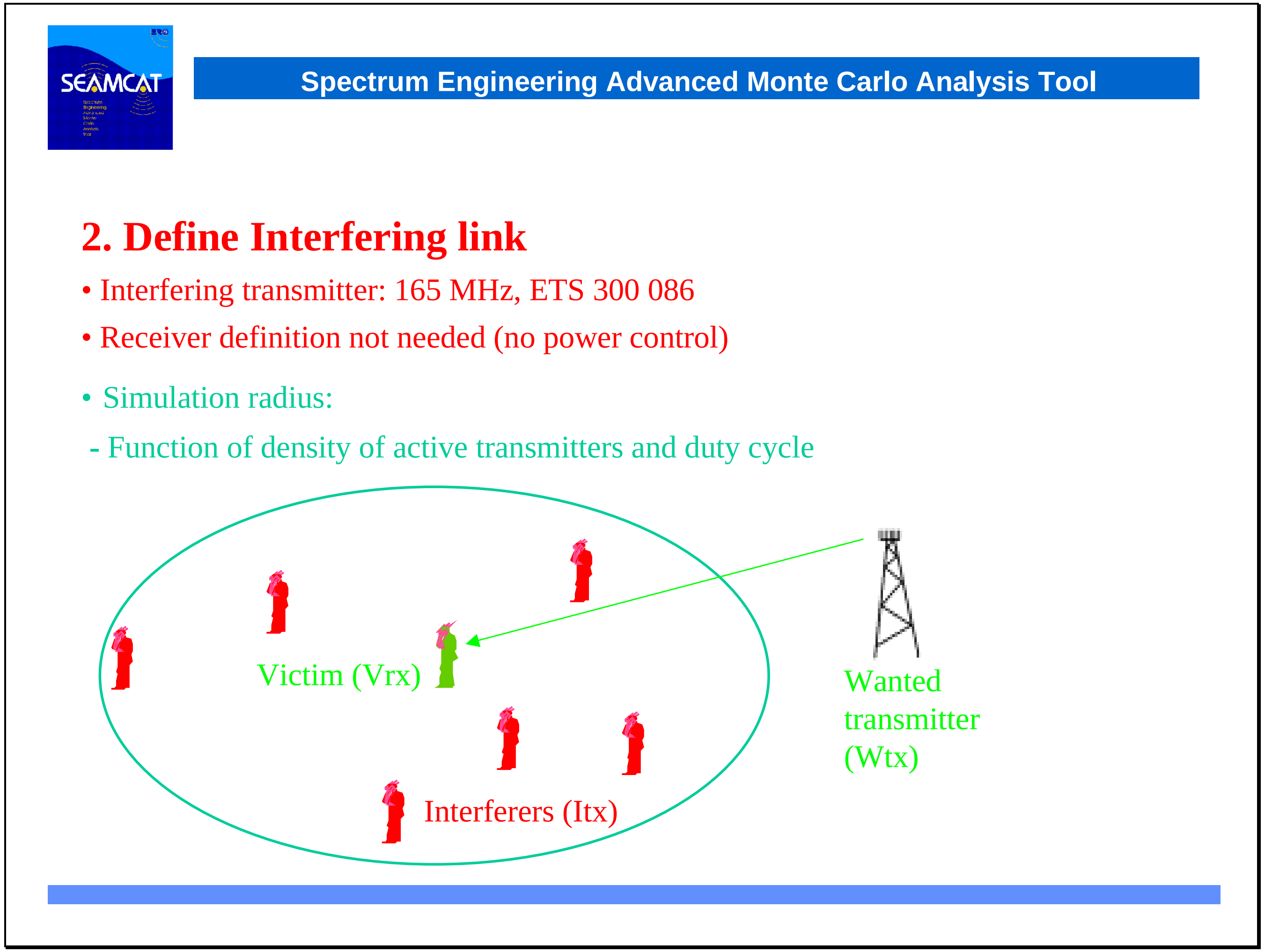
Slide 4


SEAMCAT
Spectrum Engineering Advanced Monte Carlo Analysis Tool
Victim Link
General
Victim receiver
Wanted transmitter
Wt to Vr Path
Identification
Name/Reference
Vrx
Description
Default Victim receiver
Antenna pointing
Antenna height (m)
Distribution
Antenna azimuth (°)
Distribution
Antenna elevation (°)
Distribution
Reception characteristics
Noise floor (dBm)
Distribution
Blocking response (dBm or dB)
Function
Blocking attenuation mode
User-defined
Intermodulation rejection (dB)
Function
Power control max threshold (dBm)
30
Sensitivity (dBm)
-103
Reception bandwidth (kHz)
75
Interference criteria (dB)
C/I
10
C/(N+I)
0
(N+I)/N
0
Information :
The consistency of these values is the user's responsability.
Note the values are used independently in the interference calculations.
General
Antenna
OK
Cancel

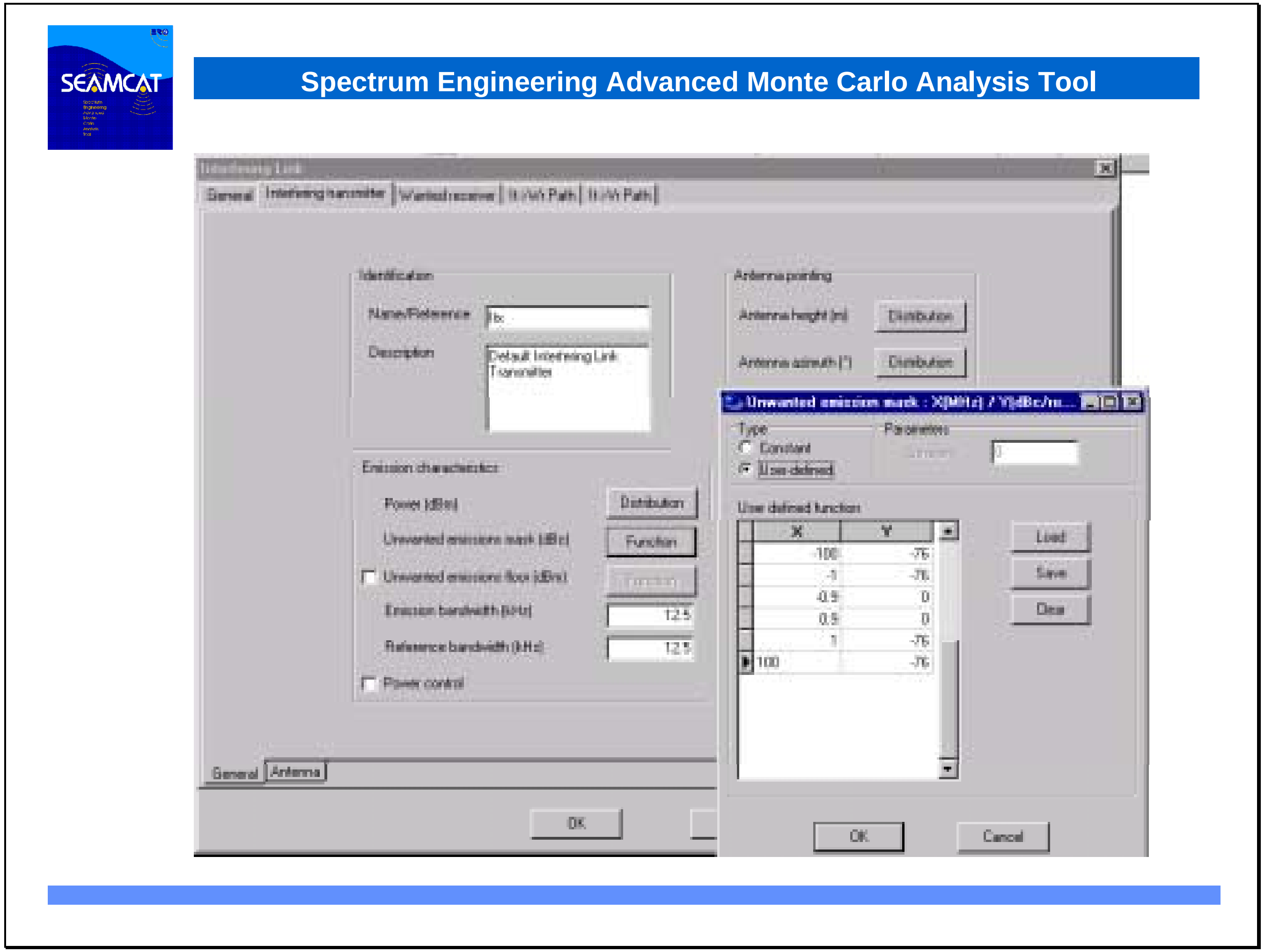
Slide 5


SEAMCAT
Spectrum Engineering Advanced Monte Carlo Analysis Tool
Horizontal pattern : Y(dB) / X(°)
Horizontal normalized pattern
Angle
Attenuation
200 -27
210 -27
220 -25
230 -23
240 -23
250 -23
260 -23
270 -23
280 -20
290 -15
300 -12
310 -8
320 -5
330 -3
340 -2
350 -1
359 0
360 0
90°
0°
-3dB
-10dB
Load
Save
Clear
OK
Cancel

