Advanced statistical techniques for spectrum engineering analysis

SEAMCAT: a European experience

European Communications Office
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ISART – May 12, 2015
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Agenda

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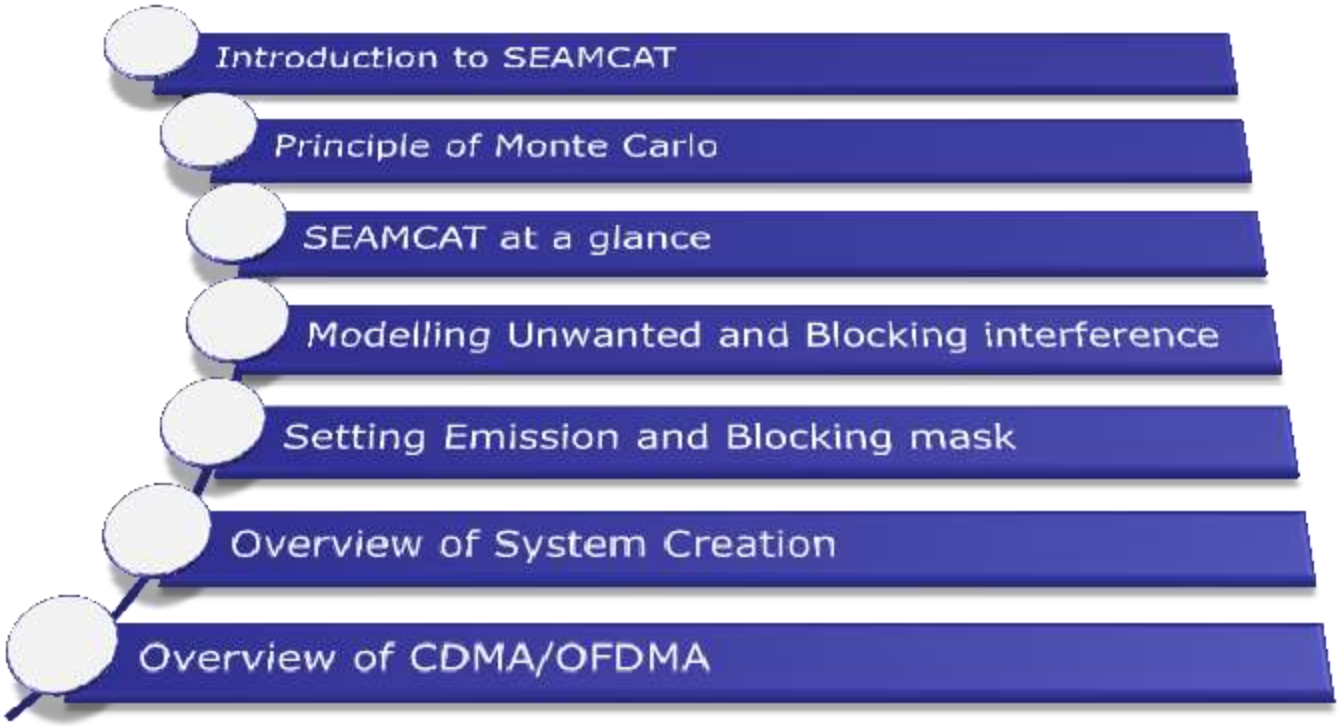

SEAMCAT
Spectrum Engineering Advanced Monte Carlo Analysis Tool

ECO
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Advanced Statistical Techniques for Spectrum Engineering Analysis

A SEAMCAT view

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Outline
Introduction to SEAMCAT

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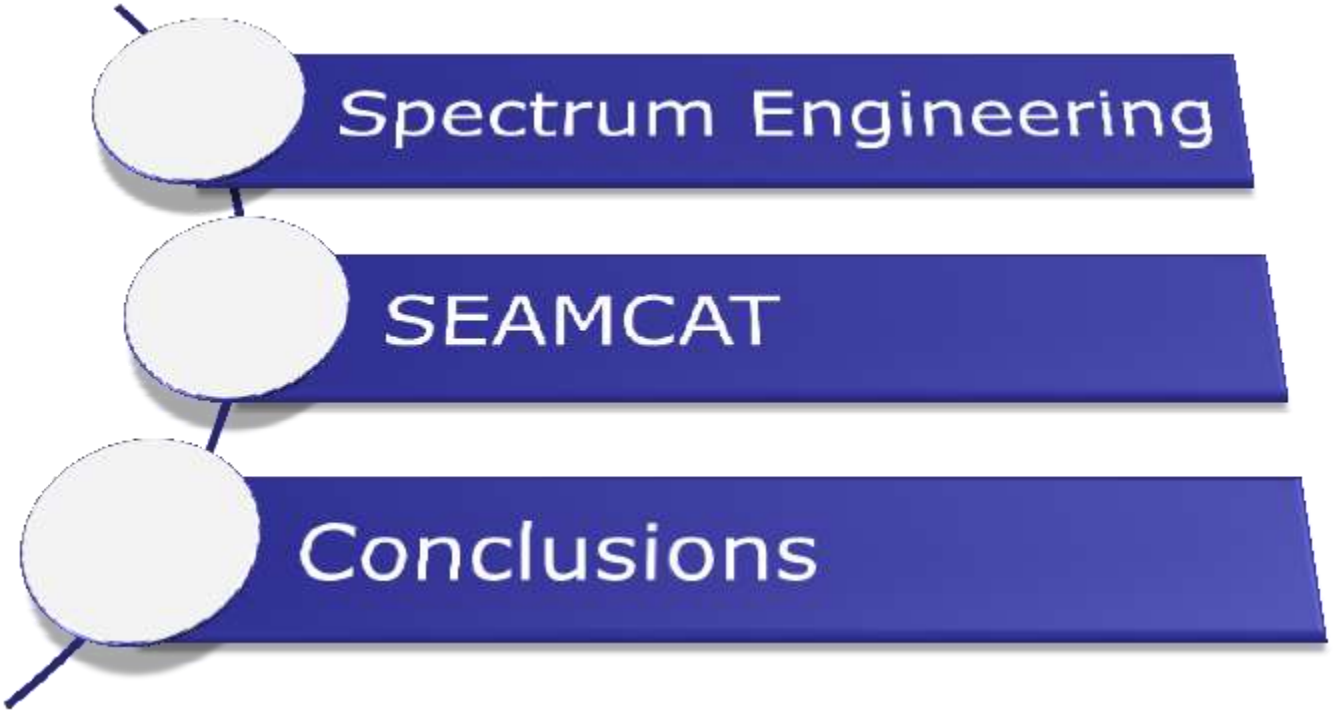

Spectrum engineering challenges

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- Increasing penetration of the existing radio applications
- Introduction of new radio applications

Regulatory

Technological

Economic considerations

Requirement for global compatibility amongst many radio systems within a congested radio spectrum

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Requirement for global compatibility amongst many radio systems within a congested radio spectrum

Need for spectrum sharing

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- There are no more "empty" spectrum
- Proposed new systems have to find way of "sharing" with some of existing systems
- Thus the need for spectrum engineering and optimisation:
  - to find which existing radio systems are easiest to share with, and then
  - determine the "sharing rules"

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Sharing methods

- Spacing radio systems in frequency
  - Using the gaps between existing channels
- Spacing geographically
  - Using the gaps between intended deployment areas (e.g. cities vs. rural areas)
- Time sharing
  - Exploiting different work time (day vs. night)
- Working at different power levels
  - E.g. “underlay” spectrum use by UWB

Sharing implementation

- Agile (cognitive) radio systems require minimum sharing rules as they could be adapting dynamically
  - Simple example: finding free channel in a given geographic area
- Traditional rigid-design radio system will require precisely defined sharing rules
  - Maximum transmit power, guard-bands to existing systems, etc

Defining the sharing rules

- Analytical analysis, usually by worst-case approach:
  - Minimum Coupling Loss (MCL) method, to establish rigid rules for minimum "separation"
- Statistical analysis of random trials:
  - The Monte-Carlo method, to establish probability of interference for a given realistic deployment scenario
  - **That is where SEAMCAT comes into picture!**

SEAMCAT-4 Software tool

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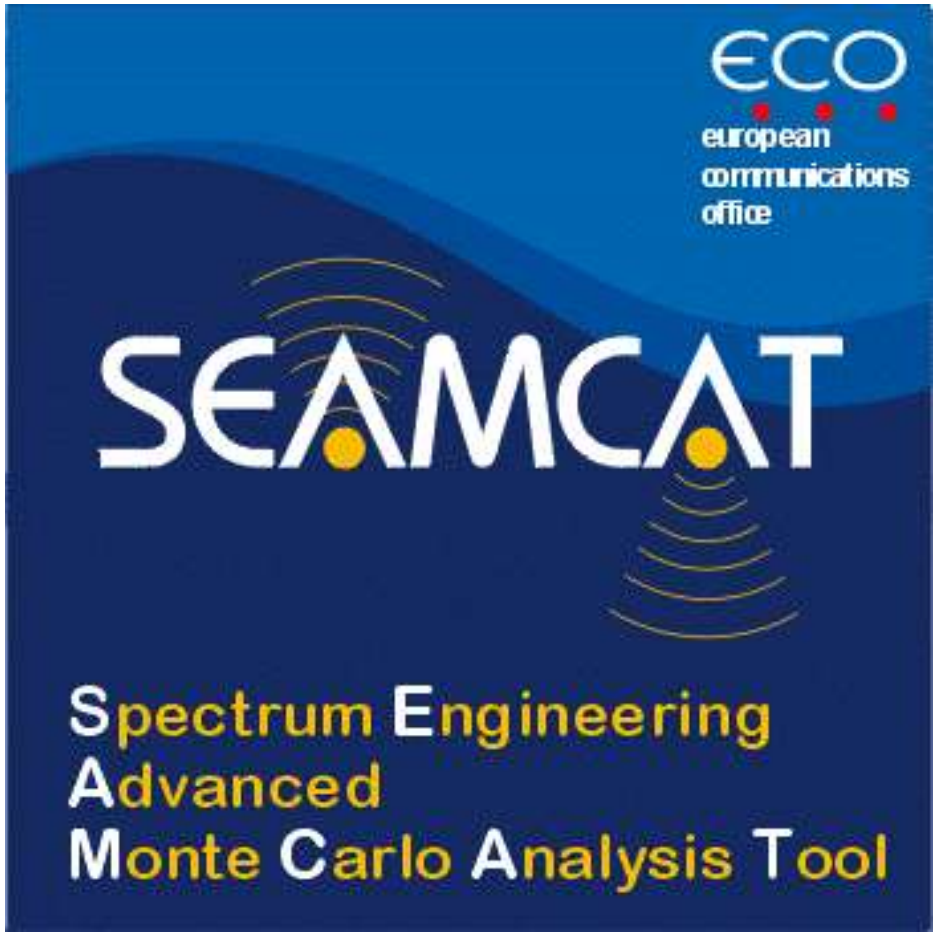

History

- Developed in CEPT as a co-operation between National Regulatory Administrations, ECO and industry
- First released in Jan-2000, then gradually developed in several phases
- Latest version 4.1.0 (October 2013)
- Freely downloadable from ECO website (www.seamcat.org)

Purpose

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- SEAMCAT is designed for:
  - **Co-existence/sharing** studies between different radio systems operating in same or adjacent frequency bands
  - Any type of radio systems in terrestrial scenarios
  - Extended to cellular system like CDMA and OFDMA
  - Quantification of probability of interference between various radio systems
- Not designed for system planning purposes
- Limitated for time domain simulation (e.g. Colision probability), radar

