SEAMCAT®

ADDITIONAL DOCUMENTATION

December 1999

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1. INTRODUCTION

1.1. Purpose of the additional documentation

The main purpose of this documentation is to assist the user to start using the software. The Documentation is supposed to be used as a complement to the on-line help.

In the last part of the documentation those items related to the SEAMCAT® are listed which might be misunderstood or misinterpreted by the user.

1.2. Background

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

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

The functional specifications of the SEAMCAT® software are based on the ERC Report 68.

2. SETUP OF THE SEAMCAT® SOFTWARE

2.1. System requirements

Hardware: PC Pentium II or higher, 32 MB RAM, 2 GB hard disk (recommended)
- required disk space for installation: 14 MB

Software: Win32 platform
For printing reports Word97 is needed

2.2. Installation procedure

Three types of installation are possible.

Both, **Typical** and **Compact** installation, include standard installation with BDE and databases.

Custom enables customisable installation.

Important notices:

1. Prior to installation of the SEAMCAT® tool the existing installed version of the software, if any, should be removed (uninstalled - not simply deleted).
2. The new installation of the SEAMCAT® software will erase the existing equipment library. There is no possibility to avoid it. The only way to preserve the existing library, if any, is to make a copy of all the files located in the directory *<INSTALLDIR>/Database/Library* prior to the new installation and to move it back to the same place after the new installation.

   Neither SEAMCAT® nor Setup must be running while the files are copied.

   Warning: The above procedure is not the standard one and can only be applied if there is no difference in the database structure between two versions of the software.

3. During the installation of the SEAMCAT® tool, the Borland Database Engine (BDE) will normally be installed. Problems may occur if BDE is already installed on the same computer and when the existing version of BDE is more recent than the SEAMCAT® one. In that case the installation program will launch a warning message. The following procedure should be applied:

   > Select the **custom installation**
   > Uncheck database engine option and
   > Proceed with installation.

   When the SEAMCAT® installation is finished, select BDE administrator in the configuration panel and create following aliases (type Paradox):

   SeamcatLibray pointing at *<INSTALLDIR>/Database/Library*

   SeamcatWorkspace pointing at *<INSTALLDIR>/Database/Workspace*

   SeamcatData pointing at *<INSTALLDIR>/Database/Data*

3. TERMINOLOGY

This chapter contains definitions and statements used in the SEAMCAT® software and in the related documents. This is provided to help the user to understand the terms and conventions which mostly originate from specification document ERC Report 68.

Some commonly used abbreviations are listed below:

SEAMCAT®	**S**pectrum **E**ngineering **A**dvanced **M**onte **C**arlo **A**nalysis **T**ool
EGE	**E**vent **G**eneration **E**ngine
DEE	**D**istribution **E**valuation **E**ngine
ICE	**I**nterference **C**alculation **E**ngine
dRSS	**d**esired **R**eceived **S**ignal **S**trength
iRSS	**i**nterfering **R**eceived **S**ignal **S**trength

3.1 Definitions - Technical aspects

This section contains definitions relative to technical entities used by the SEAMCAT® tool.

3.1.1 Simulation workspace and interference scenario

The simulation workspace is the basic entity handled by the SEAMCAT® tool. It is aimed to contain all objects and parameters required to perform a simulation. A simulation workspace is defined by:

- All static data used for the definition of the simulation. This data is referred to as **interference scenario** and include:
  - A **victim link**: victim receiver and wanted transmitter characteristics
  - One or more **interfering link** (with underlying **interference configurations**)
  - Environmental parameters including: global environment (urban / suburban / rural), time, etc.
  - Simulation control parameters
- All data generated dynamically during the simulation. This data is referred to as calculation results and include:
  - Signals generated by EGE: dRSS and iRSS
  - Interference probability yielded by ICE (single value or function of the reference parameter according to the ICE calculation mode).