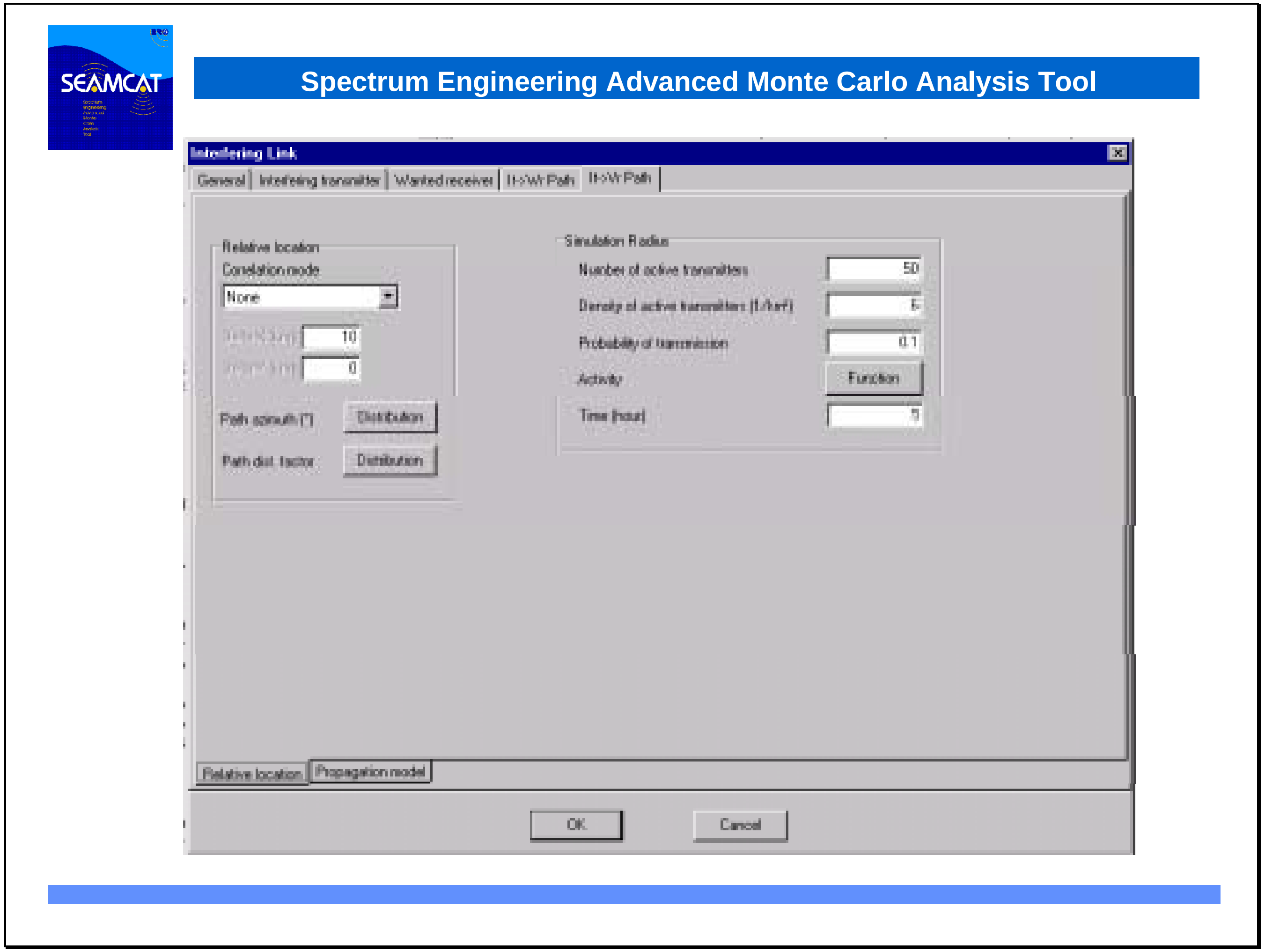
Slide 6


SEAMCAT
Spectrum Engineering Advanced Monte Carlo Analysis Tool
2. Define Interfering link
• Interfering transmitter: 165 MHz, ETS 300 086
• Receiver definition not needed (no power control)
• Simulation radius:
- Function of density of active transmitters and duty cycle
Victim (Vrx)
Wanted
transmitter
(Wtx)
Interferers (Itx)

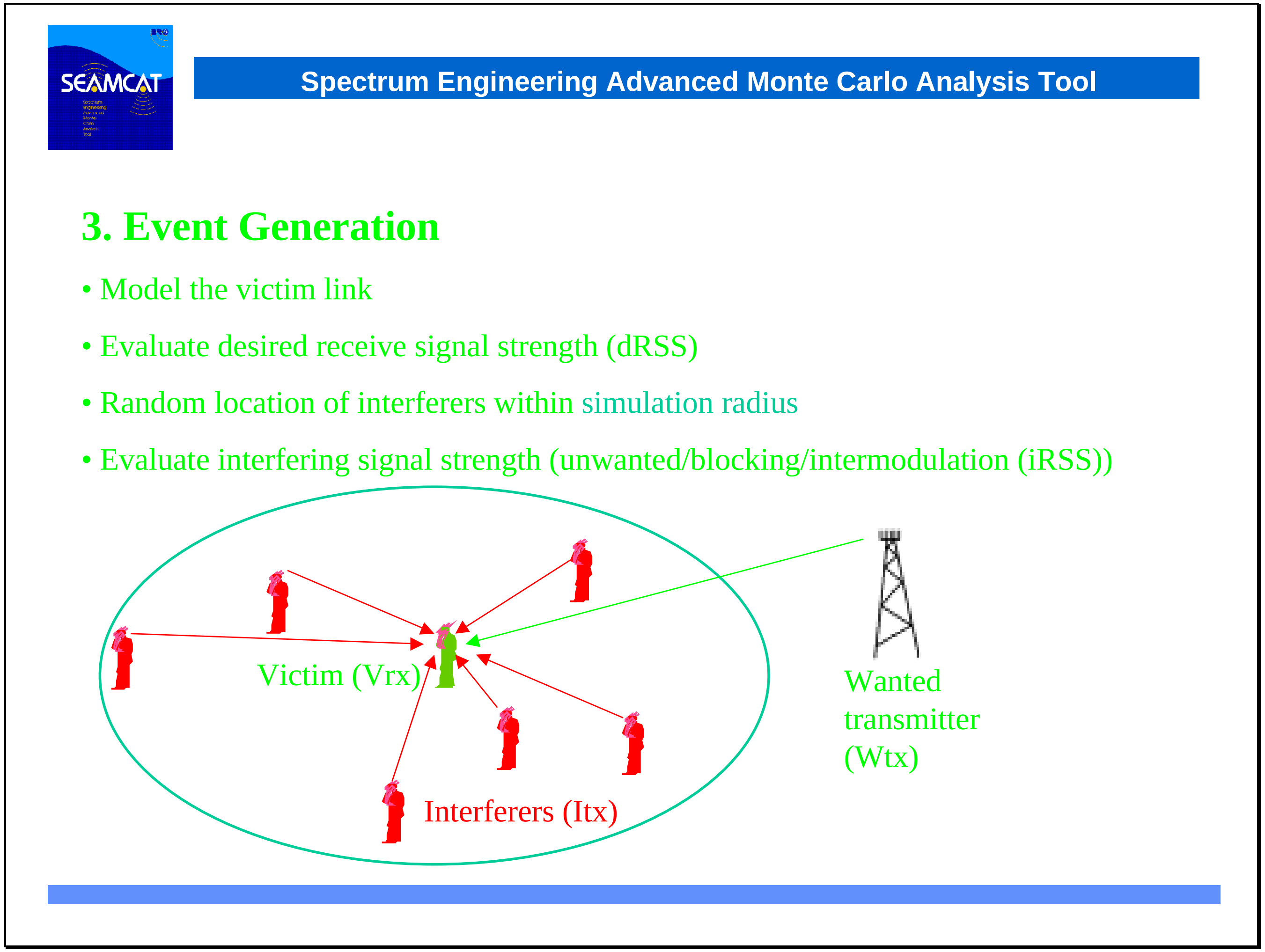
Slide 7


SEAMCAT
Spectrum Engineering Advanced Monte Carlo Analysis Tool
Identification
Name/Reference
Description
Default Interfering Link Transmitter
Antenna pointing
Antenna height (m)
Antenna azimuth (°)
Distribution
Emission characteristics
Power (dBm)
Unwanted emissions mask (dBc)
Unwanted emissions floor (dBm)
Emission bandwidth (kHz)
Reference bandwidth (kHz)
Power control
Function
General
Antenna
OK
Type
Constant
User defined
Parameters
User defined function
X
Y
Load
Save
Clear
Cancel

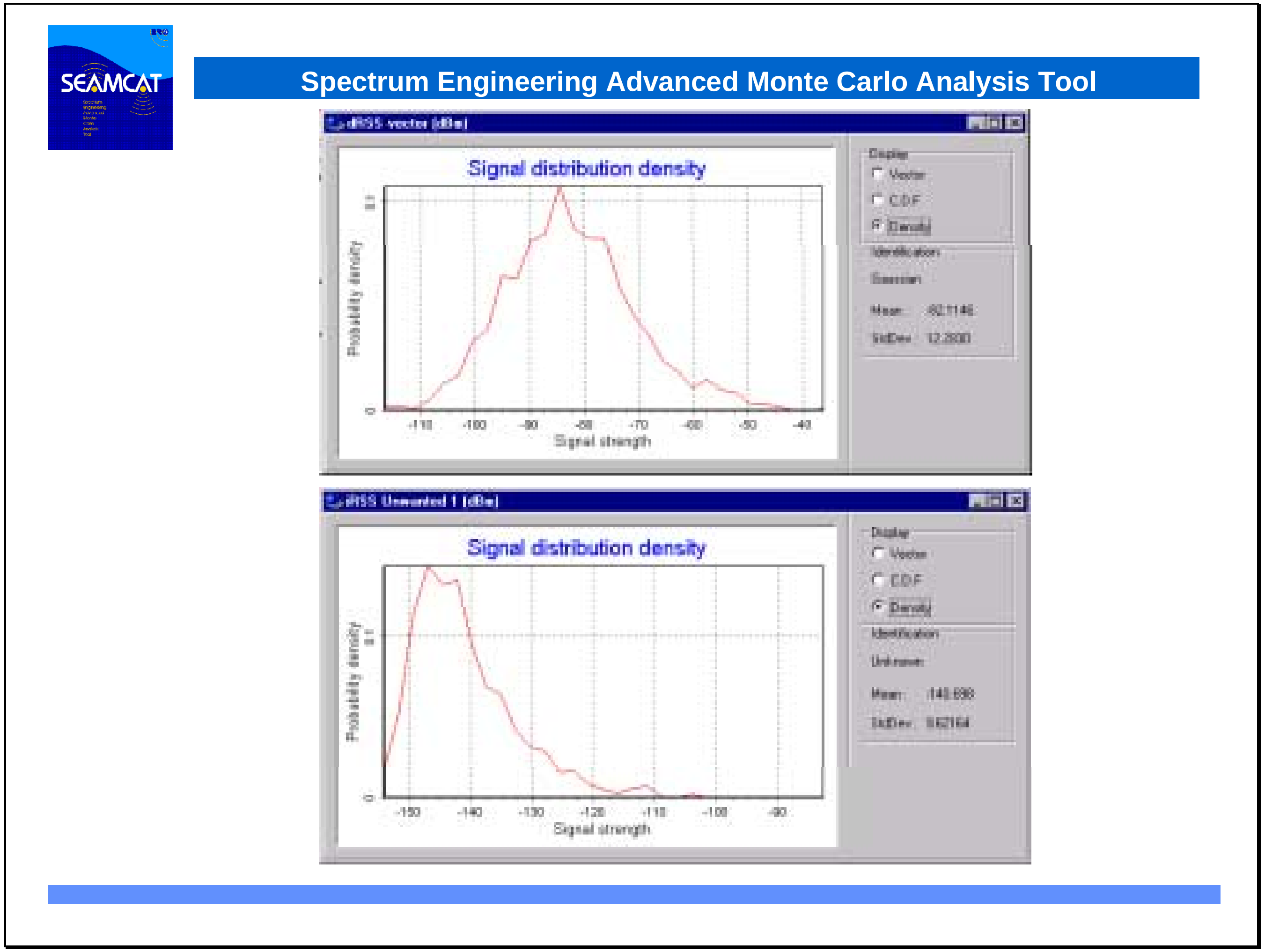
Slide 8


SEAMCAT
Spectrum Engineering Advanced Monte Carlo Analysis Tool
Interfering Link
General
Interfering transmitter
Wanted receiver
It->Wr Path
It->Vr Path
Relative location
Correlation mode
None
10
0
Path azimuth (°)
Distribution
Path dist. factor
Distribution
Simulation Radius
Number of active transmitters
50
Density of active transmitters (1/km²)
5
Probability of transmission
0.1
Activity
Function
Time (hour)
5
Relative location
Propagation model
OK
Cancel