Typical examples of modelled system

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- Mobile:
  - Land Mobile Systems
  - Short Range Devices
  - Earth based components of satellite systems
- Broadcasting:
  - terrestrial systems
  - DTH receivers of satellite systems
- Fixed:
  - Point-to-Point and Point-to-Multipoint

... and more

Strategic tool for CEPT (1)

- For performing compatibility/sharing studies
  - Used in generating studies for ECC/CEPT Reports
- As a Reference tool
  - Recognised at ITU (Rep. ITU-R SM.2028-1)
- For educating future generation of spectrum engineer (Administrations, Industry or University)

Strategic tool for CEPT (2)

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- As an agreed work platform wthin CEPT
  - CEPT Project Teams (technical experts) can focus on the input parameters and not on the algorithm
  - Exchange of simulation workspaces between proponents eases the trust in the results

Usage worlwide

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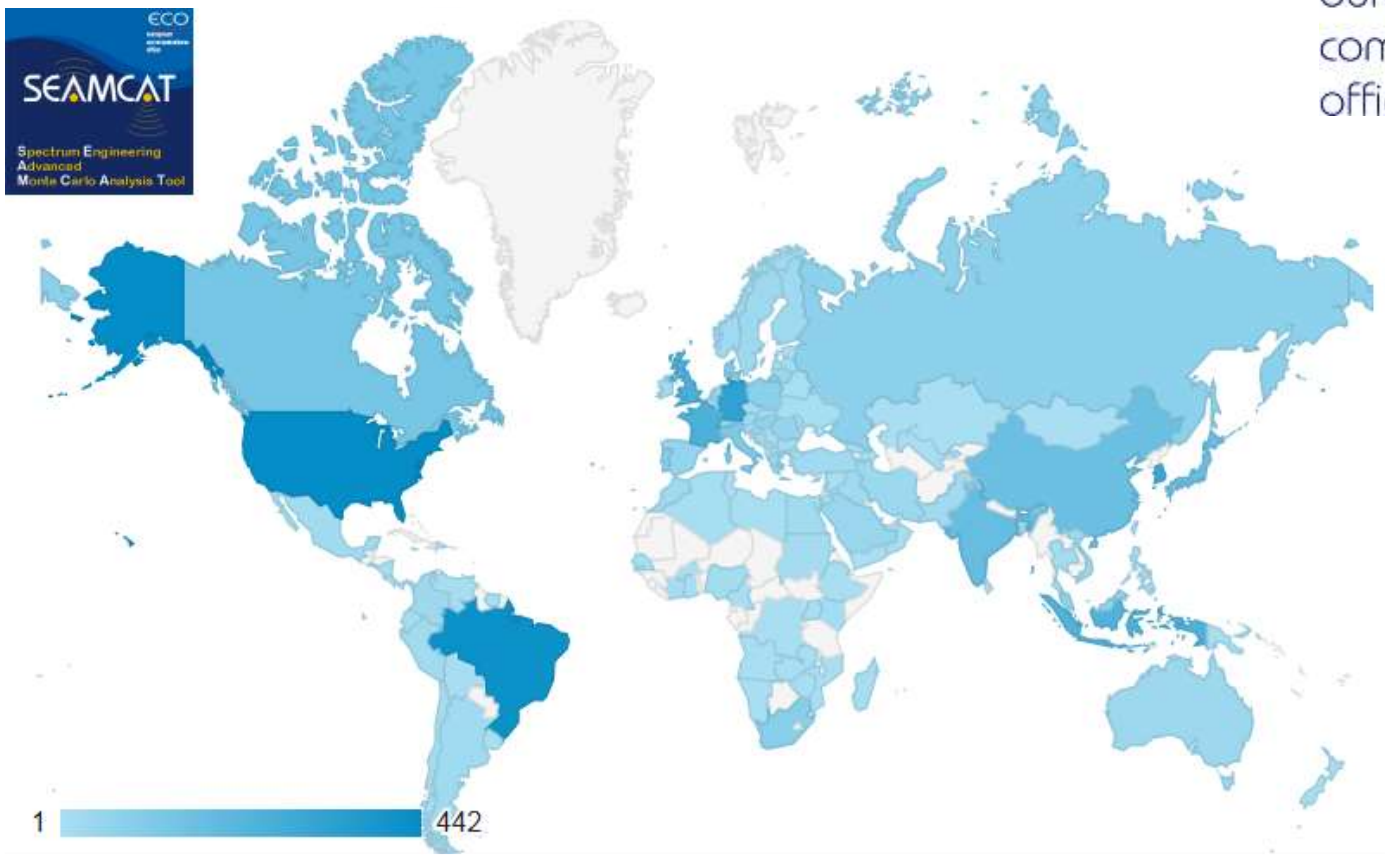

Source: google analytics on the www.seamcat.org download page in 2014.
2014 survey: about 800 people downloaded SEAMCAT.

Installing SEAMCAT
(administrative right needed)

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On-line Webstart:

Internet connection is needed at least for the installation; during later runs Internet used (if available) to check for updated version

(Windows, Linux, Mac)

Off-line

(Windows only)

Replaced in Version 5 by a .jar package

- 1GB RAM needed
- Java Runtime Environment (RTE) (version 1.6._027 and above)

Conclusions

- Sharing rules are important element of spectrum optimisation process
- Unless some intelligent interference avoidance is implemented in radio systems, the careful choice of sharing conditions is the only means for achieving successful co-existence and optimal spectrum use
- Statistical tool SEAMCAT is a powerful tool for such analysis
- Strategic tool for the CEPT
- Reference tool – recognised at ITU
- World wide usage
- Free tool to run on any operating system platform

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Thank you - Any questions?

Principle of Monte-Carlo in a SEAMCAT environment

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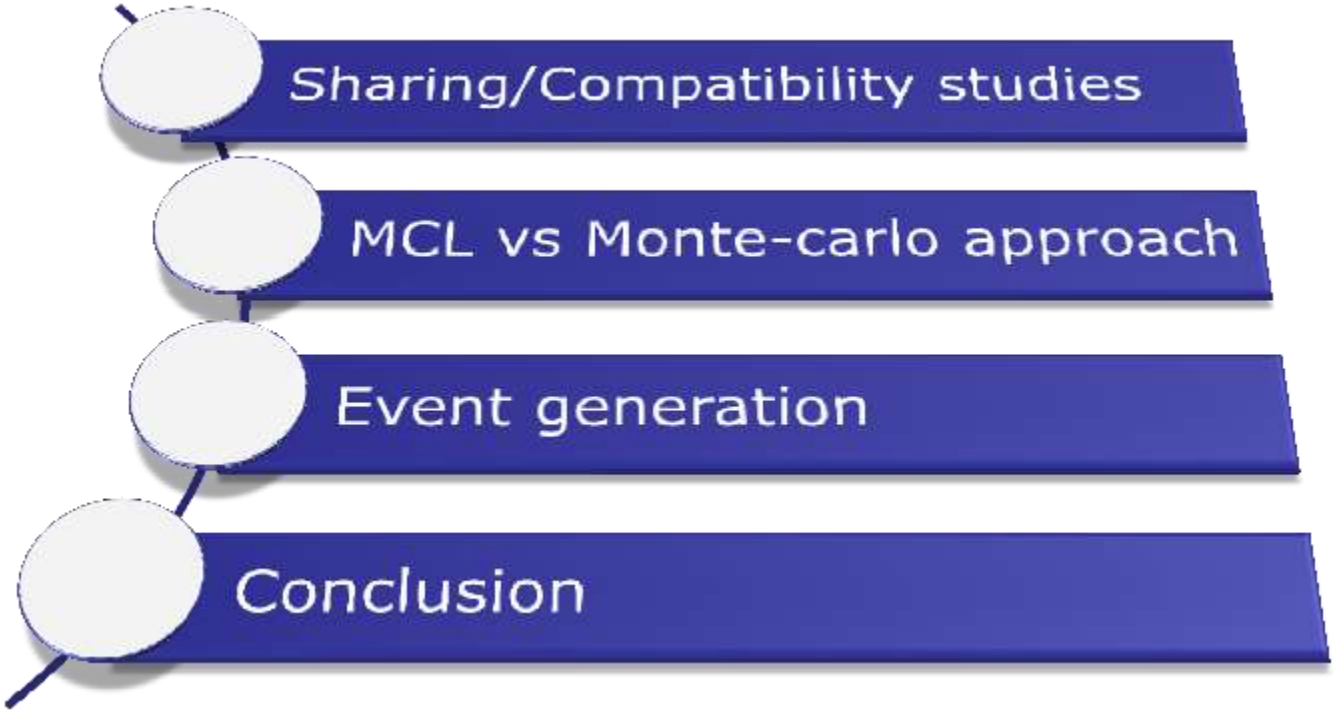

Sharing/compatibility studies

- **Sharing**: between different radio systems operating in the **same** frequency bands (ERC Report 68)
- **Compatibility**: between different radio systems operating in the **adjacent** frequency bands

- Interference criteria
- Analytical analysis: MCL (worse case)
- Statistical analysis: Monte-Carlo method

Coexistence between systems

1 660-1 710 MHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
1 675-1 690	METEOROLOGICAL AIDS FIXED METEOROLOGICAL-SATELLITE (space-to-Earth) MOBILE except aeronautical mobile 5.341	
1 690-1 700 METEOROLOGICAL AIDS METEOROLOGICAL-SATELLITE (space-to-Earth) Fixed Mobile except aeronautical mobile 5.289 5.341 5.382	**1 690-1 700** METEOROLOGICAL AIDS METEOROLOGICAL-SATELLITE (space-to-Earth) 5.289 5.341 5.381	
1 700-1 710 FIXED METEOROLOGICAL-SATELLITE (space-to-Earth) MOBILE except aeronautical mobile 5.289 5.341		**1 700-1 710** FIXED METEOROLOGICAL-SATELLITE (space-to-Earth) MOBILE except aeronautical mobile 5.289 5.341 5.384

Interference criteria

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- Interference criteria are defined to ensure:
  - Quality of service (reduce error transmission)
  - Service continuity (remote link with rockets, space shuttle)

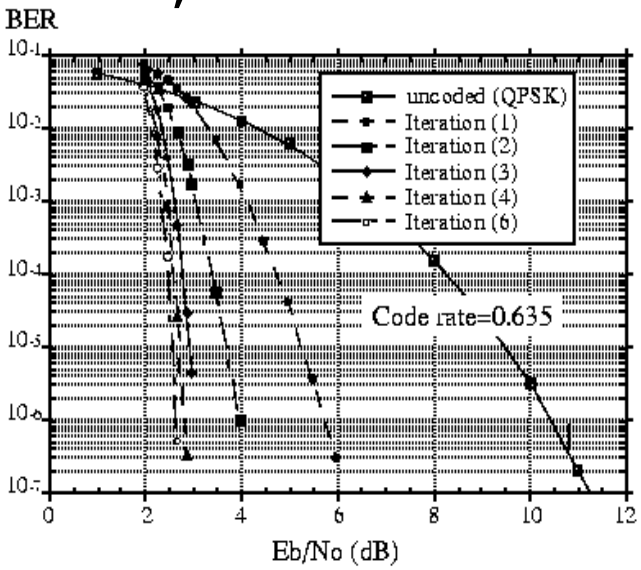
- Interference criteria defines the sharing condition.