3.1.2 Interference type vs interference configuration

Within SEAMCAT® interference sources are classified into three **generic** interference types:

- undesired (unwanted) emission including spurious, out-of band adjacent and co-channel interference
- blocking to be understood as receiver susceptibility
- inter-modulation

An interference configuration consists of:

- An **interference type**
- An **interfering link**
- A **victim receiver**

A possible interference configuration is for instance unwanted emissions on a mobile BTS due to a Fixed station.

3.1.3 Victim link

Victim link definition includes:

- **Wanted transmitter (wt)** characteristics
- **Victim receiver (vr)** characteristics
- Simulation specific characteristics (transceiver implementation, propagation models, etc.)

3.1.4 Interfering link

Interfering link definition includes:

- **Interfering transmitter (it)** characteristics
- **Wanted receiver (wr)** characteristics
- Simulation specific characteristics (transceiver implementation, propagation models, etc.)

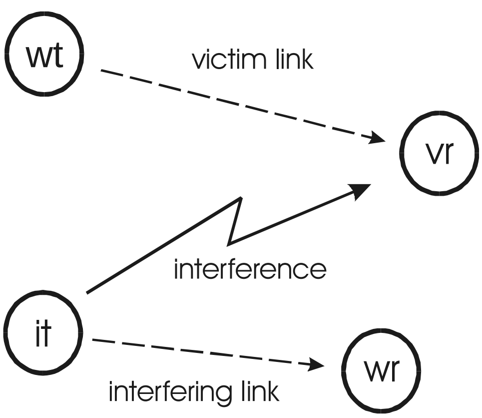


Figure 3.1: Interference scenario

3.2 Definitions - Statistical aspects

This section gathers mathematical issues and notations later used in description of the different functions of the tool.

3.2.1 Vector vs distribution

Within the SEAMCAT® environment, two distinct representations may be applied to handled signals:

- **distribution**: the signal is handled as a random variable and totally defined by the relative density of probability or cumulative distribution function.
- **array vector:** which stands for the result of N successive samples of the simulated signal, which is in turn a function of different trials according to distributions. This representation is the only one which may be used when the signals are correlated.

3.3 Trial functions

Notations: *T(f)* refers to a trial according to a statistical law *f*.

3.3.1 Pseudo-random number generation

All statistical trials are derived from trials supposing a uniform distribution between values 0 and 1, hereafter denoted *U(0,1)*:

$$U(0,1) = \begin{cases} 1 & \text{if } 0 \le x \le 1 \\ 0 & \text{otherwise} \end{cases}$$

Each sample u_k is derived from the sample issued by the previous call of the function as follows:

$$u_{i+1} = T(U(0,1)) = \frac{x_{i+1}}{m}$$

where:

$$x_{i+1} = (a \cdot x_i) \pmod m$$

a = multiplier e. g. $a = 16{,}807$ or $397{,}204{,}094$ or $950{,}706{,}376$

m = modulus e. g. $m = 2^{31} - 1 = 2{,}147{,}483{,}647$

x_0 = seed, integer variable taking a value between 1 and (m-1)

3.3.2 Uniform distribution

A uniform distribution between min and max values, hereafter denoted $U(u_{min}, u_{max})$ is defined by following probability density:

$$U(u_{\min}, u_{\max}) = \begin{cases} 1 & \text{if } u_{\min} \le x \le u_{\max} \\ 0 & \text{otherwise} \end{cases}$$

Trial is based upon following variable substitution:

$$T(U(u_{\min}, u_{\max})) = u_{\min} + (u_{\max} - u_{\min}) \times T(U(0,1))$$

3.3.3 Gaussian distribution

A gaussian distribution of mean *m*, standard deviation σ hereafter denoted *G(m, σ)* or *G(σ)* if *m = 0*, is defined by following probability density:

$$G(m,\sigma) = m + \frac{1}{\sqrt{2\pi}\sigma}\exp\left(-\frac{x^2}{2\sigma^2}\right)$$

Trials are based upon the following variable substitution:

$$T\big(G(m,\sigma)\big) = m + v_1\sqrt{\frac{-2\cdot\ln(s)}{s}}$$

where:

$$\text{while } s \geq 1,\ \text{do } \begin{cases} v_1 = 2\cdot T_{seed\ 1}(U(0,1)) - 1 \\ v_2 = 2\cdot T_{seed\ 2}(U(0,1)) - 1 \\ s = v_1^2 + v_2^2 \end{cases}$$

v_1 and v_2 are two independent random variables (**using two different seeds**) uniformly distributed between -1 and +1.