Slide 9


SEAMCAT
Spectrum Engineering Advanced Monte Carlo Analysis Tool
3. Event Generation
• Model the victim link
• Evaluate desired receive signal strength (dRSS)
• Random location of interferers within simulation radius
• Evaluate interfering signal strength (unwanted/blocking/intermodulation (iRSS))
Victim (Vrx)
Interferers (Itx)
Wanted
transmitter
(Wtx)

Slide 10

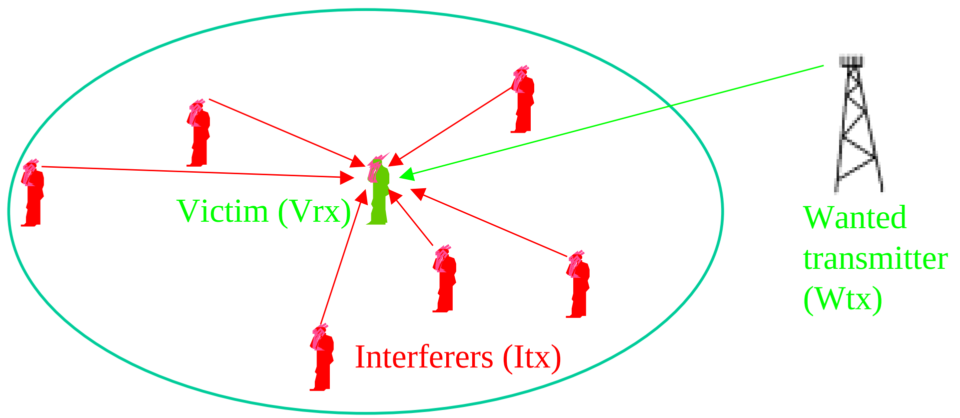

SEAMCAT
Spectrum Engineering Advanced Monte Carlo Analysis Tool
Signal distribution density
Probability density
Signal strength
Display
Vector
C.D.F
Density
Identification
Gaussian
Mean: -82.1146
StdDev: 12.2600
Signal distribution density
Probability density
Signal strength
Display
Vector
C.D.F
Density
Identification
Unknown
Mean: -140.698
StdDev: 9.62164

Slide 11

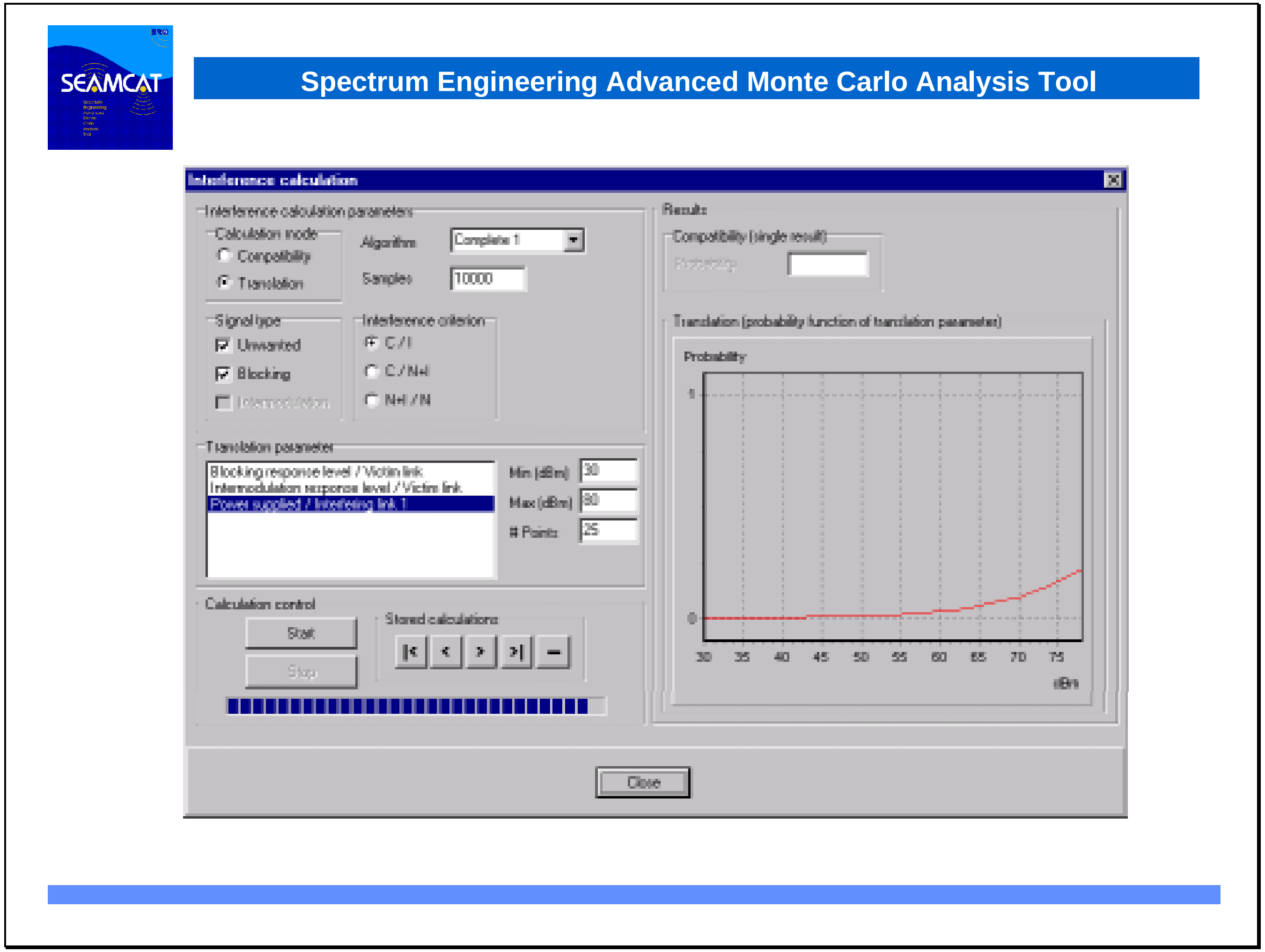
Spectrum Engineering Advanced Monte Carlo Analysis Tool

4. Interference Calculation

- Effect of interfering transmitters unwanted emissions
- Effect of victim receiver blocking
- *Intermodulation may also be evaluated*



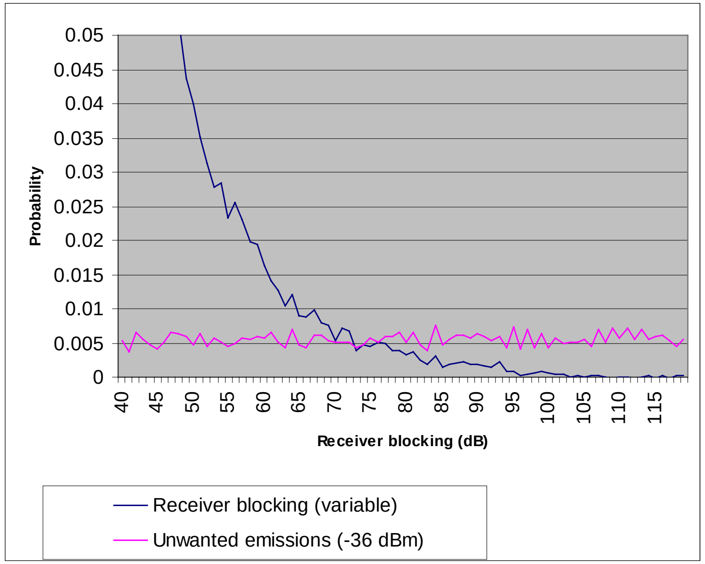
Slide 12


Spectrum Engineering Advanced Monte Carlo Analysis Tool
SEAMCAT
Interference calculation
Interference calculation parameters
Calculation mode
Compatibility
Translation
Algorithm
Complete 1
Samples
10000
Signal type
Unwanted
Blocking
Interference criterion
C / I
C / N+I
N+I / N
Translation parameter
Blocking response level / Victim link
Intermodulation response level / Victim link
Power supplied / Interfering link 1
Min (dBm)
30
Max (dBm)
80
Points
25
Calculation control
Start
Stop
Stored calculations
Results
Compatibility (single result)
Translation (probability function of translation parameter)
Probability
1
0
30
35
40
45
50
55
60
65
70
75
dBm
Close

Slide 13

Spectrum Engineering Advanced Monte Carlo Analysis Tool

5. Alternative presentation of results:

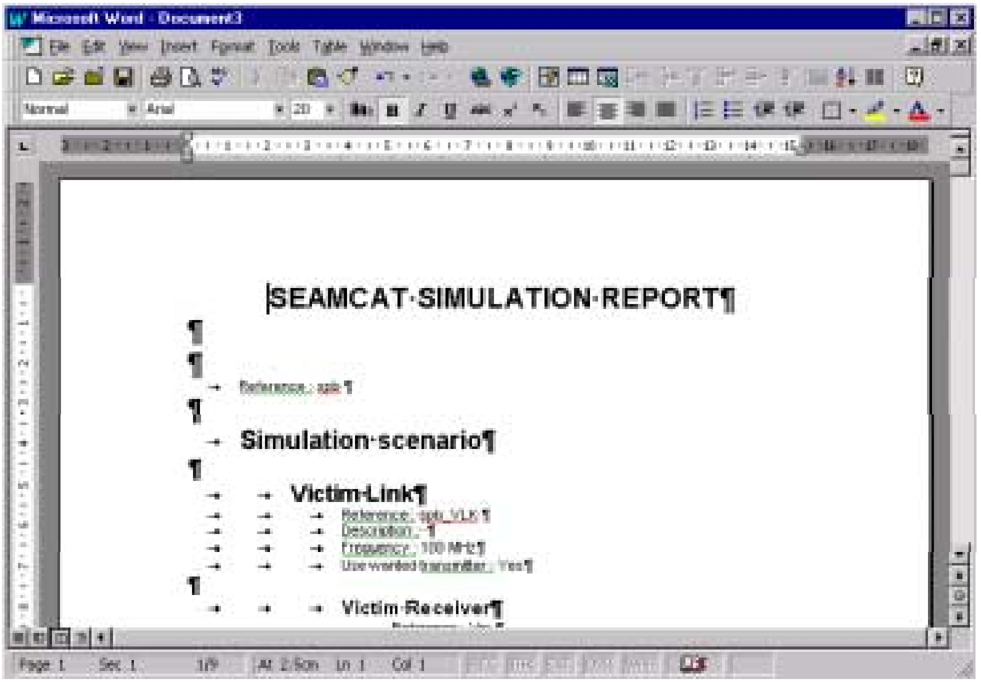


Slide 14

SEAMCAT

Spectrum Engineering Advanced Monte Carlo Analysis Tool

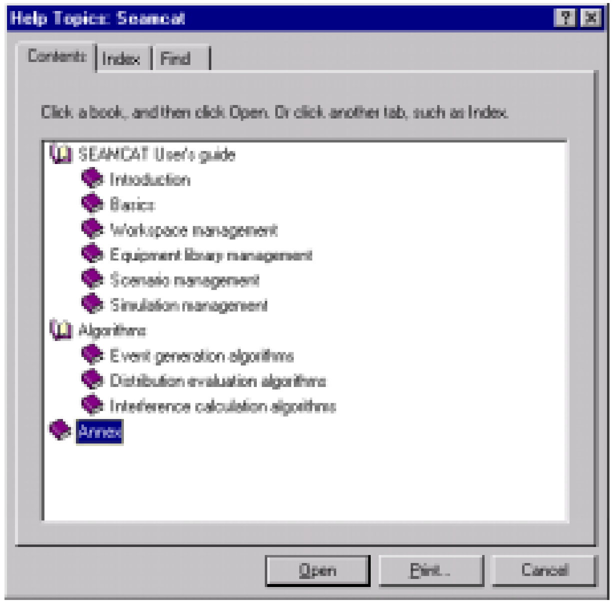
6. Reporting the results:



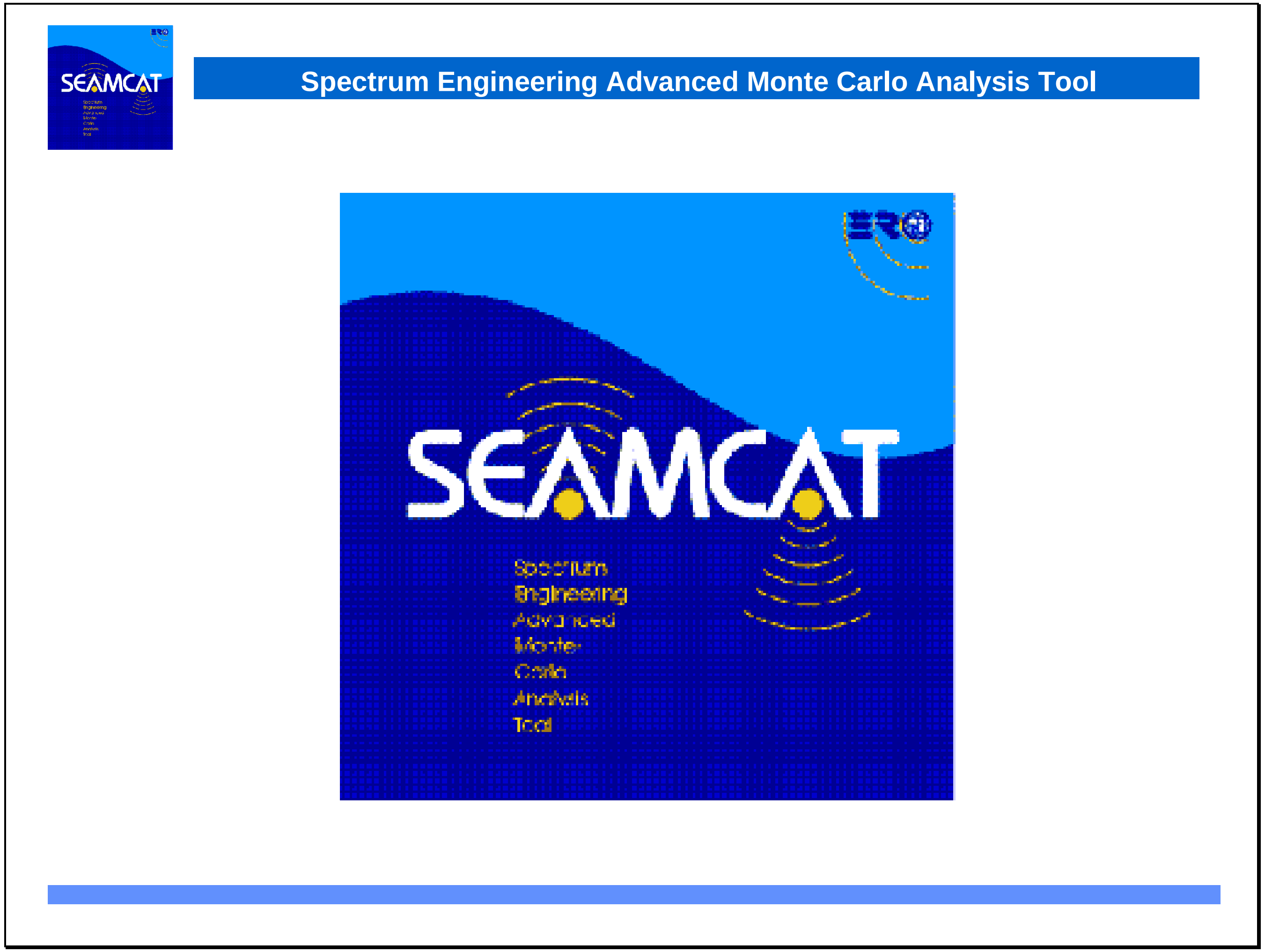
Slide 15

Spectrum Engineering Advanced Monte Carlo Analysis Tool

7. On-line help:



Slide 16


Spectrum Engineering Advanced Monte Carlo Analysis Tool
SEAMCAT

5 Meaning of SEAMCAT error messages

Using SEAMCAT, unclear error messages can pop up without any real definition of the reason why. This section is aimed to explain the meaning of these error messages.

5.1 "   is not a floating point value   "

This error message means that an empty field has been input instead of a number.

ANNEXES

Annex 1: correlation

The correlation is a measure of dependency between two values:

- means of vectors X and Y: m_X, m_Y
- variances of vectors X and Y:

The correlation factor is then given by the following expression:

$$\rho = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}(X_i - m_X)(Y_i - m_Y)}{\sigma_X{}^2\sigma_Y{}^2} = E[XY]-E[Y]E[X]/\ \sigma_x\sigma_y$$

Annex 2: To define a distribution

Description	Notation	Type	Unit	Comments
Constant		S		Type a constant value
User defined		D		Define a distribution i.e. values associated with probability.
Uniform		D		Define the min and the max values. All the values between them will have the same probability.
Gaussian		D		Define a Gaussian distribution with its mean and standard deviation.
Rayleigh		D		Define a Rayleigh distribution with its min and standard deviation.
Uniform polar distance		D		Define the max distance. Distances less than the max distance have the same probability.
Uniform polar angle		D		Define the angle max. The values included between -αmax and αmax have the same probability.
User defined distribution		D		Input area for the user defined distribution. Load and save allow the import/export of user defined values.

Note:
To see the formula of the distribution open the distribution's window and press F1.

Annex 3: To define a function

Description	Notation	Type	Unit	Comments
Constant		S		Constant function
User-defined		F		Input values for several abscissa values.

Annex 4: Definition of the antenna azimuth and elevation angle

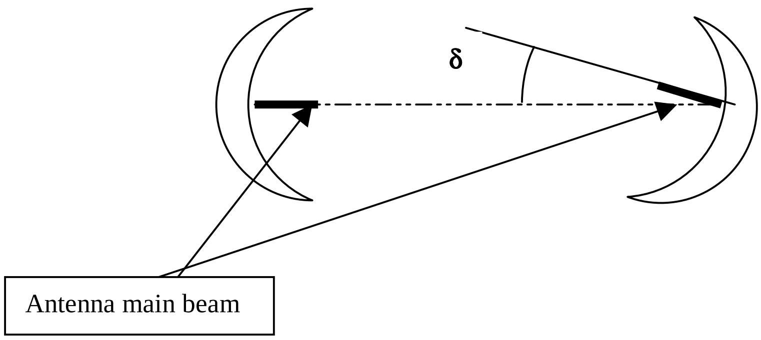


Figure 3, Definition of the antenna Azimuth/Elevation angle

δ: Azimuth angle or elevation angle
–--–--– : Aligned direction
The plane of the figure is the horizontal plane for the Azimuth angle and the vertical plane for the Elevation angle.

Annex 5: Receiver Blocking

This annex aims to explain the calculations of the receiver attenuation a_{vr} using the Blocking values defined by the user.

1 Basic concept

The receiver is capturing some unwanted signal because its filter is not ideal.

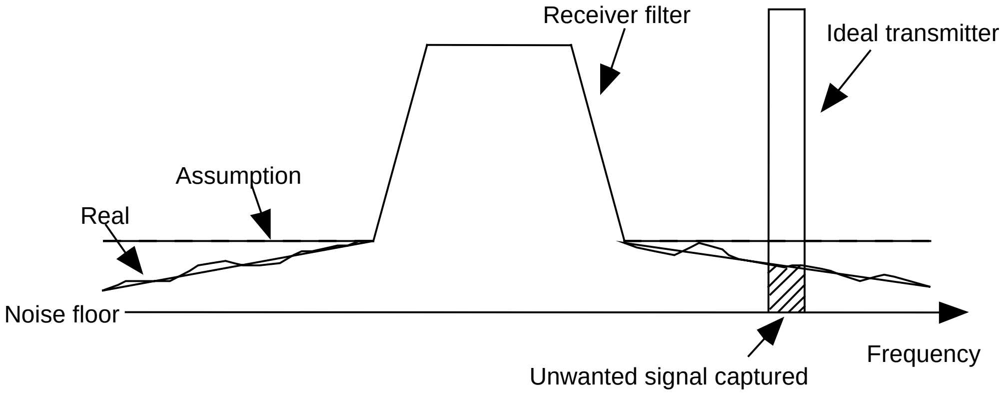


Figure 1, Basic concept

The Blocking is a measure of the receiver capability to receive a modulated wanted input signal in presence of an unwanted input signal without these unwanted input signals causing a degradation of the performance of the receiver beyond a specified limit. The blocking rejection can be expressed as the ratio of the interfering Signal Level/Desired Signal Level obtained during the measurements.

2 Blocking level measurements

- Adjust the desired signal at the BER limit level.
- Increase this desired signal by 3 dB and add the interfering signal which is increased until the same BER is obtained.
- The ratio (interfering signal/desired signal) is the value of the Receiver blocking rejection.

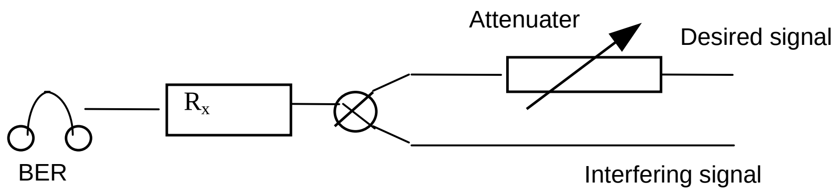


Figure 2, Measurement procedure

3 *Attenuation of the receiver*

During the measurement procedure, the three following equations are valid:

- Noise Floor + Protection ratio + 3 dB = Desired Signal Level (f_{vr}),
- Desired Signal Level (f_{vr}) + Blocking (Δf) = Interfering Signal Level (f_{it}),
- Interfering Signal Level (f_{it}) – Attenuation (Δf) = Noise Floor

Where $\Delta f = (f_{it} - f_{vr})$.