Interference criteria: C/I

C/I (dB) ratio between

- C: received wanted signal (dBW)
- I: External noise level (dBW)

Example: Fixed Service, mobile

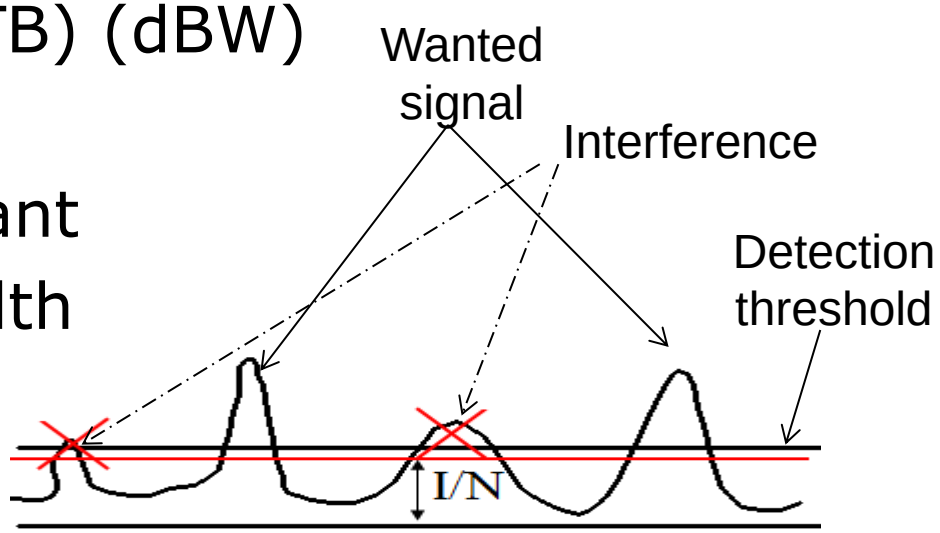


Interference criteria: I/N

I/N (dB) ratio between:

- I: External noise level (dBW)
- N: Internal noise (FkTB) (dBW)
  - F: noise factor
  - k: Boltzman constant
  - B: system bandwidth

Example: Radars



- I/N limit the maximum level of interference and the risk of false alarm

Other criteria:

- C/(N+I) (dB)
- I/(I+N) (dB)
- Link between C/I , C/(N+I), (I+N)/N

$$\frac{N+I}{N}=10\log\left[1+\frac{1}{10^{\wedge}\left(\frac{\frac{C}{I}-\frac{C}{N+I}}{10}\right)-1}\right]$$

- Example: C/I=19dB and C/(N+I)=16dB

$$\frac{N+I}{N}=10\log\left[1+\frac{1}{10^{\wedge}\left(\frac{19-16}{10}\right)-1}\right]=3dB$$

Other criteria:

- Link between I/N and (N+I)/N

$$\frac{N+I}{N} = 10\log\left[1+10\text{^}\left(\frac{I}{10N}\right)\right]$$

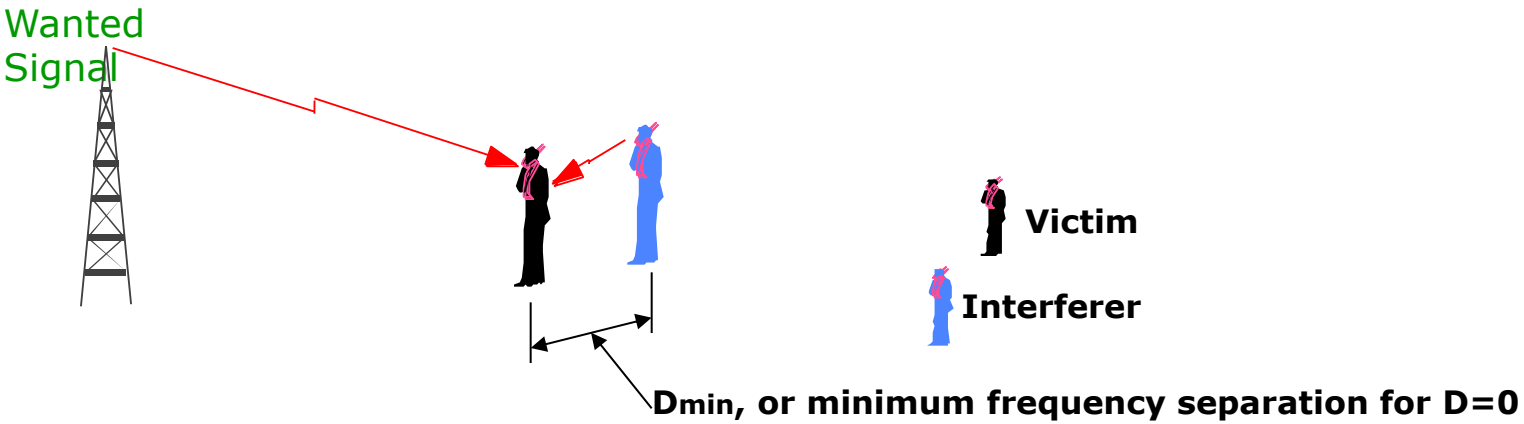
- Example: I/N=-6 dB

$$\frac{N+I}{N} = 10\log\left[1+10\text{^}\left(\frac{-6}{10}\right)\right] \approx 1dB$$

- But also, capacity loss or bit rate loss

The MCL approach

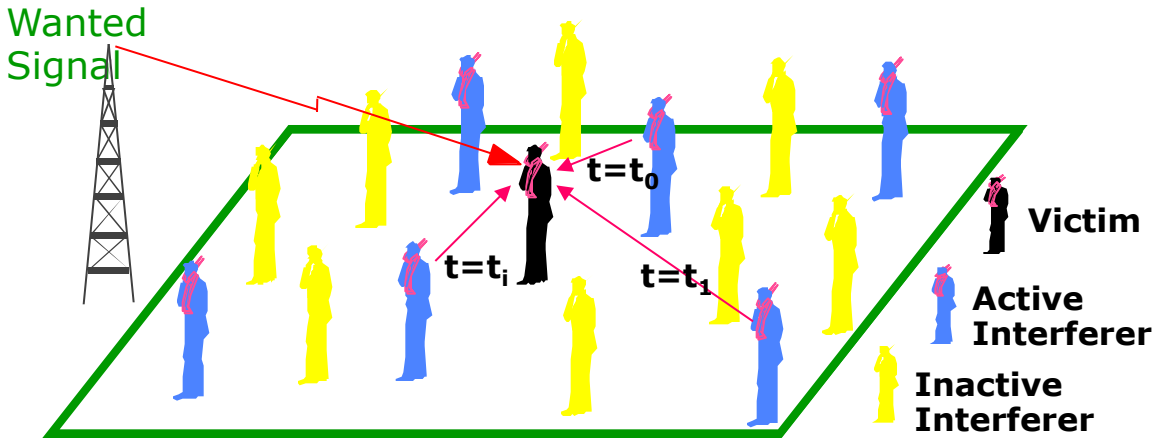
- The stationary worst-case is assumed



  - However such worst-case assumption will not be permanent during normal operation and therefore sharing rules might be unnecessarily stringent – **spectrum use <u>not</u> optimal!**

Monte-Carlo approach

- Repeated random generation of interferers and their parameters (activity, power, etc…)



  - After many trials, not only unfavourable, but also favourable cases will be accounted, the resulting rules will be more "fair"
    - **spectrum use optimal!**

Monte-Carlo Assumption

- User will need to define the distributions of various input parameters, e.g.:
  - How the power of interferer varies (Power Control?)
  - How the interferer's frequency channel varies
  - How the distance between interferer and victim varies
  - Etc..
- Number of trials has to be sufficiently high for statistical reliability:
  - Not a problem with modern computers

Event generation
Generic module

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- Random generation of transceivers
- Link budget
- Signal values

- **Only 1 victim <u>link</u>**

- **<u>MANY</u>** interfering links

... or interfering systems

example for one event

… after 1000 Events

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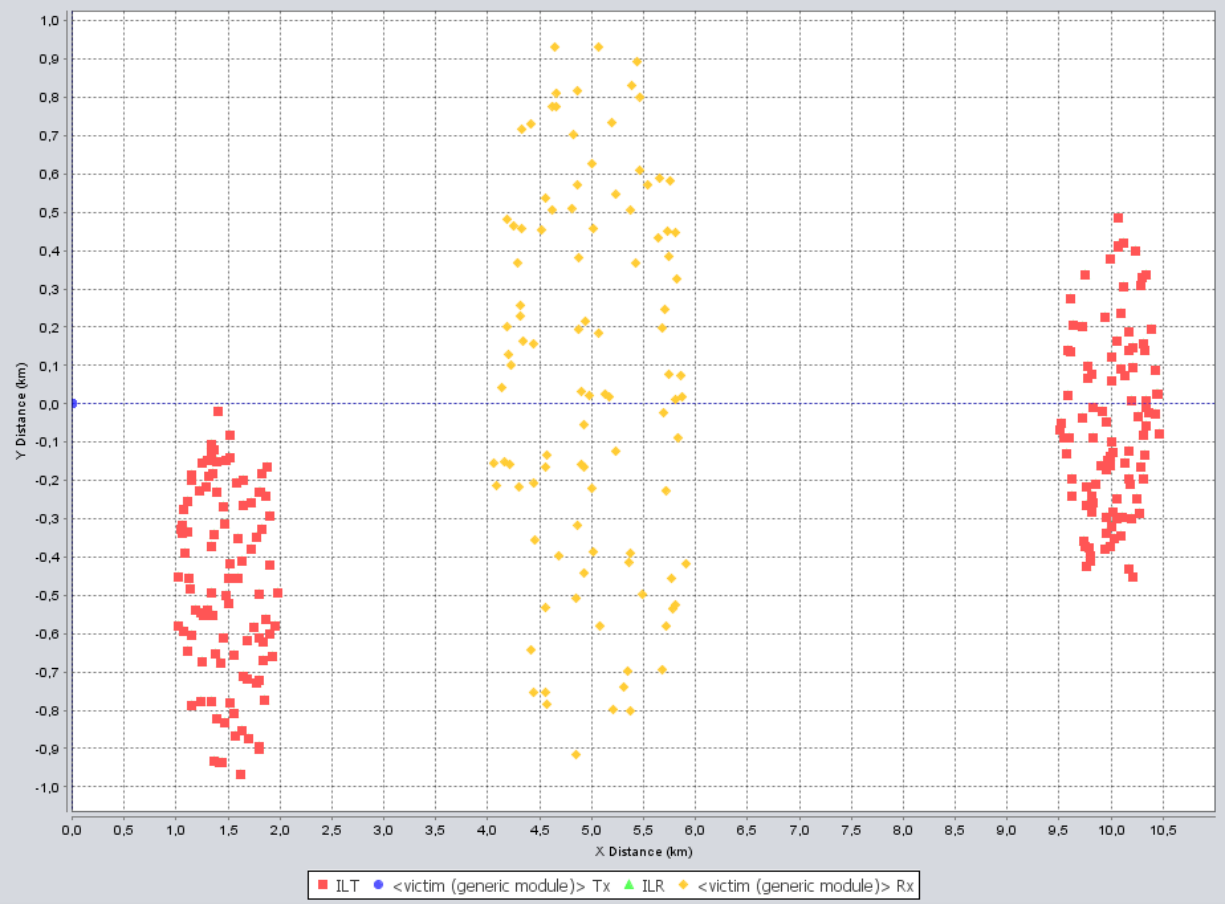
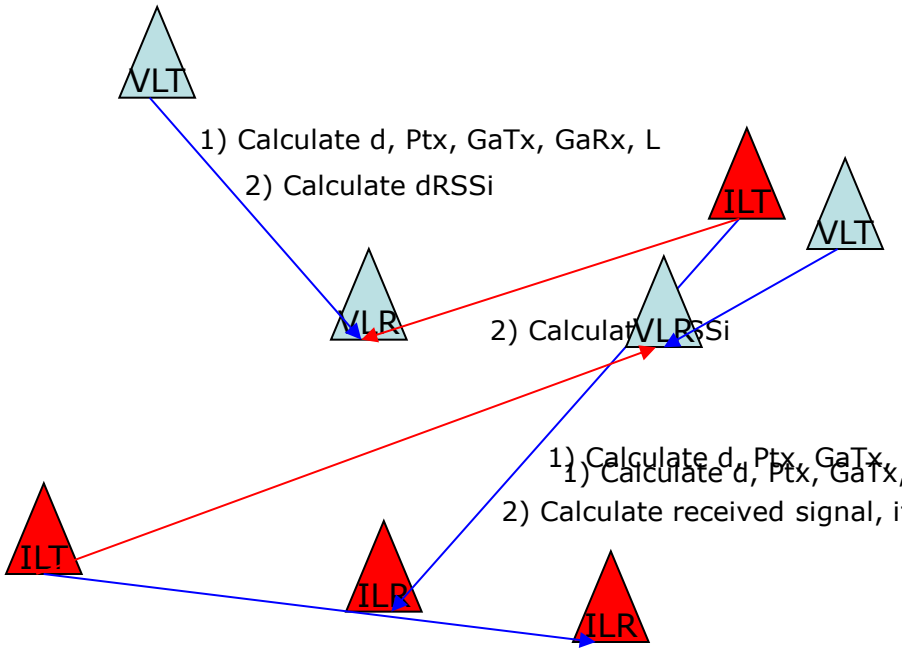
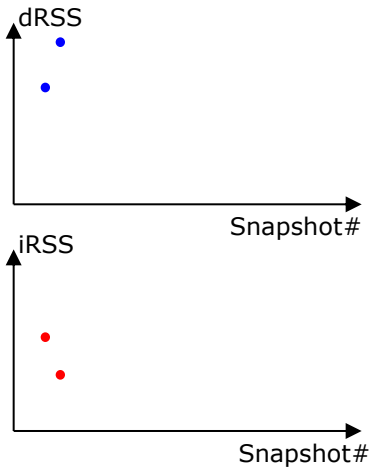