3.2.3.4 Rayleigh distribution

A Rayleigh distribution of mean *m*, standard deviation σ hereafter denoted *R(m, σ)* or *R(σ)* if *m = 0*, is defined by following probability density:

$$R(m,\sigma) = m + \frac{r}{\sigma^2}\exp\left(-\frac{r^2}{2\sigma^2}\right)$$

Trial is based upon the following variable substitution:

$$T\big(R(\sigma)\big) = m + \sqrt{\left(v_1^2 + v_2^2\right)\cdot\frac{-2\cdot\ln(s)}{s}}$$

where:

$$\text{while } s \geq 1,\ \text{do } \begin{cases} v_1 = 2\cdot T_{seed1}\big(U(0,1)\big) - 1 \\ v_2 = 2\cdot T_{seed2}\big(U(0,1)\big) - 1 \\ s = v_1^2 + v_2^2 \end{cases}$$

v_1 and v_2 are two independent random variables (**using two different seeds**) uniformly distributed between -1 and +1.

3.3.5 *User-defined distribution*

Some trials may be performed according to a user-defined distribution *f*.

Trials are based on the use of the reciprocal cumulative distribution function cdf^{-1} relative to the user-defined distribution *f* applied to the result of a uniform sample between 0 and 1.

$$T(distribution) = cdf^{-1}(p)$$

where:

$p = T(U(0,1))$ (uniform trial between 0 and 1)

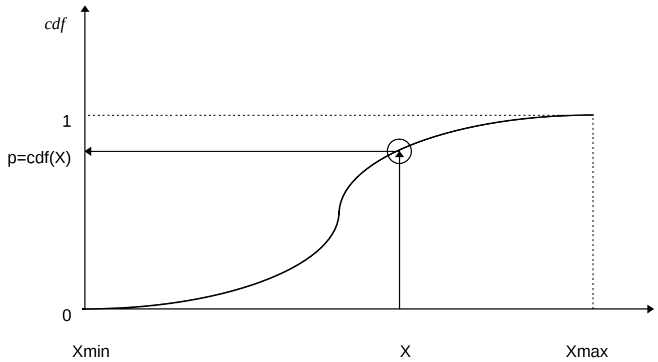


Figure 3.2 : Direct cumulative distribution function:

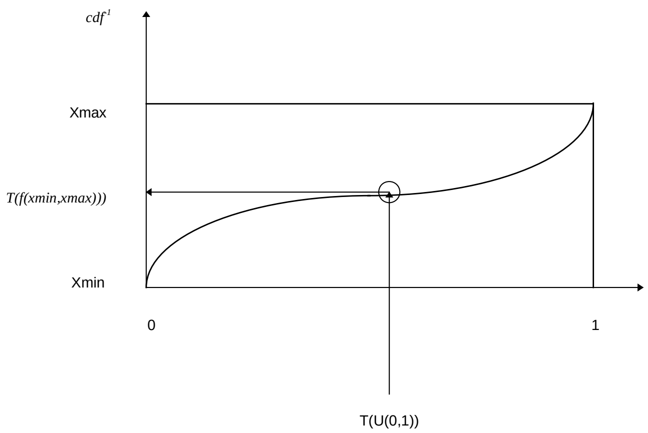


Figure 3.3 : Inverse cumulative distribution function

3.4 Vector / distribution operators

3.4.1 Derivation of a distribution from an array vector

Deduction of distribution from an array vector which is believed to be a realisation of this distribution mainly consists of:

- first, sorting the vector (by increasing values),
- secondly, associating a number of occurrences to each distinct value.