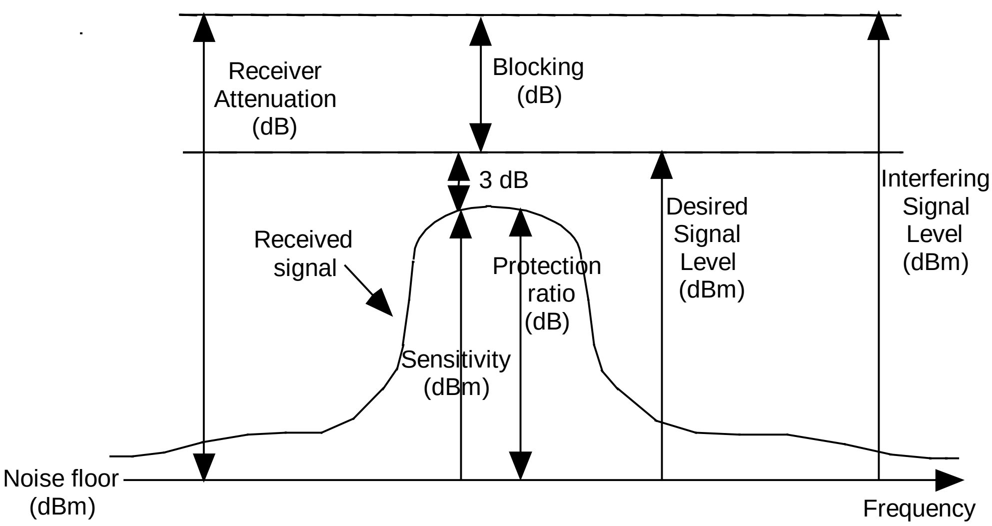


Figure 3, Definition of the blocking

The receiver attenuation is calculated in SEAMCAT based on the Blocking input.

4 Calculation modes

Three calculation modes are available:

- User-defined
- Sensitivity
- Protection-ratio

➢ *User-defined mode*

In this case, the Blocking is input in dB and represents the Net Filter Discrimination. Then the resulting receiver attenuation equals to the user-defined input values.

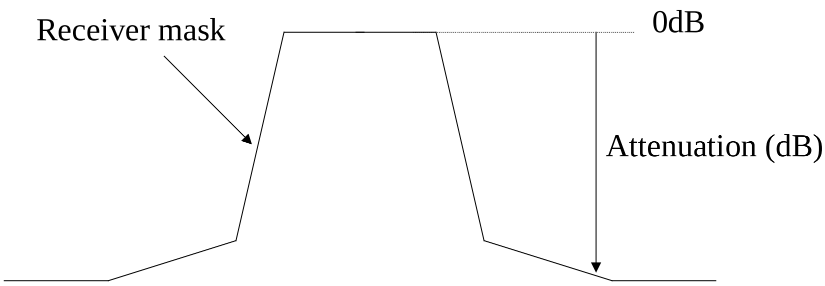


Figure 4, illustration of the user-defined Blocking

➢ *Sensitivity mode*

The user inputs the Blocking value in dBm (absolute value) which is the maximum acceptable interfering power (dBm). The following equations apply:

- Desired Signal Level (f_{it}) = Sensitivity (f_{it}) + 3dB
- Desired signal level (f_{it}) + Blocking (Δf) gives the maximum acceptable Interfering Signal level (f_{it}) .

Therefore, the user provides the Maximum acceptable Interfering Signal level:

Interfering Signal level (f_{it}) = Blocking (Δf) + Sensitivity + 3dB

And the attenuation is then calculated by SEAMCAT using the sensitivity:

- Attenuation (Δf) = Interfering Signal Level (f_{it}) – Sensitivity + C/(N+I)

➢ *protection ratio mode*

This mode is identical to the "sensitivity" mode since the only difference is that the Blocking value (relative to the noise floor) is input in dB. The software processes the information using exactly the same way to obtain the value of the receiver attenuation.

- Attenuation (Δ_f) = Blocking (Δ_f) + C/(N+I) + 3 dB
- Attenuation (Δ_f) = Interfering Signal Level (f_{it}) – Noise Floor

Where:

$\Delta_f = (f_{it} - f_{vr})$

and:

Interfering Signal Level (f_{it}) – Noise Floor is the Protection Ratio at Δf.

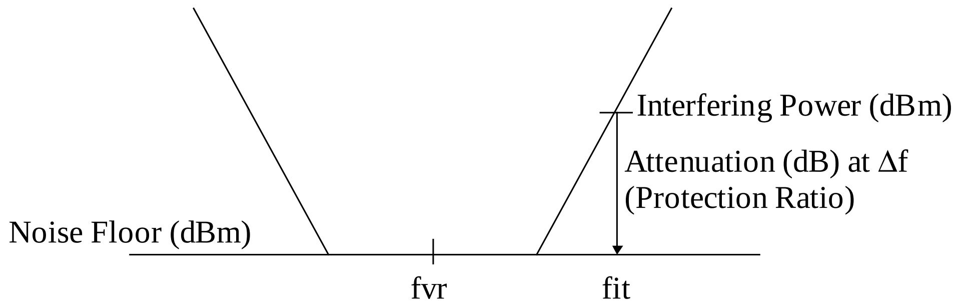


Figure 5, Protection Ratio

Note:

If the user uses the sensitivity or protection ratio modes he must define the C/N+I criterion. The other criteria (C/I and (N+I)/N) do not have any influence on the attenuation calculations. The content of this note has been checked by practical use of SEAMCAT.

5 *Calculation of the iRSS* ***block***

$$iRSS_{block} = (p_{it\,supplied} + g_{it\,PC} + g_{it\to vr}(f_{it}) - pl_{it\to vr} - a_{vr} + g_{vr\to it}(f_{it}))$$

f_{it} = interferer transmitting frequency

$p_{it\,supplied}$ = **maximum** power supplied to the interfering transmitter antenna (before power control)

$g_{it\,PC}$ = power control gain for the interfering transmitter with the power control function f_{pc} given in Annex 18

$pl_{it\to vr}$ = path loss between the interfering transmitter *i* and the victim receiver

$g_{vr\to it}(f_{it})$ = receiving antenna gain in the interfering direction direction

$a_{vr}(f_{it}, f_{vr})$ = attenuation of the victim receiver

Annex 6: Antenna

Description	Notation	Type	Unit	Comments
Name: name of the Antenna				
Description: comments on the antenna				
Antenna peak gain	g_{max}	S	dBi	Peak antenna gain.
Horizontal patterns: Horizontal normalized antenna pattern	$g^{V}(\theta)$	F	dB/degree	Input positive values for the angle, so between 0 and 360. For the gain, only input negative values relative to the Antenna peak gain.
Vertical patterns: Vertical normalized antenna pattern	$g^{H}(\phi)$	F	dB/degree	input angle values between –90 and 90. For the gain, only input negative values relative to the Antenna peak gain.

Annex 7: User-defined coverage radius

Description	Notation	Type	Unit	Comments
Coverage radius	R_{max}	S	km	Input a coverage radius, and fix it with a path loss constant or make little variation around this radius. Useful to give a fixed value for the coverage radius.

Annex 8: Noise limited network

Description	Notation	Type	Unit	Comments
Propagation model				Choose between Hata, Spherical diffraction
Reference antenna height (receiver): (used for coverage radius calculations)	h^0	S	m	If a distribution is inputed the coverage radius will be different in each sample, here the value may be fixed.
Reference antenna height (transceiver): (used for coverage radius calculations)	h^0	S	m	
Reference frequency	f_{vr}	S	MHz	
Reference power	P_{wt}	S	dBm	
Minimum distance			km	
Maximum distance			km	
Availability			%	
Fading standard deviation			dB	

The coverage radius $R_{\max}^{wt}$ (Victim link) (Interfering Link (not available for the interfering link due to the fact that the sensitivity of the wanted receiver is not defined)) is determined from the following equation:

$$F_{medianloss}(f_{vr}, h_{vr}, h_{wt}, R_{\max}, env) + F_{slowfading}(X\%) = P_{wt} + g_{wt} + g_{vr} - sens_{vr}$$

$F_{medianloss}$ = propagation loss not including slow fading

$F_{slowfading}(X\%)$ = fading margin to be used for 1-X% coverage loss

- In the case of log-normal fading and a 95% coverage loss at the edge of the coverage, for large distances, the value $F_{slowfading}$ is the well known 1.64 times the standard deviation of the propagation loss.
- The modified Hata model is applied as propagation model

If it is found after running the simulation that the resulting coverage radius is equal or very close to the minimum distance or the maximum distance, used in the calculation of the coverage radius, it is likely that there is a mistake in the values which were provided by the user. This can be solve by reducing the minimum distance or increase the minimum distance used in the calculation, so that the algorithm may found the corresponding coverage radius.

NB: in this case, formulas given for $F_{medianloss}(f_{vr}, h_{vr}, h_{wt}, R_{\max}, env)$ have to be inverted.

Annex 9: Traffic limited network

Description	Notation	Type	Unit	Comments
Density			1/km^2	
Number of channels				
Number of users per channel				
Frequency cluster				

The coverage radius $R_{\max}^{it}$ (Interfering link) or R_{max}^{wt} (Victim link) is determined from the following equation: $\pi \times dens_{\max} \times \left(R_{\max}^{it}\right)^2 = \frac{n_{channels}^{it} \times n_{usersperchannel}^{it}}{cluster_{frequency}^{it}}$

hence:

$$R_{\max}^{it} = \sqrt{\frac{n_{channels} \times n_{usersperchannel}}{\pi \times dens_{\max} \times cluster_{frequency}}}$$

Annex 10: Hata propagation model

Description	Notation	Type	Unit	Comments
Hata modified model/**Variation**				Variation in path loss takes into account the uncertainty of building design, furniture, room size, etc. This is a **standard deviation** which refers to the mean of the Median path loss.
Hata modified model/**Median path loss**				Depending of the distance, the environment, the frequency and the height of the antenna. This is a **mean.**
Hata modified model/**General environment**				Environment of the propagation: urban, rural, suburban
Hata modified model/**Local environment(Vr)**				Environment of the receiver antenna: outdoor, indoor
Hata modified model/ **Local environment(Wt)**				Environment of the transmitter antenna: outdoor, indoor
Hata modified model/**Propagation environment**				Environment of the propagation: Below roof, Above roof (used for standard deviation calculations) ONLY USED IF VARIATION OPTION IS CHECKED
Hata modified model/**Wall loss**(indoor indoor)		S	dB	
Hata modified model/ **Wall loss std dev** (indoor indoor)		S	dB	
Hata modified model/ **Wall loss**(indoor outdoor)		S	dB	
Hata modified model**/ Wall loss std dev** (indoor outdoor)		S	dB	
Hata modified model/**Loss between adjacent floor**		S	dB	
Hata modified model/**empirical parameters**	b			
Hata modified model/**Size of the room** (droom)	droom	S	m	
Hata modified model/**Height of each floor**	hfloor	S	m	

The propagation loss due to the modified Hata model can be expressed very generally

$$f_{propag}(f, h_1, h_2, d, env) = L + T(G(\sigma))$$

where

L	median propagation loss (dB)
σ	deviation of the slow fading distribution (dB)
f	frequency (MHz)
H_m	min((h_1, h_2) , (m)
H_b	max((h_1, h_2) , (m)
d	distance (km), preferably less than 100 km
env	environment variable: outdoor/outdoor, rural/suburban/urban, propagation above/below roof)
$T(G(\sigma))$	Gaussian distribution of the slow fading depending on *d* and *env*

The modified Hata model distinguishes between the three cases:

- < d = 40 m, the free space model is applied
- > d = 100 m, the Hata model is used
- Between these distances a linear interpolation is performed used.