Positioning of transceivers for 1000 events

How event generation works*

- Succession of snapshots…





(*) Except CDMA/OFDMA systems

Results of event generation

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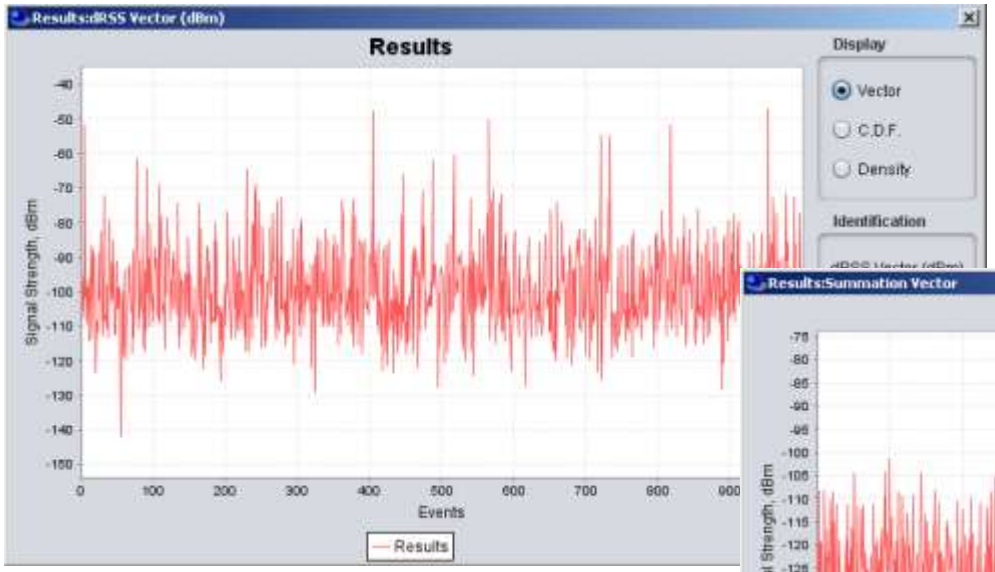
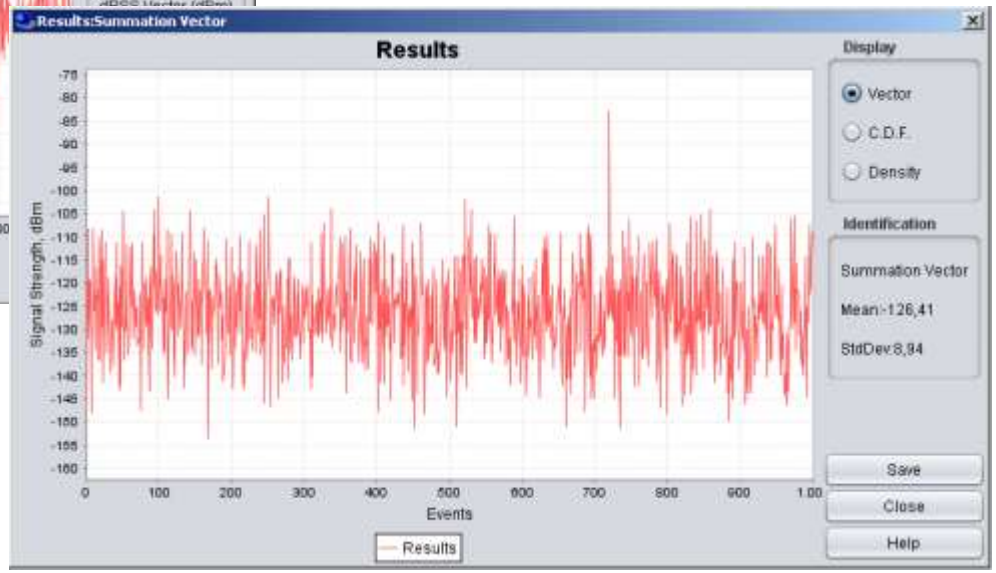
- Vectors for useful and interfering signals:

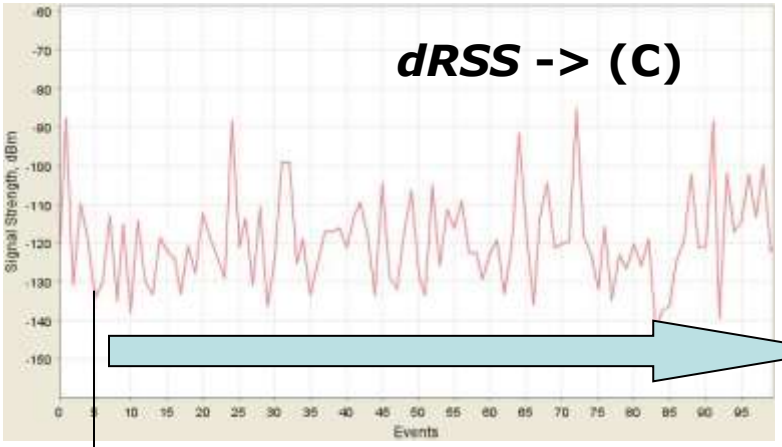


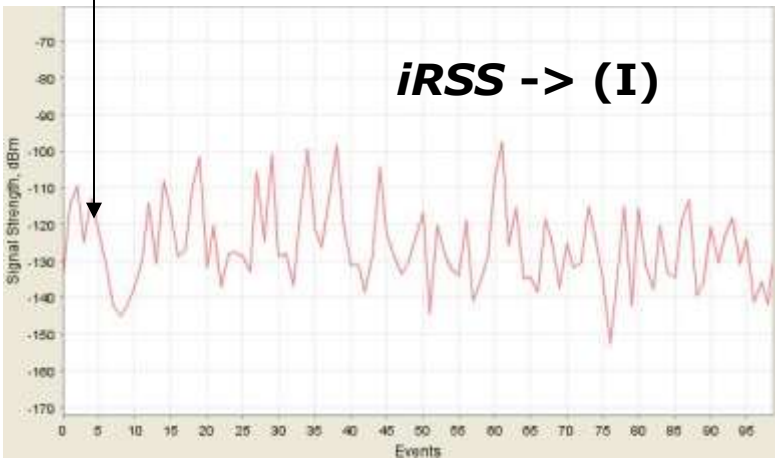
dRSS



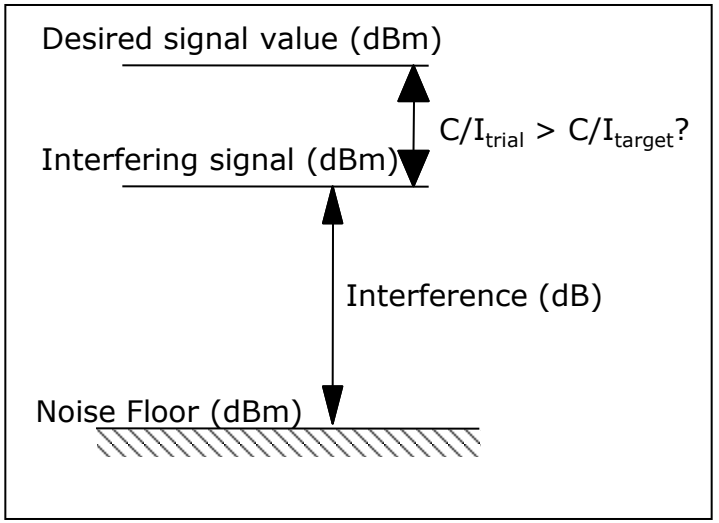
iRSS

Evaluating probability of interference





- For each random event where dRSS>sensitivity:



- If $C/I_{trial}^{i} > C/I_{target}$: "good" event
- If $C/I_{trial}^{i} < C/I_{target}$: "interfered"

- Finally, after cycle of N_{all} events:
  Overall $P_{interference} = 1 - (N_{good}/N_{all})_{dRSS>sens}$

Event generation
Ceular system module

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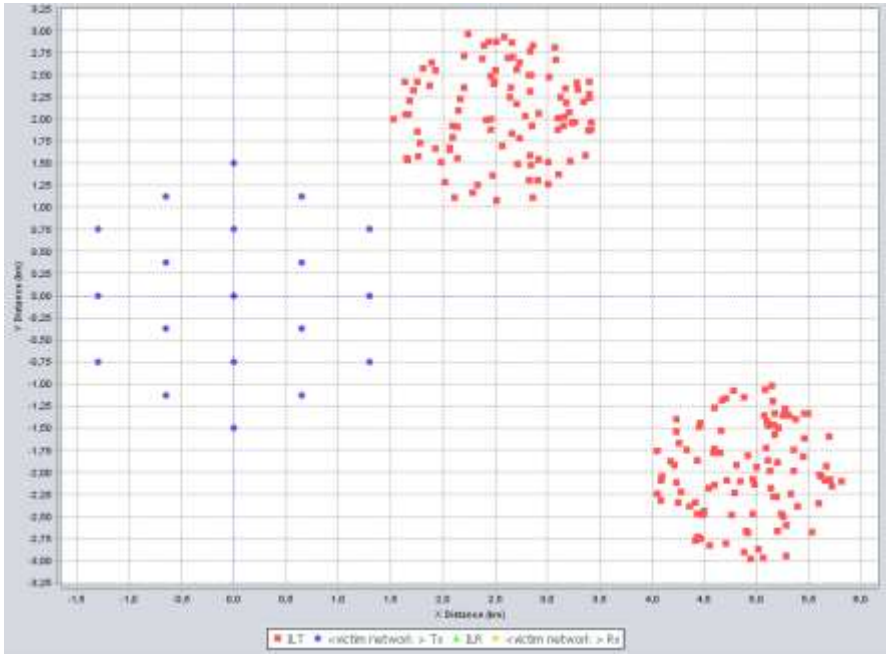
- Random generation of transceivers
- Link budget