3.4.2 Kolmogorov-Smirnov adequation test on two distributions

Kolmogorov-Smirnov test is used to evaluate to which extent an array vector conforms to a reference distribution. This distribution may be either explicitly expressed as a distribution or implicitly defined by another array vector.

3.4.3 Correlation between two array vectors

Let us denote:

- 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:

$$\rho = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}(X_i - m_X)(Y_i - m_Y)}{\sigma_X{}^2\sigma_Y{}^2}$$

4. FUNCTIONAL ARCHITECTURE

The aim of this chapter is to outline the functional design of the SEAMCAT® tool.

The SEAMCAT® tool provides a flexible architecture for analysis of a variety of composite interference scenarios in which a mixture of radio equipment sharing the same habitat and/or multiple sources of interference (e.g. out-of-band emission, unwanted emission, intermodulation etc.) can be involved and treated concurrently.

The architecture itself is versatile enough to allow treatment of the composite interference scenarios. Figure 4.1. illustrates the functional division applied in the SEAMCAT® tool.

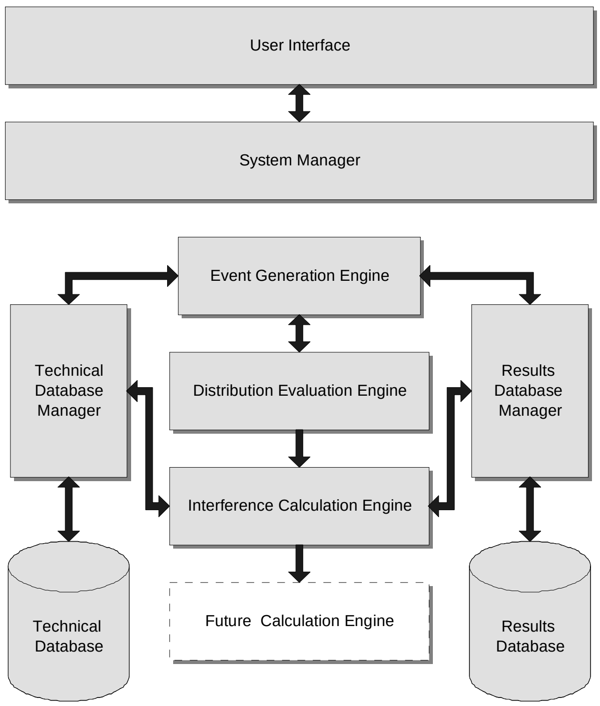


Figure 4.1: SEAMCAT® functional architecture

The functions of the SEAMCAT® tool may be organised in three main components:

- signal simulation and interference calculation engines (EGE, DEE, ICE)
- data management functions
- user interface / link manager

4.1 Signal simulation and interference calculation functions

The calculation module is the core engine for simulation and interference calculations. The following sequential process is implemented:

- event generation
- distribution evaluation
- interference calculation

4.1.1 Event generation

An event is to be understood as a snapshot of the interference simulation defined by the user.

Event Generation Engine (EGE) is in charge of generating of the received signal strength of the desired and interfering signals included in the composite interference scenario.

This process of event generation is repeated N times, where N is a user-specified number of trials which should be large enough to produce statistically significant results.

Trials on parameters being common for desired and interfering radio paths such as victim receiver antenna height are done concurrently in order to capture possible correlation between desired and interfering signals.

Such an implementation will not cover the rare cases of interference for which one interference mechanism is excited by another interference (e.g. a strong transmitter mixes with unwanted emission of the second transmitter and produce an inter-modulation type of interference).

Three main types of interference may be distinguished:

- blocking
- unwanted
- intermodulation

Each of the above three categories requires a different propagation model for physical processes being characteristic for that interfering mechanism. Two models have been retained:

- Hata modified model for frequencies between 30 MHz and 3GHz
- Spherical diffraction model for frequencies above 3 GHz

The man-made noise and the antenna temperature noise can be considered as an increase of the thermal noise level, decreasing thus the sensitivity of a receiver, and can be entered in the simulation when the criteria of interference is I/N or C/I+N.