Annex 11: Spherical diffraction propagation model

Description	Notation	Type	Unit	Comments
Spherical diffraction model/**Variation**				Variation in path loss takes into account the uncertainty of building design, furniture, room size, etc. Empirical
Spherical diffraction model/**Median path loss**				Depending of the distance, the environment, the frequency and the height of the antenna. It is the free space attenuation.
Spherical diffraction model/**General environment**				Environment of the propagation: urban, rural, suburban
Spherical diffraction model/**Local environment(Vr)**				Environment of the receiver antenna: outdoor, indoor
Spherical diffraction model/ **Local environment(Wt)**				Environment of the transmitter antenna: outdoor, indoor
Spherical diffraction model/**Wall loss**(indoor indoor)		S	dB	
Spherical diffraction model/ **Wall loss std dev** (indoor indoor)		S	dB	
Spherical diffraction model/ **Wall loss**(indoor outdoor)		S	dB	
Hata modified model/ **Wall loss std dev** (indoor outdoor)		S	dB	
Spherical diffraction model/**Loss between adjacent floor**		S	dB	
Spherical diffraction model/**empirical parameters**	b			
Spherical diffraction model/**Size of the room** (droom)	droom	S	m	
Spherical diffraction model/**Height of each floor**	hfloor	S	m	
Spherical diffraction model/**Water concentration**		S	g/m^2	
Spherical diffraction model/**Earth surface admittance**				
Spherical diffraction model/**index gradient**				
Spherical diffraction model/**Refraction layer prob**				

Annex 12: user defined propagation model

Description	Notation	Type	Unit	Comments
User-define model/**General environment**				Environment of the propagation: urban, rural, suburban
User-define model/**Local environment(Vr)**				Environment of the receiver antenna: outdoor, indoor
User-define model / **Local environment(Wt)**				Environment of the transmitter antenna: outdoor, indoor
User-define model /**Propagation environment**				Environment of the propagation: Below roof, Above roof
Comments				

Annex 13: Simulation radius, calculation

Function:
This function is aimed for the calculation of the radius R_{simu} of the area where the interfering transmitter are spread (centered on the victim receiver).

Input:

- Interfering transmitter
  - n^{active}: number of active interferers in the simulation (n^{active} should be sufficiently large so that the $(n+1)^{th}$ interferer would bring a negligible additional interfering power).
  - $dens_{it}^{active}$: density of active transmitters
  - P_{it}: probability of transmission
  - $activity_{it}(time)$: temporal activity variation as a function of the time of the day (hh/mm/ss)
  - *time*: Time of the day

Output:

- Radius of interferer area R_{simu}

Processing:
R_{simu} is defined as:

$$R_{simu} = \sqrt{\frac{n^{active}}{\pi \times dens_{it}^{active}}}$$

where $dens_{it}^{active}$ is the density of active transmitters:

$$dens_{it}^{active} = dens_{it} \times p_{it}^{tx} \times activity_{it}(time)$$

(d_0)

Annex 14: *dRSS* and *iRSS* Calculations

In this section, T represents a trial from a given distribution (Annex 2). These distributions can be constant, user-defined, uniform $U(0,1)$, Gaussian $G(\sigma)$, Rayleigh$R(\sigma)$ uniform polar distance and uniform polar angle.
If the user wishes to understand and check SEAMCAT, the easiest way is to use freespace loss propagation which makes manual calculation simple (Annex 17).

1. *dRSS* calculation

1.1. Case of variable distance

$$dRSS = f(p_{wt\ supplied}, g_{wt \to vr}, pl_{wt \to vr}, g_{vr \to wt})$$

$$= p_{wt\ \mathrm{supplied}} + g_{wt \to vr}(f_{vr}) - pl_{wt \to vr}(f_{vr}) + g_{vr \to wt}(f_{vr})$$

If the received signal can not exceed a given value (i.e. if depending on the power control implemented in the victim system) :

$$dRSS = \min(dRSS, dRSS\ \mathrm{max})$$

Using *dRSS* as calculated with the formula before.
The following variables are used in the formula above:

$p_{wt\ supplied} = T(P_{wt\ supplied})$ maximum power supplied to the wanted transmitter antenna

$pl_{wt \to vr}$ path loss between the wanted transmitter and the victim receiver (propagation loss depending on the propagation model, slow fading and clutter losses taken into account). Depending on whether the criteria of interference will apply to

- the instantaneous dRSS (rayleigh fading excluded), do not apply the same path loss for each trial:

  $pl_{wt \to vr} = f_{propag}(f_{vr}, h_{vr}, h_{wt}, d_{vr \to wt}, env) = L + T(Dv)$

  f_{propag} = Propagation law (median loss L+ variation in tabsheet Wt to Vr path/propagation model $T(Dv)$)

- to the mean dRSS, apply the same path loss for each trial:
  $pl_{wt \to vr} = f_{median}(f_{vr}, h_{vr}, h_{wt}, d_{vr \to wt}, env) = L$

f_{median} = Propagation law (median loss L only in tabsheet Wt to Vr path/propagation model)

f_{vr} = frequency of the victim receiver

$h_{vr} = T(H_{vr})$ victim receiver antenna height
e.g. $h_{vr} = T(U(h_{vr\ min}, h_{vr\ max})) = h_{vr\ min} + (h_{vr\ max} - h_{vr\ min})\ T(U(0,1))$

$h_{wt} = T(H_{wt})$ wanted transmitter antenna height
e.g. $h_{wt} = T(U(h_{wt\ min}, h_{wt\ max})) = h_{wt\ min} + (h_{wt\ max} - h_{wt\ min})\ T(U(0,1))$

env environment type (indoor/indoor, outdoor/indoor….)

R^{wt}_{max} Radius of the wanted transmitter coverage.
$d_{wt->vr} = T(R^{wt}_{max})$ distance between the victim receiver and the wanted transmitter
e.g. $d_{wt->vr} = R^{wt}_{max} * \sqrt{T(U(0,1))}$

Three different choices for R^{wt}_{max} are considered:

- Given distance R^{wt}_{max}
- Noise limited network (see Annex 8)
- Traffic limited network (see Annex 9)

$g_{wt->vr} = f(g_{wt\ max}, pattern_{wt}) = g_{wt\ max} \times pattern_{wt}(\theta_{wt->vr}, \varphi_{wt->vr}, f_{vr})$

wanted transmitter antenna gain in the victim receiver direction with
$g_{wt\ max}$ = Maximum antenna gain of the Wanted transceiver
$pattern_{wt}$ = Wanted transmitter normalised antenna pattern within operating bandwidth
$(\theta_{wt->vr}, \varphi_{wt->vr})$ = azimuth and elevation angles between the top of the wanted transmitter antenna and the top of the victim receiver antenna.
e.g. $\theta_{wt->vr} = T(U(0, 2\pi)) = 2\pi \times T(U(0,1))$
$\varphi_{wt->vr} = T(U(-\pi/2, \pi/2)) = \pi \times T(U(0,1)) - \pi/2$

$g_{vr->wt} = f(g_{vr\ max}, pattern_{vr}) = g_{vr\ max} * pattern_{vr}(\theta_{wt->vr} + \pi, -\varphi_{wt->vr}, f_{vr})$
victim receiver antenna gain in the wanted transmitter direction

1.2. *Case of fixed distances (correlation distance)*

The gain is constant.

$$dRSS = f(P_{\text{wt nominal}}, f_{\text{fading, fixed link}}) = T(P_{\text{wt nominal}}) - T(f_{\text{fading, fixed link}})$$

where $P_{wt\ nominal}$ = nominal power distribution
$f_{fading\ ,\ fixed\ link}$ = fading distribution

2. *iRSS* calculations

For the *iRSS* calculation *k* different interfering systems having *n* active interfering transmitters. The resulting interfering power in the victim receiver is computed similar the algorithms given below. The following consideration are restricted to *k*=1 for simplification only.

2.1. iRSS block calculation

$$iRSS_{block} = \sum_{i=1,\ i=n\ interferers} f\left(p_{it\ supplied},\ g_{it\ PC},\ g_{it\to vr},\ pl_{it\to vr},\ a_{vr},\ g_{vr\to it}\right)_i$$

$$iRSS_{block} = 10\log\left(\sum_{i=1}^{n} 10^{\frac{iRSS_{block,i}}{10}}\right)$$

where the i-th interferer signal is given by

$$\text{iRSS}_{\text{block,i}} = \left(p_{it\ supplied} + g_{it\ PC} + g_{it\to vr}(f_{it}) - pl_{it\to vr} - a_{vr} + g_{vr\to it}(f_{it})\right)$$

where for each interferer:

$f_{it} = T(f_{it})$ interferer transmitting frequency

$p_{it\ supplied} = T(P_{it\ supplied})$ maximum power supplied to the interfering transmitter antenna (before power control)

$g_{it\ PC} = f_{pc}\left(p_{it\ supplied},\ g_{it\to wr},\ pl_{it\to wr},\ g_{wt\to it},\ pc_{min\_r},\ pc_{max\_r},\ pc_{step}\right)$
power control gain for the interfering transmitter
with the power control function f_{pc} given in Annex 18

$pl_{it\to wr}$ path loss between the interfering transmitter and the wanted receiver

pc_{min_r} lowest power level received where no power control takes place

pc_{max_r} highest power level received where the full power control takes place

pc_{step} steps of power control

Note: The power control is differently noted.