- **MANY** interfering links

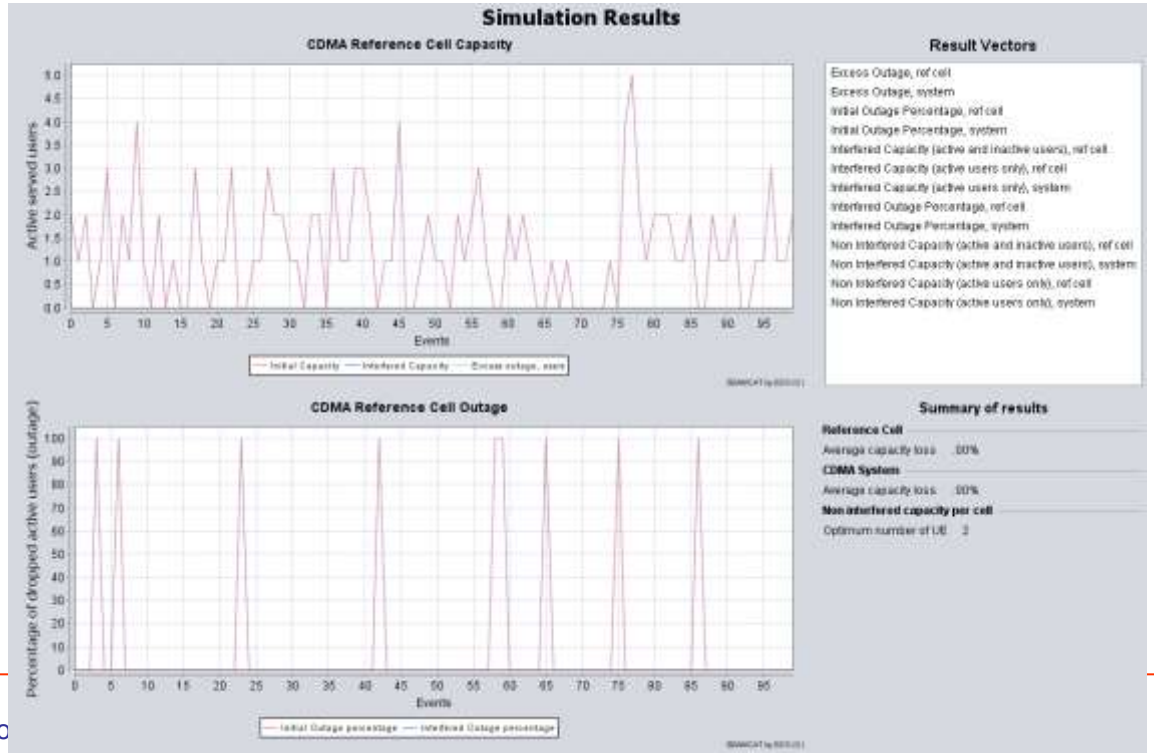
.. or interfering systems

- **Only 1 victim network**

.... but many victim links (UE-BS) computation

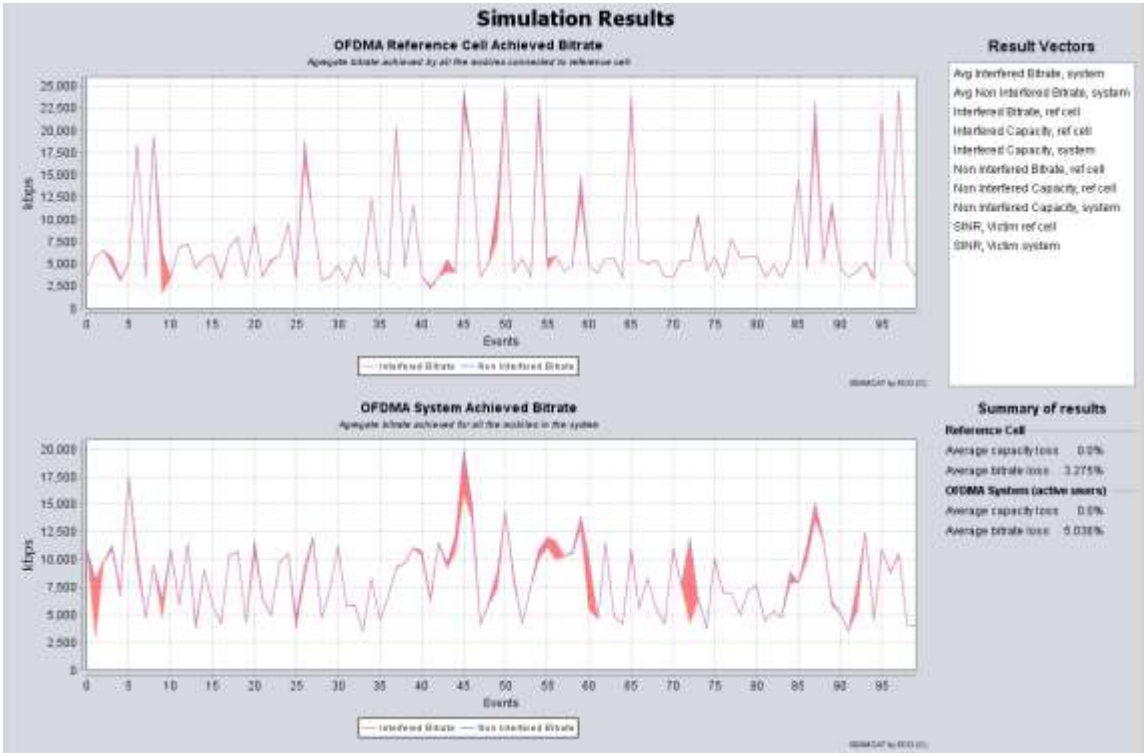
CDMA results

- **Initial capacity**: Number of connected UEs before any external interference is considered.
- **Interfered capacity**: Results after external interference is applied.
- **Excess outage, users**: How many UEs were dropped due to external interference.
- **Outage percentage**: Percentage of UEs dropped due to external interference.



OFDMA results

- **Non interfered bitrate**: bitrate before any external interference
- **interfered bitrate**: bitrate after external interference is applied.



Conclusions

- Versatile tool to configure victim and interferer
- SEAMCAT returns the following results

Victim system	Intereference criteria
Classical (generic module i.e. non CDMA/OFDMA module)	Probability of interference based on C/I, C/(I+N), (N+I)/N, I/N
CDMA	Capacity loss: number of voice users being dropped
OFDMA	Bitrate loss: number of bit rate lossed compared to a non interfered victim network

Extra - Reminder

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- log10(1)=0 10*log10(1)=0
- log10(2)=0.3 10*log10(2)=3
- log10(10)=1 10*log10(10)=10

- log10(100)=log(10^2)=2*log10(10)=2
- 10*log10(100)=20

- 10*log10(25)=10*log10(100/4)=10*log10(100)-10*log(4)
  =10*log10(10^2)-10*log10(2^2)
  =2*log10(10)-20*log10(2)
  =2*10 - 2*3=14dB

- 10*log10(2500)=10*log10(25*100)
  =10*log10(25)+10*log(100)=14dB+20dB=34dB

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A glance at the tool

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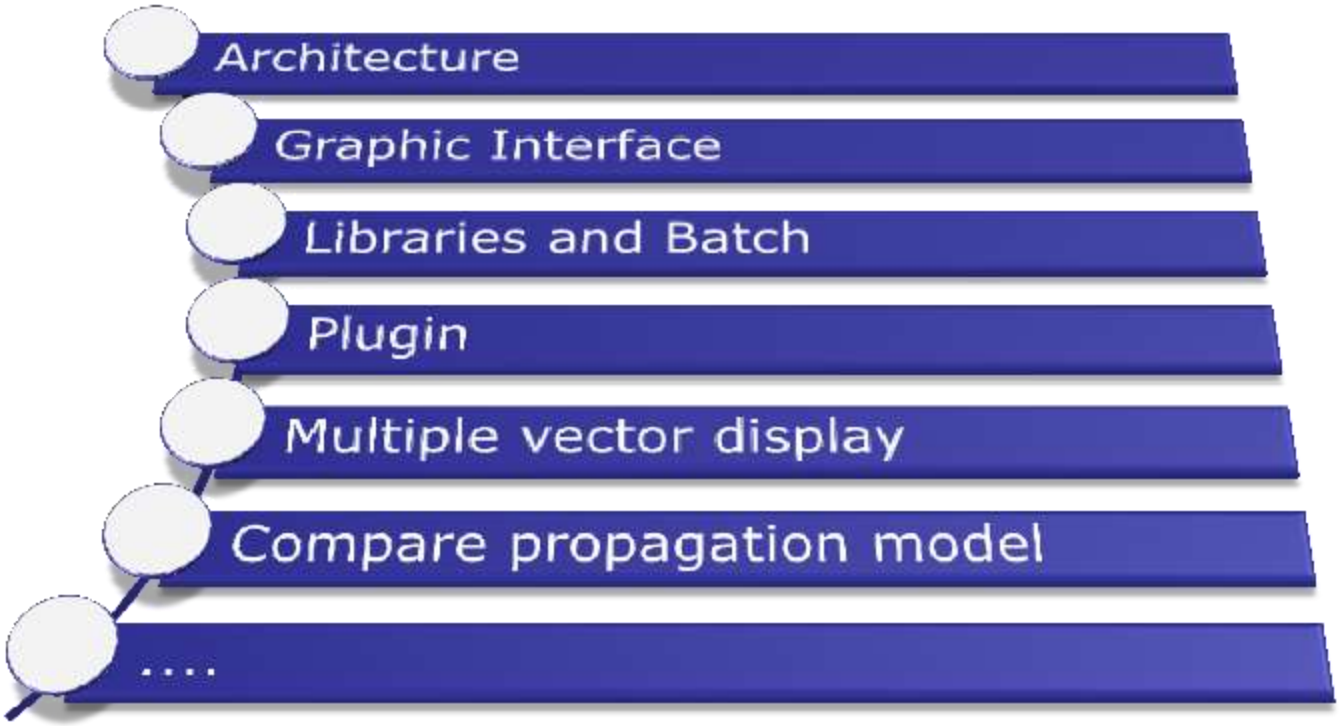
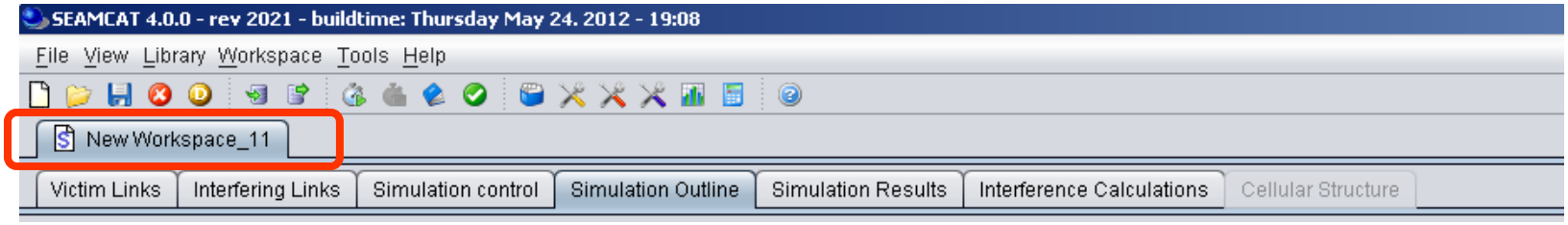


Main interface

- Windows GUI - oriented
- Main element – **workspace.sws**



Simulation controls:
number of events etc..