4.1.2 Distribution evaluation

The SEAMCAT® tool provides functions to ensure that the signal vectors generated by the EGE are suitable for interference calculation. Those functions are incorporated in the Distribution Evaluation Engine (DEE), according to the following criteria:

- Evaluation of the stability of the distributions generated by the EGE according to goodness-of-fit test. If the number of samples is considered as insufficient to ensure stability, the DEE engine requires the EGE to generate more samples.

- Detection of possible correlation between the dRSS and iRSS signals and between the iRSS signals themselves.
- Identification tests if the generated distribution of signals could be approximated by a known analytical low, in order to make later calculations more efficient.

4.1.3 Interference calculation

The SEAMCAT® tool facilitates calculation of the interference probability function of the desired and interfering signals yielded by the event Generation Engine.
The Interference Calculation Engine (ICE) evaluates for each sample of the distributions whether the victim receiver is interfered or not.

Two calculation mode should be available:

- simple interference calculation
- translation of the interference calculation for a set of values of the reference parameters

4.2 Data management functions

Two different modules are aimed at encapsulating of all data accessing and management functions:

- technical data management module
- results management module

The technical data management module is in charge of the management of the technical elements used in the interference scenarios and stored in the technical library (antennas, transmitters, receivers).

The results management module provides the functions for management (accessing, storing and deleting) of the both intermediate (distributions/signals generated by EGE) and final calculation results (interference probability) generated by the application. Calculation results can be stored in the results database.

4.3 User interface

The user interface (UI) enables the access to and efficient use of all the functionalities of the SEAMCAT® tool. This module communicates with:

- the technical data management module to get data from the technical database or to update the database using the information entered by the user,
- the calculation module to launch an interference calculation,
- the results management module to visualise results, to save them or to delete them.

5. FREQUENTLY ASKED QUESTIONS

5.1 Help function

Help Icon is added to the Windows program files folder. The help function is also available through F1 key.

5.2 What is the unwanted emission floor? Why is it needed in addition to the unwanted emission mask?

The unwanted emission cannot drop under that floor even in the case of power control.

5.3 The relative emission mask

The advantage of a relative mask given in dBc is that this mask can be applied for different power levels without changing it. The lower restriction for emission should be defined by the unwanted emission floor.

The unwanted emissions expressed in dBm and then in dBm/Hz were used in only one place: the budget link of the iRSS unwanted. Therefore, there was no objection to changing the expression of the unwanted emission mask in dBc/Hz. On the contrary unwanted emission floor remains in dBm/Hz.

5.4 User defined propagation model

The detailed description of user-defined propagation model and the used syntax is given in the corresponding section of the On-line help.

For certain test purposes this module can be used also to eliminate the propagation path loss:

L=0; eval L;

This test procedure allows the test of the system components, e.g. emission masks.

5.5 Different bandwidths

The principle of consideration of radio services having different bandwidths is described in the ERC Report 68. However, the algorithms used in the tool are slightly different in order to reduce the computation time. The following algorithms are implemented:

5.5.1 User-defined mask

The total interfering power relative to carrier spur_rel can be calculated by integration over the receiver bandwidth from $a = f_{vr} - f_{it} - b_{vr} / 2$ to $b = f_{vr} - f_{it} + b_{vr} / 2$

$$spur\_rel = 10\log\left\{\int_a^b P_{rel}^{linear}\left(\Delta f\right)d\Delta f\right\} = 10\log\left\{\int_a^b 10^{\frac{P_{rel}^{dBc}\left(\Delta f\right)}{10}} d\Delta f\right\}$$

With P^{dBc}_{rel} denoting the normalised mask in **dBc/Hz.**

This mask is expressed as an array of N+1 points (Δfi, Pi) and assumed linear between these points.