$pl_{it\to vr}$ = path loss between the interfering transmitter i and the victim receiver

e.g. $pl_{it\to vr} = f_{propag}(f_{it}, h_{vr}, h_{it}, d_{it\to vr}, env) + f_{clutter}(env)$ or

$pl_{it\to vr} = f_{median}(f_{it}, h_{vr}, h_{it}, d_{it\to vr}, env) + f_{clutter}(env)$

The choice between f_{median} and f_{propag} would depend on the criteria of interference, and is closely related to the choice made for assessment of dRSS, e.g. whether ICE will evaluate:

$dRSS_{mean} / iRSS_{mean}$; $dRSS_{propag} / iRSS_{propag}$; $dRSS_{mean} / iRSS_{propag}$ ...

where

h_{vr} = victim receiver antenna height (defined in the dRSS calculation)

h_{it} = interfering transmitter antenna height (defined previously)

$d_{it\to vr}$ = distance between the victim receiver and the interfering transmitter

Two different ways to choose $d_{it\to vr}$:

- The most common case is when there is no spatial correlation between the elements of the victim system and the elements of the interfering system. Then $d_{it\to vr}$ is a result of a trial:

$$d_{it\to vr} = R_{simu} * \sqrt{T(U(0,1))}$$

R_{simu} = radius of the area where interferers are spread

R_{simu} is defined as :

$$R_{simu} = \sqrt{\frac{n^{active}}{\pi \times dens_{it}^{active}}}$$

where $dens_{it}^{active}$ is the density of active transmitters :

$$dens_{it}^{active} = dens_{it} \times p_{it}^{tx} \times activity_{it}(time)$$

where

n_{active} = number of active interferers considered in the simulation.

n_{active} should be sufficiently large so that the n+1 interferer would bring a negligible additional interfering power.

- This case deals with the situation where the victim system and the interfering system are geographically correlated (e.g. co-located base stations).

  This correlation is assumed to be only between one element (victim or wanted transmitter) of the victim system and one element (interferer or wanted receiver) of the interfering system.

  A trial (if the distance is not fixed) of the distances and angles between the two correlated elements is made (e.g. $\theta_{wr\to vr}$, $d_{wr\to vr}$). The knowledge of $\theta_{it\to wr}$, $d_{it\to wr}$, $\theta_{vr\to wt}$, $d_{vr\to wt}$ enables to derive the missing coordinates (e.g. $\theta_{it\to vr}$, $d_{it\to vr}$)

$$\sigma = \frac{1}{\sqrt{2\pi dens_{it}^{active}}}$$

$g_{it \to vr}(f_{it}) = (g_{it\,max}, pattern_{it}) = g_{it\,max} \times pattern_{it}(\theta_{it \to vr}, \varphi_{it \to vr}, f_{it})$
interfering transmitter antenna gain in the victim receiver direction

$g_{vr \to it}(f_{it}) = (g_{vr\,max}, pattern_{vr}) = g_{vr\,max} \times pattern_{vr}(\theta_{it \to vr}, \varphi_{it \to vr}, f_{it})$
receiving antenna gain in the interfering direction direction

$a_{vr}(f_{it}, f_{vr})$ = attenuation of the victim receiver

Three possible ways are considered for calculating this attenuation:

- a_{vr} is given by the user
- blocking is given in terms of blocking attenuation or protection ratio.
- blocking is given in terms of absolute level of blocking.

Details of the algorithms are given in Annex 5. Two cases are envisaged:

1) *block* is a mask (in dB or dBm) which is a function of $\Delta_f = (f_{it} - f_{vr})$. It is introduced to enable calculations of interference between systems in adjacent band.
2) *block* is a fixed value (e.g. 80 dBm). It is used to derive generic limits.

2.2. iRSS spur calculation = unwanted

The used algorithms is similar to the one described in section 2.1.

$$iRSS_{spur} = f(\text{spur}, g_{it\,PC}, g_{it \to vr}, pl_{it \to vr}, g_{vr \to it})_i$$

$$iRSS_{spur} = 10\log\left(\sum_{i=1}^{n} 10^{\frac{iRSS_{spur,i}}{10}}\right)$$

where the i-th interferer signal is defined as

$$iRSS_{spur,i} = (spur(f_{it}, f_{vr}) + g_{it \to vr}(f_{vr}) - pl_{it \to vr}(f_{vr}) + g_{vr \to it}(f_{vr}))$$

where
f_{it} = interferer transmitting frequency

$spur(f_{it}, f_{vr}, g_{pc})$ = unwanted emission by the interfering transmitter

Two cases are envisaged :

- *spur* is a mask which is a function of $\Delta_f = (f_{it} - f_{vr})$. It is introduced to enable calculations of interference between systems in adjacent band.

- *spur* is a fixed value (e.g. -36 dBm). It is used to derive generic limits.

  $spur(f_{it}, f_{vr}, g_{pc})$ generally depends on the effect of the power control.

  Either :

  $spur(f_{it}, f_{vr}, g_{pc}) = \max\left(spur_0(f_{it}, f_{vr}), spur(f_{it}, f_{vr}) - g_{pc}\right)$

  or

  $spur(f_{it}, f_{vr}, g_{pc})$ is defined as a function of $\Delta_f = (f_{it} - f_{vr})$ for each possible steps of the power control.

  e.g. without power control:

  $spur_0(f_{it}, f_{vr}) = p_{it} +$ Integration in the bandwidth of the victim receiver of the bandwidth of the interfering transmitter = p_{it} + 10*log10(width of the band where the interfering transmitter is transmitting in the victim receiver bandwidth) - 10*log10(Bandwidth of the IT/1MHz)

  $g_{it\,PC}$ = power control gain for the interfering transmitter (see Annex 18)

  $pl_{it\to vr} = f_{propag}(f_{vr}, h_{vr}, h_{it}, d_{it\to vr}, env) + f_{clutter}(env)$

  path loss between the interfering transmitter and the victim receiver

  with h_{vr} = victim receiver antenna height (defined in dRSS calculation)
  h_{it} = interfering transmitter antenna height
  $d_{it\to vr}$ = distance between the victim receiver and the interfering transmitter

  $g_{it\to vr}(f_{vr}) = (g_{it\,\max}, pattern_{it}) = g_{it\,\max} \times pattern_{it}(\theta_{it\to vr}, \varphi_{it\to vr}, f_{vr})$
  interfering transmitter antenna gain in the victim receiver direction.

  $g_{vr\to it}(f_{vr}) = (g_{vr\,\max}, pattern_{vr}) = g_{vr\,\max} \times pattern_{vr}(\theta_{it\to vr} + \pi, -\varphi_{it\to vr}, f_{it})$
  victim receiver antenna gain in the interfering transmitter direction

2.3. *iRSS intermod calculation*

For the computation of the intermodulation products two different interfering systems are required, i.e. k > 1.

$iRSS_{intermod} = f\left(p_{it,k\ supplied}, g_{it,k\,PC}, g_{it,k\to vr}, pl_{it,k\to vr}, g_{vr\to it,k}, sens_{vr}, \text{intermod}\right)$

with k=i,j

$$iRSS_{intermod} = 10\log\left(\sum_{i=1}^{n}\sum_{\substack{i=1\\ i\neq j}}^{n} 10^{\frac{iRSS_{intermod,i,j}}{10}}\right)$$

where

$i_{i,j}RSS_{intermod}$ = intermodulation product of third order at the frequency f_0

$$i_{i,j}RSS_{intermod} = 2 * i_iRSS_{int} + i_jRSS_{int} - 3intermod - 3\,sens_{vr} - 9\mathrm{dB}$$

The interferer i transmits at the frequency $f_{it,i} = f_{it}$ and the interferer j at $f_{it,j}$, which defines $\Delta f = (f_{it,j} - f_{it})$ and yields $f_0 = f_{it} - \Delta f = 2f_{it} - f_{it,j}$. Assuming an ideal filter (roll off factor 0) the intermodulation product has to be considered only for the bandwidth b

$$f_{vr} - b/2 \le f_0 \le f_{vr} + b/2$$

For all other cases the intermodulation product can be neglected.

The parameters used in the formula above are defined by

$i_kRSS_{int} = p_{it,k\ supplied}, g_{it,k\ PC}, g_{it,k\to vr}, pl_{it,k\to vr}, g_{vr\to it,k}$
received power in the victim receiver due to interferer $k=i$ at f_{it} or interferer $k=j$ at $f_{it,j}$.

intermod = receiver intermodulation rejection for a wanted signal 3 dB above the sensitivity

2 cases are envisaged:

- *intermod* is given by the user, e.g. typical values are 70 dB for base station equipment and 65 dB for mobile and handportable equipment.It is used to derive generic limits.
- intermod(Δf) is measured as a function of Δf refered to f_{vr}.

$sens_{vr}$ = sensitivity of victim receiver

Annex 15: Unwanted emissions

This annex aims to explain the calculation of the Unwanted emissions.

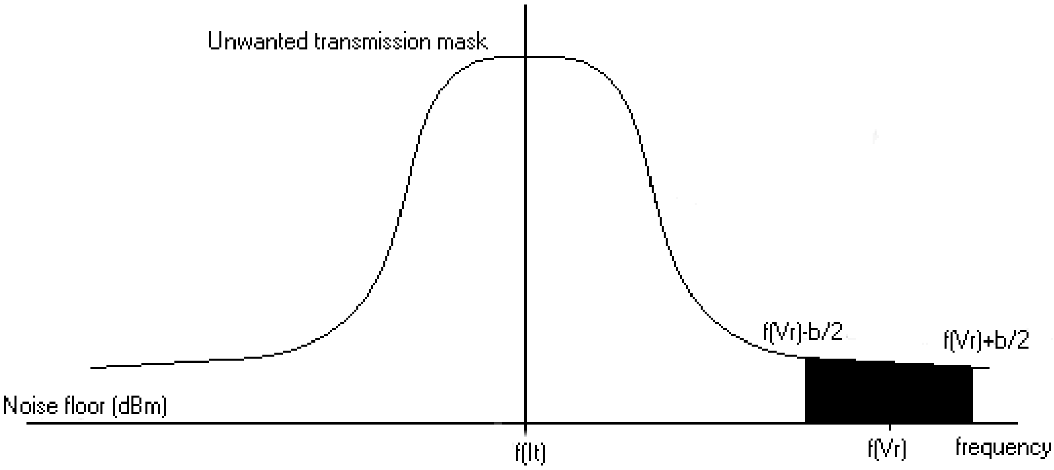


Figure 1, unwanted emissions in the victim receiver band

$spur(f_{it}, f_{vr}, g_{pc})$ = unwanted emission from the interfering transmitter (see figure 1).

For the interfering transmitter, an unwanted transmission mask p_{mi} is defined as a function of $\Delta f = f - f_{it}$ and should be defined as maximum power levels $p_{mi}(\Delta f)$ in reference bandwidth specified by the user.

1 Constant mask

With a constant mask, the unwanted emission bandwidth b_{it} must be defined and the transmitted power should be assumed to spread uniformly over b_{it} with no emission outside b_{it}.
For a constant mask, the Interfering power p_{it} is defined as dBm/emission bandwidth b_{it} and there is no attenuation within b_{it}.