Simulations input data – scenario:
Equipment parameters, placement, propagations settings, etc.

Simulation results:
dRSS/iRSS vectors, P*interference*, Cellular structure

Data exchange via XML

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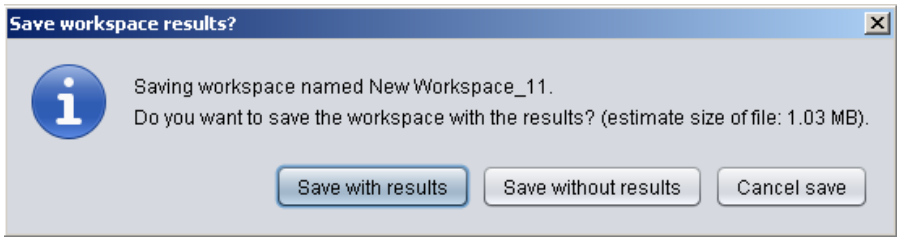
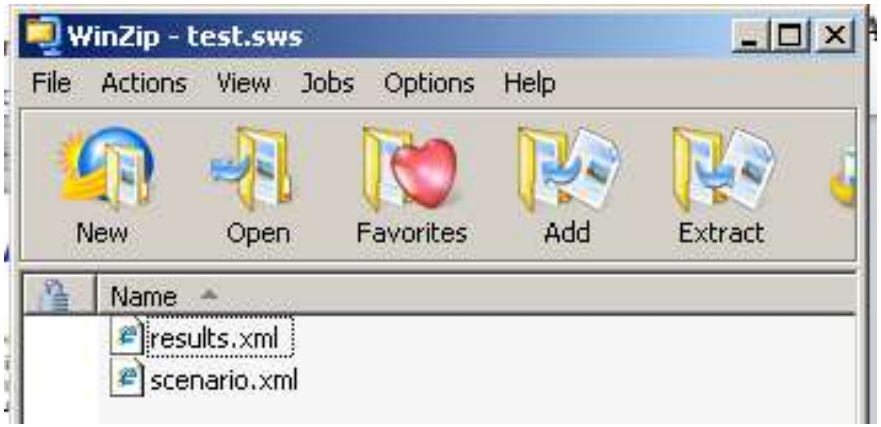
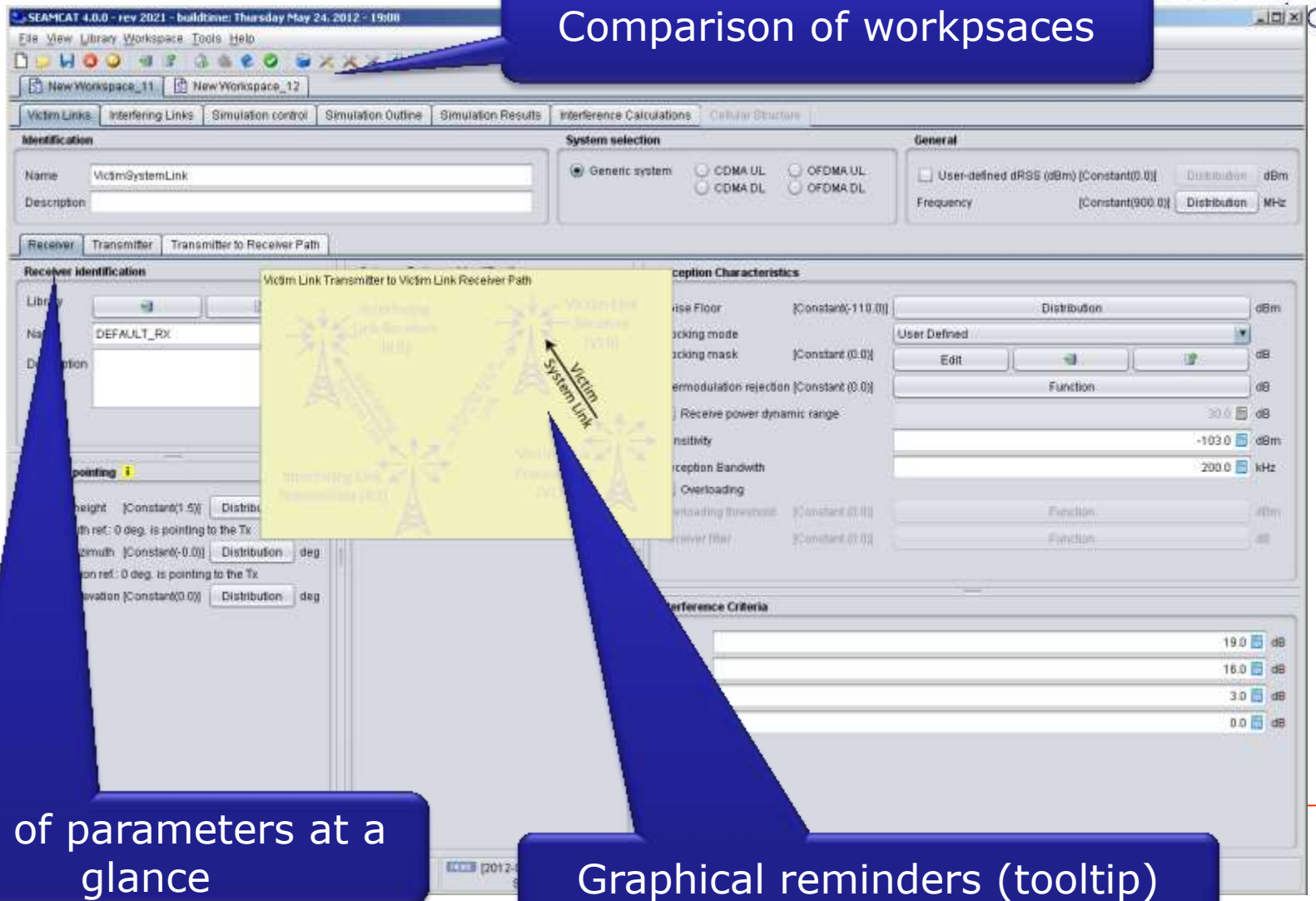
Physically a **.zip** file with "sws" extension including XML files for the **scenario** and the **results**



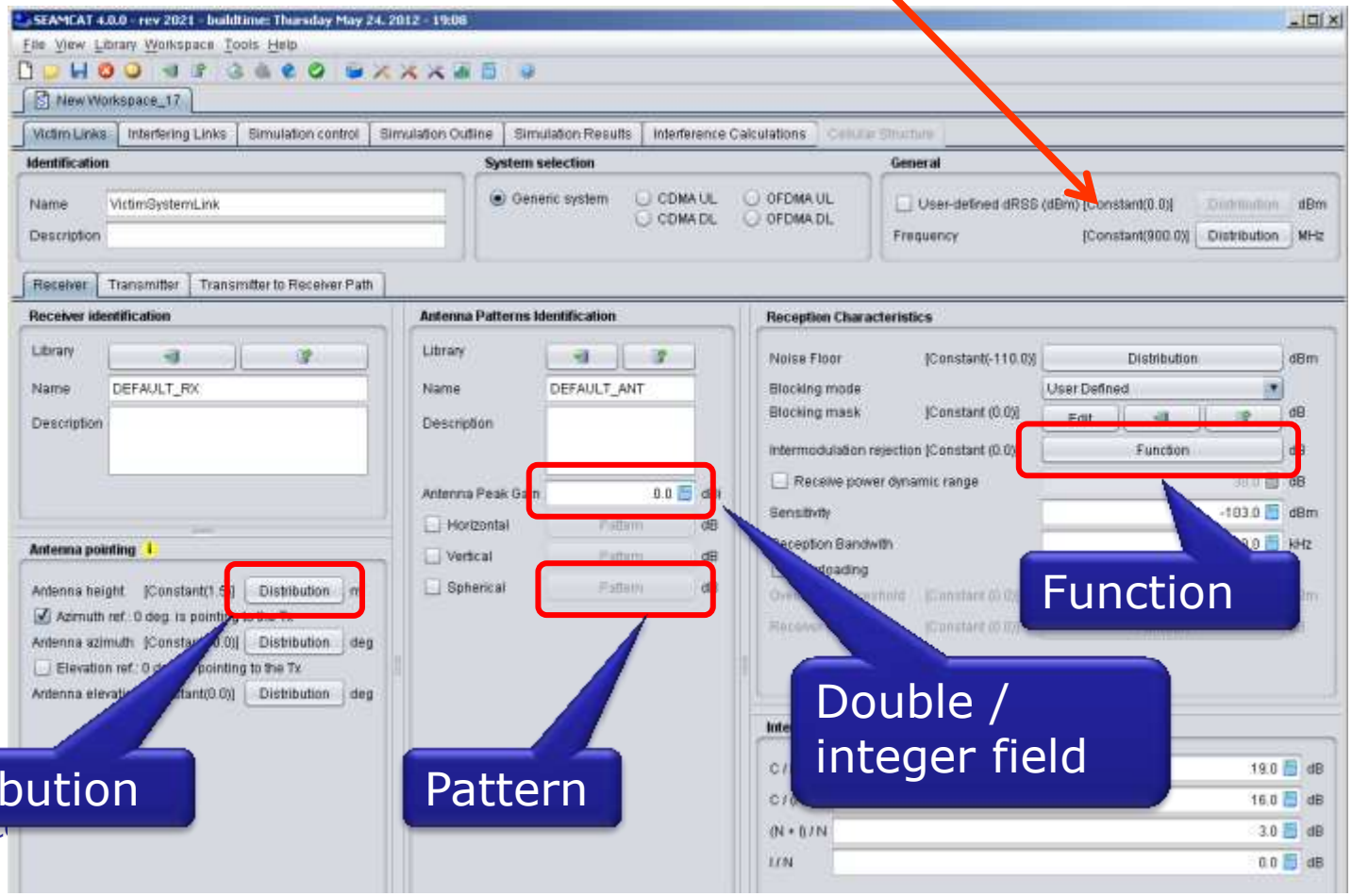


Graphic interface (1/1)



Scenario parameters

- Positioning of two systems in frequency
- Powers
- Masks
- Activity
- Antenna
- Etc...