$$P_{rel}(\Delta f) = P_i + \frac{\Delta f - \Delta f_i}{\Delta f_{i+1} - \Delta f_i}\left(P_{i+1} - P_i\right)$$

This leads to:

$$spur\_rel = 10\log\left\{\sum_{i=0}^{N-1}\int_{\Delta f_i}^{\Delta f_{i+1}} 10^{\frac{P_{rel}^{dBc}(\Delta f)}{10}} d\Delta f\right\}$$

where:

$$\Delta f_0 = a = f_{vr} - f_{it} - B_{vr}/2$$
$$\Delta f_N = b = f_{vr} - f_{it} + B_{vr}/2$$

Intermediate calculation

$$spur_i^{dBc} = \int_{\Delta f_i}^{\Delta f_{i+1}} 10^{\frac{P_{rel}^{dBc}(\Delta f)}{10}} d\Delta f$$

$$spur_i^{dBc} = 10^{\frac{P_i}{10}}\int_{\Delta f_i}^{\Delta f_{i+1}}\left[10^{\frac{P_{i+1}-P_i}{10(\Delta f_{i+1}-\Delta f_i)}}\right]^{(\Delta f - \Delta f_i)} d\Delta f$$

$$spur_i^{dBc} = \frac{10^{\frac{P_i}{10}}}{K^{\Delta f_i}}\int_{\Delta f_i}^{\Delta f_{i+1}} K^{(\Delta f - \Delta f_i)} d\Delta f, \quad K = 10^{\frac{P_{i+1}-P_i}{10(\Delta f_{i+1}-\Delta f_i)}}$$

$$spur_i^{dBc} = \frac{10^{\frac{P_i}{10}}}{K^{\Delta f_i}}\left[e^{\ln K}\right]_{\Delta f_i}^{\Delta f_{i+1}} = \frac{10^{\frac{P_i}{10}}}{\ln K}\left[K^{\Delta f_{i+1}-\Delta f_i} - 1\right], \quad \ln K = \frac{\ln 10}{10}.\frac{P_{i+1}-P_i}{\Delta f_{i+1}-\Delta f_i}$$

$$spur_i^{dBc} = \frac{10}{\ln 10}\frac{10^{P_{i+1}} - 10^{P_i}}{P_{i+1}-P_i}\left(\Delta f_{i+1} - \Delta f_i\right)$$

Eventually:

$$spur\_rel = 10\log\left\{\frac{10}{\ln 10}\sum_{i=0}^{N-1}\frac{\left(P_{i+1}^{linear} - P_i^{linear}\right)\left(\Delta f_{i+1} - \Delta f_i\right)}{\left(P_{i+1}^{dBc} - P_i^{dBc}\right)}\right\}$$

To get the total unwanted emission one has then to add the nominal power of the interfering transmitter:

$spur\_tot = spur\_rel + P_{it}$

5.5.2 Constant mask

When a constant mask P_{rel}^{dBc} is used one also has to use the bandwidth Bit of the interfering transmitter. The initial formula remains the same.

$$spur\_rel = 10\log\left\{\int_a^b P_{rel}^{linear}(\Delta f)d\Delta f\right\} = 10\log\left\{\int_a^b 10^{\frac{P_{rel}^{dBc}(\Delta f)}{10}} d\Delta f\right\}$$

Inside the bandwidth the linear power density is equal to $10^{\frac{P_{rel}^{dBc}}{10}}$
Outside the bandwidth it is assumed equal to 0.
In this case:

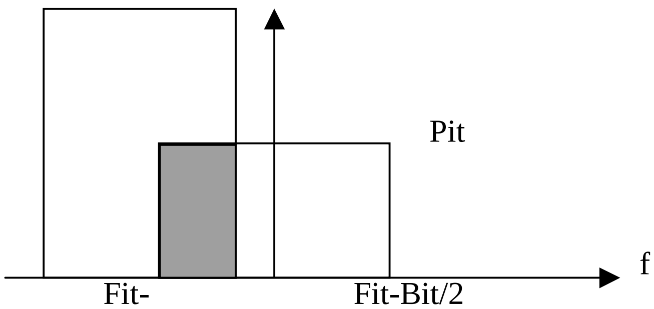
$$spur\_rel = P_{rel}^{dBc} + 10\log\frac{b-a}{B_{it}}$$

$$spur\_tot = spur\_rel + P_{it}$$

Where

$$a = \max\left\{ f_{vr} - B_{vr}/2, f_{it} - B_{it}/2 \right\}$$

$$b = \min\left\{ f_{vr} + B_{vr}/2, f_{it} + B_{it}/2 \right\}$$



Note that these formulas are generic and that there is no need to check whether Bvr is greater or less than Bit.

If b-a<=0, i.e. there is no overlapping frequency range between the victim and interferer, the resulting values for iRSS are set to the default -1000dBm. For general investigation of the influence of adjacent channels or spurious emissions far apart, a simple user-defined mask should be used: e.g. frequency_offset: -100MHz, rel_mask: -70dBc and +100, -70.

5.5.3 Unwanted emission floor

The afore-mentioned formulas are also applicable to unwanted emission floor *spur_floor(dBm)* except that in the end no power is added. If unwanted emission floor is selected then the mechanism is the same whenever one of the two masks is constant or not.

Note that the comparison involves the power control gain if power control is selected.

$$Pit(dBm) + spur\_rel(dBc) + g_{PC} > spur\_floor\ (dBm)$$

5.6 Intermodulation

Intermodulation products are computed only between two different interfering radio systems. The parameter which can be freely chosen is the intermodulation rejection in the receiver.

If no intermodulation mask is chosen and the frequency relation 2*f1+ -f2 or 2*f2+ -f1 is outside the receiver bandwidth centred around the centre frequency of the victim receiver, then the received signal power iRSS_intermod is set artificially to -1000 dBm in order to indicate that no intermodulation product was generated.

5.7 Determination of the radio cell size in the noise limited network

5.7.1 The principle

Assuming that the received power is equal to the sensitivity of the victim receiver, then the radius $R_{\max}$ can be determined for the wanted radio path by the following equation according to ERC Report 68

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

where the path loss is defined by a median loss plus an additional term representing the distribution

$$p_{loss} = f_{median} + f_{slowfading}(X\%)$$

The distribution of the path loss p_{loss} can be expressed in a general way by the following equation

$$Q(\mu + a, R_{\max}) = y$$

where Q is the cumulative distribution for $R_{\max}$ and the resulting mean path loss μ and an additional path loss a due to availability or coverage y . The coverage loss x corresponds to y by $1-y$. Assuming that slow fading can be approximated by log-normal distribution, i.e. median $\approx$ mean, the relation $a = b\sigma$ can be introduced where b stands for a multiple of the well known standard deviation σ. A few examples for illustration: At a 95 % coverage, b results in 1.96, for 99 % in 2.58, for 99.9 % in 3.29, or $b=1$ 68 % coverage, for $b=2$ for 95.5 %. The exact values can be easily determined by using the inverse Gaussian function.

Then the transcental equation

$$g(R_{\max}) = P_{wt} + g_{wt} + g_{vr} - sens_{vr} - f_{median}(f_{vr}, h_{vr}, h_{wt}, R_{\max}, env) - b\sigma$$

can be solved by using a linear iteration like regula falsi.

$$\tilde{R}_{\max} = R_{\max 0} - \frac{R_{\max 0} - R_{\max 1}}{g(R_{\max 0}) - g(R_{\max 1})} g(R_{\max 0})$$

5.7.2 Implementation in SEAMCAT®:

The following assumptions and simplifications were met:

- Propagation model: model used for calculation of propagation loss within the considered link
- Slow fading: gaussian distribution, σ can be chosen independently used for calculation of field strength at coverage limit.
- Antenna gains: 0 dBi for all antennas