If there is no power control the calculations of the unwanted level are:

Step 1: The constant mask function is normalized to 1 MHz.

$$p_{ni} = -10\text{LOG}(b_{ref}/1\text{MHz})$$

Step 2: The total received interfering power *spurtot* can easily be calculated by integration over the receiver bandwidth from a = lower edge of the common band between b_{it} and b_{vr} and b = higher edge of the common band between b_{it} and b_{vr} (in MHz).

$$spurtot = 10\log\left\{\int_a^b 10\wedge(p_{ni}(\Delta f)/10)\, d\Delta f\right\} = 10\log((b-a)/b_{ref}) \quad \text{(constant mask)}$$

Step 3: The iRSS calculation

$$iRSS_{spur} = p_{it} - 10LOG(b_{it}) + spurtot + g_{it->vr}(f_{vr}) - pl_{it->vr}(f_{vr}) + g_{vr->it}(f_{vr})$$

p_{it} = Interfering power defined as in dBm/emission bandwidth b_{it}

$g_{it->vr}(f_{vr})$ = The interfering transmitter antenna gain in the direction of the victim receiver

$g_{vr->it}(f_{vr})$ = The victim receiver antenna gain in the direction of the interfering transmitter

$pl_{it->vr}(f_{vr})$ = path loss in dB between the It and the Vr

Note : In this case (unwanted constant mask), the $iRSS_{spur}$ is defined in dBm/ MHz

2 User-defined mask

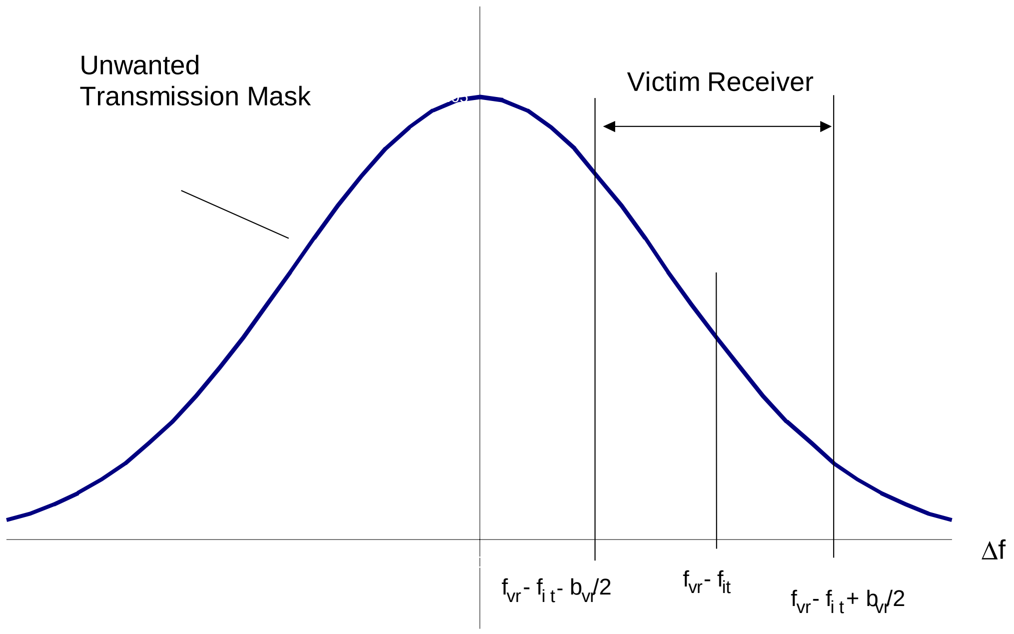


Figure 2, integration of the unwanted emissions in the victim receiver band

The emission bandwidth b_{it} has no more influence in the calculations because the result is in dBm/b_{it} .

If there is no power control the calculations of the unwanted level are:

For a user-defined mask, the Interfering power p_{it} is defined as dBm/emission bandwidth b_{it} and the mask attenuation is defined as dBc/reference bandwidth $b_{ref.}$

Step 1: For simplification within the algorithms the mask function p_{mi} is normalized to 1MHz reference bandwidth:

$$p_{ni} = p_{mi} \text{-10LOG}(b_{ref}/\text{1MHz})$$

Step 2: The total received interfering power *spurtot* can easily calculated by integration over the receiver bandwidth from $a = f_{vr} - f_{it} - b_{vr}/2$ to $b = f_{vr} - f_{it} + b_{vr}/2$ (in MHz)

$$spurtot = 10\log\left\{\int_a^b 10\hat{}\,(p_{ni}(\Delta f)/10)\, d\Delta f\right\}$$

Step 3: Finally, the iRSS calculation

$$\text{iRSS}_{spur} = p_{it} + spurtot + g_{it\text{–>}vr}(f_{vr}) - pl_{it\text{–>}vr}(f_{vr}) + g_{vr\text{–>}it}(f_{vr})$$

p_{It} = the Interfering power defined as dBm/emission bandwidth b_{it}.

Note: If the unwanted user-defined mask is used, the iRSS_{spur} is defined in dBm/ b_{it}, it being emission bandwidth.

Annex 16: Probability calculation

For the Unwanted: I = power supplied It + $iRSS_{spur}$

The probability is equaled to 0 when the criteria verify for all sample

- C/I or C/(N+I) calculated > C/I or C/(N+I) input, or
- (N+I)/N calculated < (N+I)/N input

The probability is equaled to 1 when the criteria verifies for all sample

- C/I or C/(N+I) calculated < C/I or C/(N+I) input, or
- (N+I/N) calculated > (N+I)/N input

e.g.

N+I/N = 10*LOG{[10^(I/10) + 10^(N)] / 10^(N)}= (N+I)/N input
(with I and N in dB)

Power supplied IT = 10 LOG{ [(10^(input value/10)) –1] 10^(N/10)} – $iRSS_{spur}$

Then checking some point of the translation curve is possible with for instance max and min $iRSS_{spur}$.

For the blocking: I = Blocking response level + iRSSblock

The probability is equaled to 0 when the criteria verifies for all sample

- C/I or C/(N+I) calculated > C/I or C/(N+I) input, or
- (N+I)/N calculated < (N+I)/N input

The probability is equalled to 1 when the criteria verifies for all sample

- C/I or C/(N+I) calculated < C/I or C/(N+I) input, or
- (N+I/N) calculated > (N+I)/N input

e.g.

N+I/N = 10*LOG{[10^((I)/10) + 10^(N)] / 10^(N)}= input value
(with I and N in dB)

Blocking response level =-(10 LOG{ [(10^(input value/10)) –1] 10^(N/10)} – $iRSS_{block}$)

Then checking some point of the translation curve is possible with for instance max and min $iRSS_{block}$.

Annex 17: free space loss implementation

The user-defined model is intended to allow the user to create its own propagation models through a script describing the pass loss calculation. This script consists of a sequence of formulas conforming to a well-defined syntax and may be edited by means of standard text editor available on the current environment such as NotePad.

Following script illustrates the application of user-defined model for simulation of free-space attenuation taking into account the difference in antenna height:

```
L1 = 32.44;
L2 = 20 * log10(freq());
L3 = 10 * log10(dist()*dist() + (hrx()-htx()) * (hrx()-htx())/1000/1000);
L = L1 + L2 + L3;
eval  L;
```

Annex 18: Power control function

$g_{it\,PC} = f_{pc}\left(p_{it\,supplied},\ g_{it \rightarrow wr},\ pl_{it \rightarrow wr},\ g_{wt \rightarrow it},\ pc_{min\_r},\ pc_{max\_r},\ pc_{step}\right)$
power control gain for the interfering transmitter

where

$p_{it\,supplied}$	Power supplied by the interferer before power control
$g_{it \rightarrow wt}$	Interfering transmitter antenna gain in wanted receiver direction
$g_{wt \rightarrow it}$	Wanted receiver antenna gain in interfering transmitter direction
$pl_{it \rightarrow wr}$	path loss between the interfering transmitter and the wanted receiver
pc_{min_r}	lowest power level received where no power control takes place
pc_{max_r}	highest power level received where the full power control takes place
pc_{step}	steps of power control

The power received in the wanted receiver results in

$$p = p_{it\,supplied} + g_{it \rightarrow wr} - pl_{it \rightarrow wr} + g_{wt \rightarrow it}$$

In the following it is referred to the notation given in ERC Rep 68:

$pc_{min\_r} = pc_{hold}$

$pc_{dyn} = pc_{max\_r} - pc_{min\_r}$

It distinguished between 3 cases:

Case 1: $p \le pc_{min\_r}$

$g_{it\,PC} = 0$

Case (i+1): $pc_{hold} + (i-1)\,pc_{step} \le p < pc_{hold} + i\,pc_{step}$

$g_{it\,PC} = -(i-1)\ pc_{step}$

where i is an integer ranging from 1 to $n\_step = (pc_{dyn}) / (pc_{step})$

Case (n_step +2): $p \ge pc_{hold} + pc_{dyn}$

$g_{it\,PC} = -\,pc_{dyn}$

Annex 19: Path azimuth

This is the way the user has to input the angle in order to calculate the relative positioning of each transceivers.

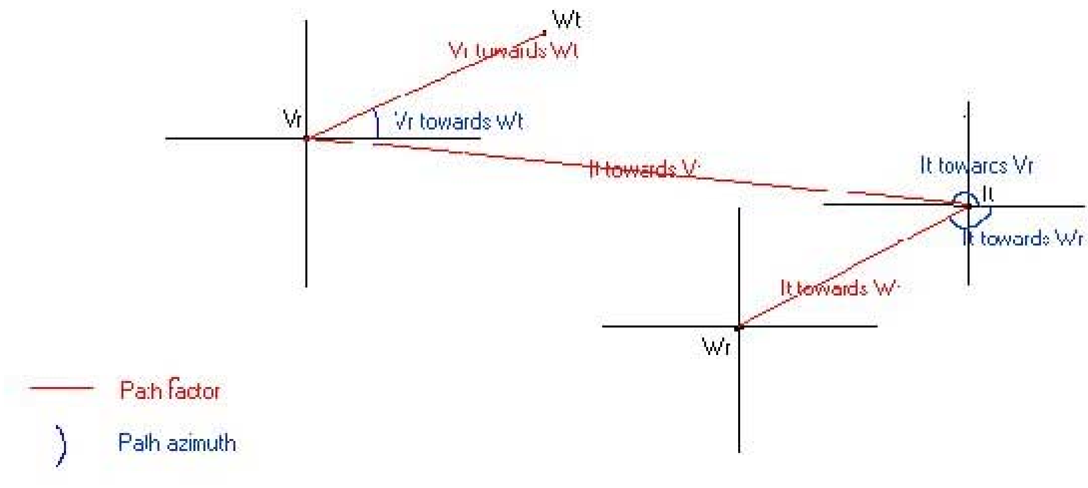


Figure 1, Path azimuth

Annex 20: History

Document history		
Phase 1	September 2000	**Produced by Jerome Deloziere and Arnaud Toury of British Telecom and approved by SEAMCAT Management Committee**
Phase 1	August 2001	**Revised by Marc Le Dévendec of the Agence Nationale des Fréquences**