Graphic interface (1/2)

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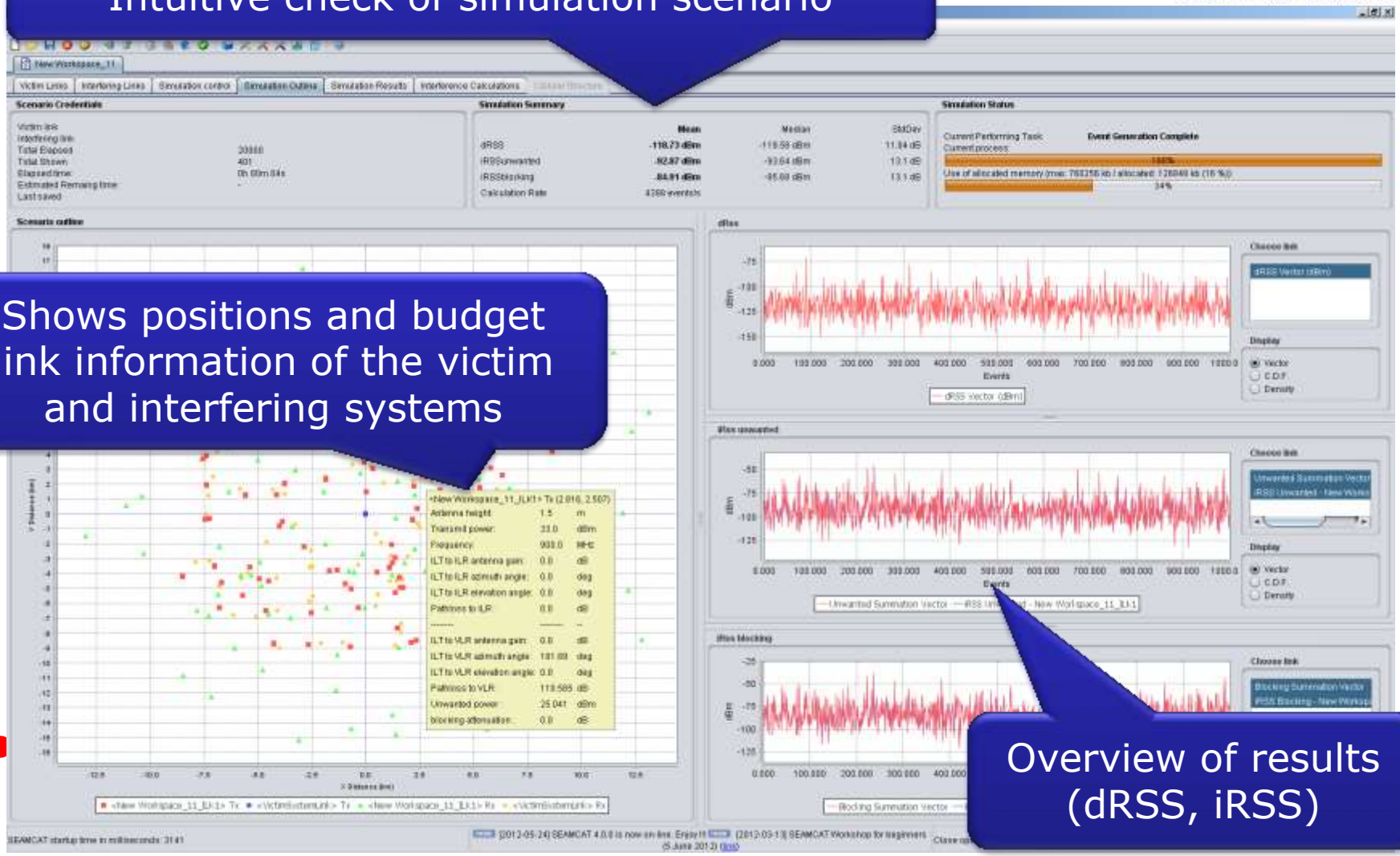
Intuitive check of simulation scenario



Shows positions and budget link information of the victim and interfering systems

Libraries and Batch

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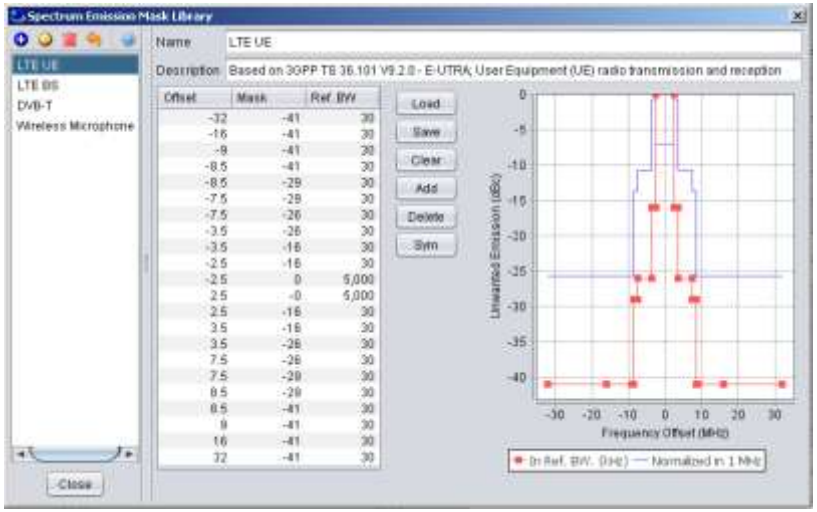
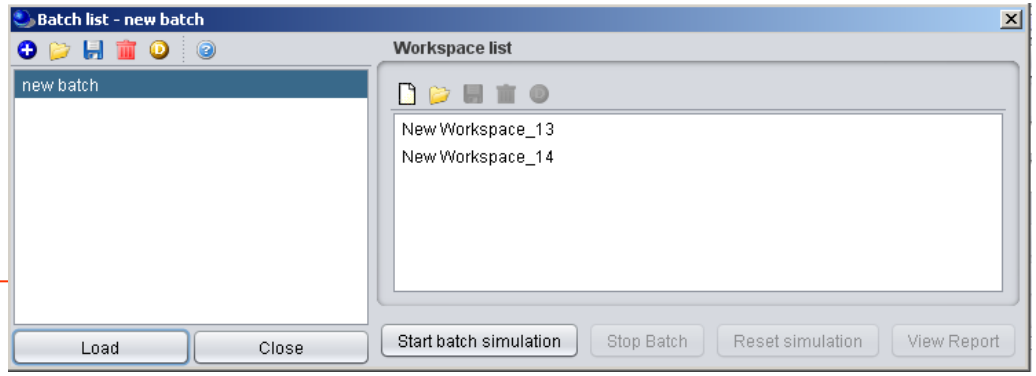
- Easy to create workspaces with predefined **libraries**
  - Edit, import, export



- Easy to run sequentially workspaces
  - **Batch** operation
  - Intuitive use



Welcome + News History

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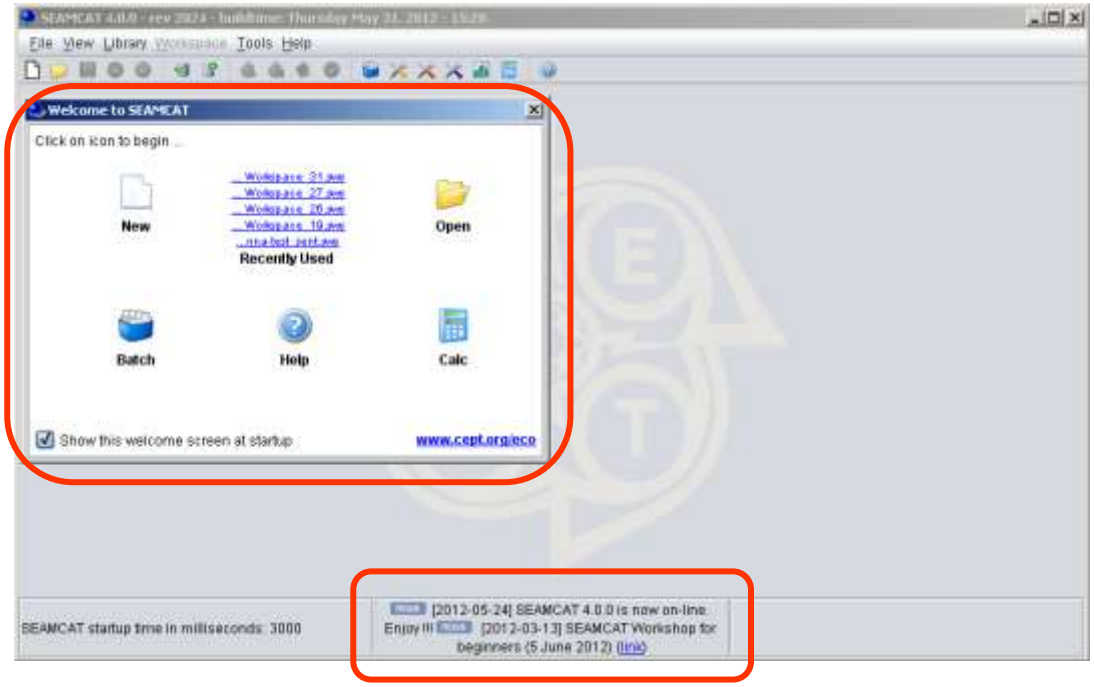
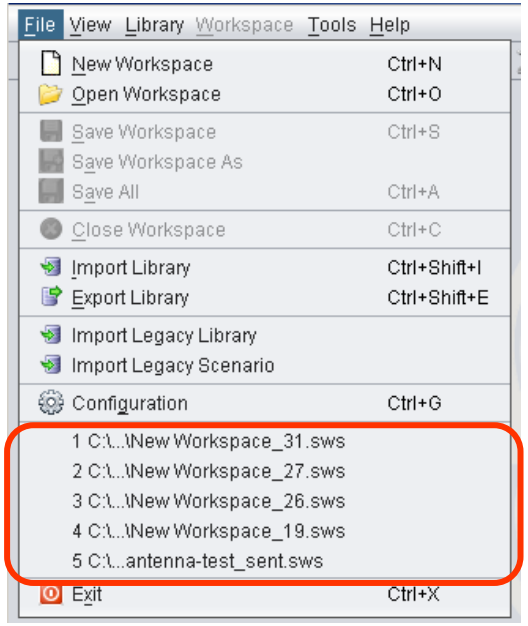
- Welcome + News



- History



Propagation model plug-in

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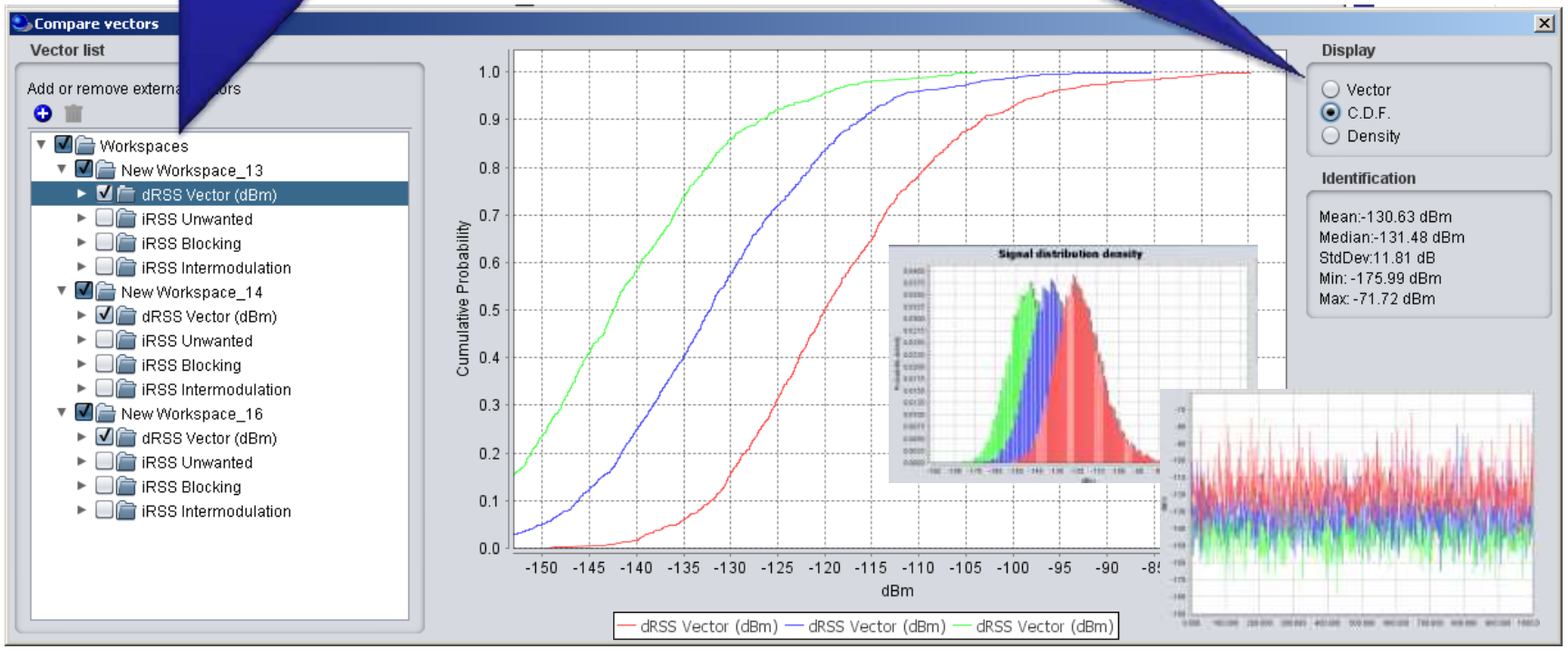
- This plug-in may be used to define **ANY** kind of propagation model
- The plug-in can replace a built-in model
- It is a software programme developed by **YOU**
- Use Java language, compile using open development tools
- Can be embedded to the workspace for sharing with others
- **Examples (+ source code) available on the on-line manual**.

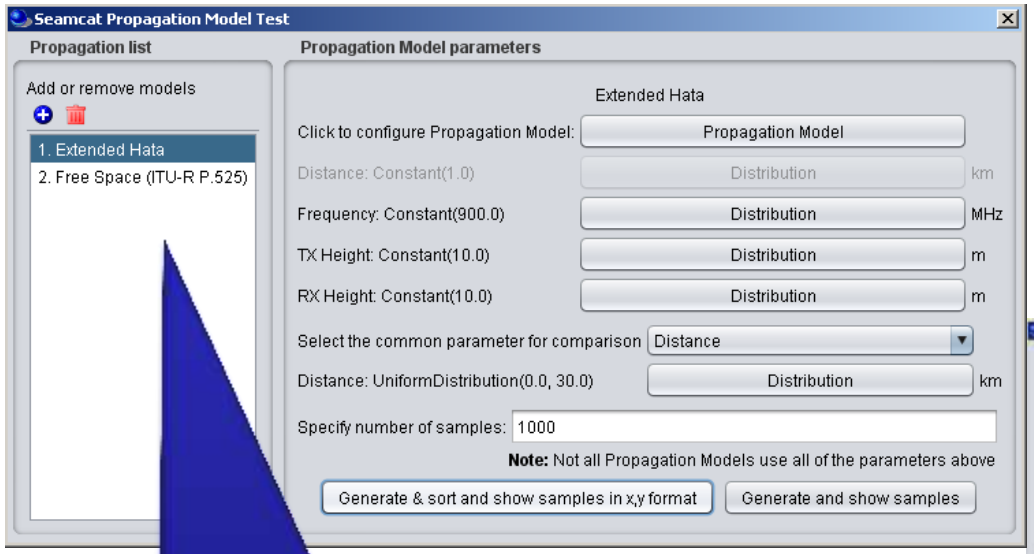
Multiple vectors display

Calculated vectors or external vectors

Statistics and signal type

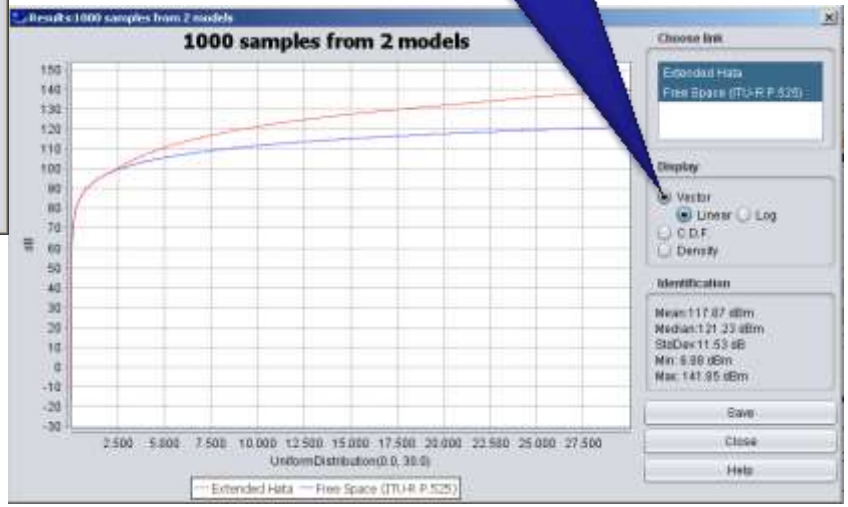


Comparing propagation model



Compare two or more propagation models

Results in linear or log format



Open source

- Open source in **Java**
- Source code available upon request
- **2 steps procedure**:
  1. License agreement **to sign**
  2. Register to the "seamcat source code" group

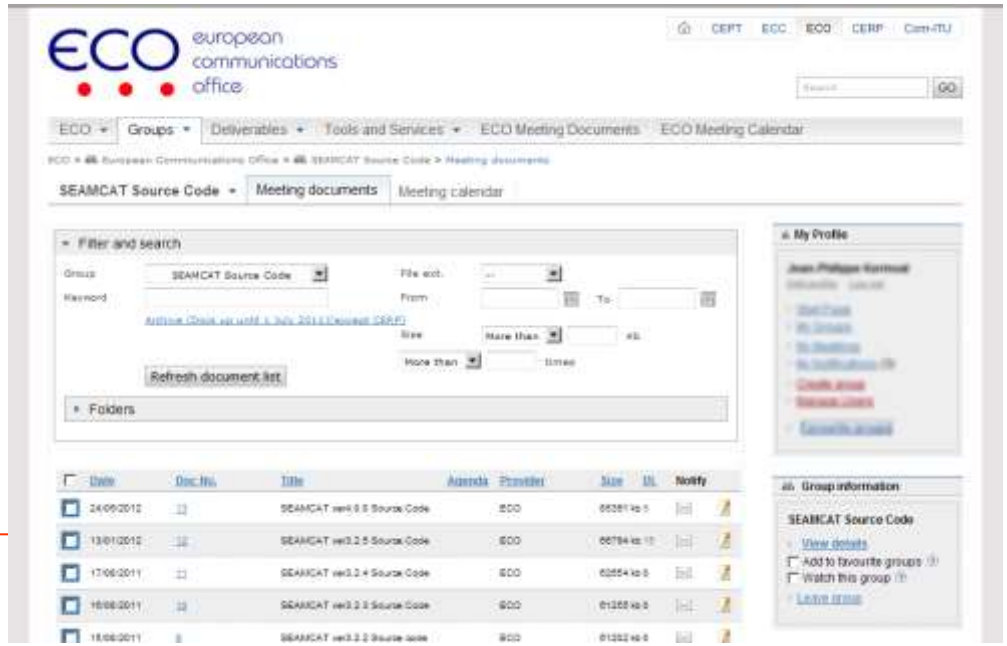
SEAMCAT™ SOURCE CODE USER'S
LICENCE AGREEMENT

1 Preamble

1.1 SEAMCAT™ is a public-domain software; its executable code being distributed free-of-charge by the European Communications Office (ECO); its purpose is the statistical assessment of interference between various radiocommunications systems. SEAMCAT had been developed through a joint effort of several Telecommunications Administrations of CEPT countries, co-operating industry partners and ECO.

1.2 "SEAMCAT" is a trademark registered in the name of ECO in many jurisdictions around the world.

1.3 By signing this Licence Agreement, the undersigned (hereinafter - the User) enters into agreement with ECO



Conclusions

- Simple architecture allowing any radio system to simulate
- XML data exchange
- Intuitive graphic interface
- Libraries and batch to help your daily SEAMCAT work
- Propagation model plugin interface
- World wide usage

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Thank you - Any questions?

Modelling of Unwanted and Blocking Interference Modes

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ISART – May 12, 2015

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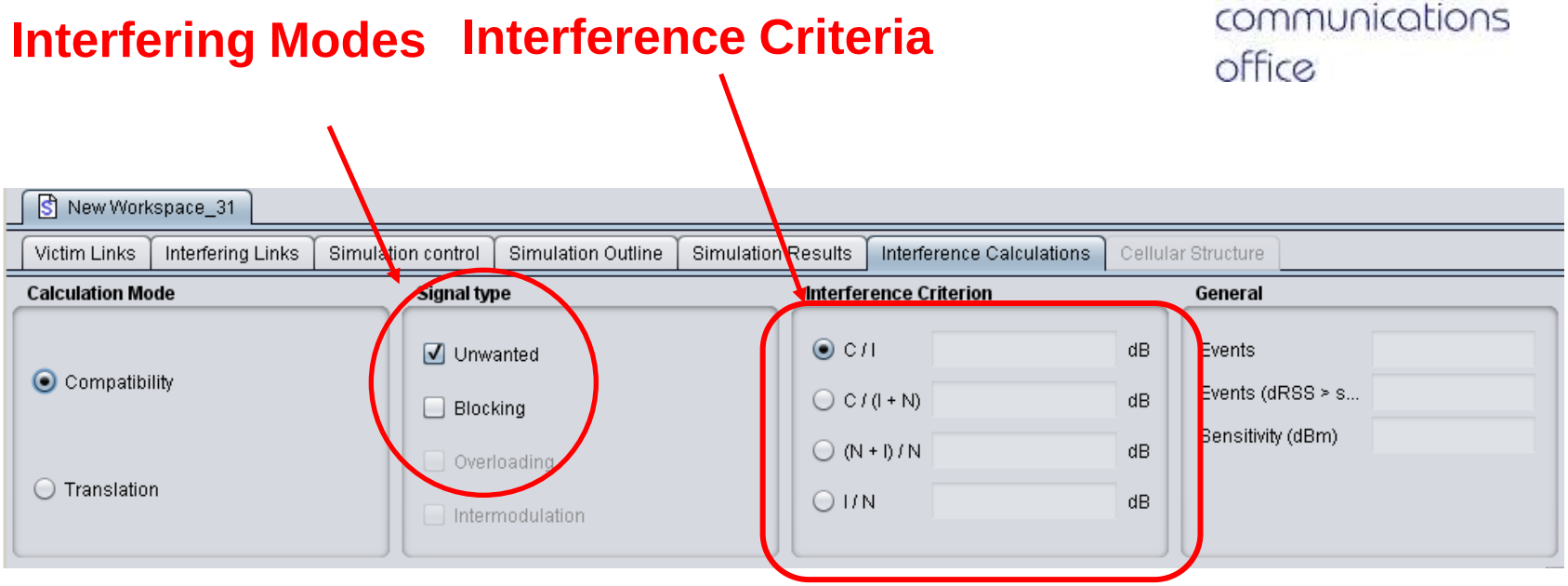
Outline


Interfering modes
Unwanted emissions case
Exercise #1
Exercise #2
Blocking case
Exercise #3

Interference Calculations



Unwanted and Blocking Signals

Unwanted Emissions

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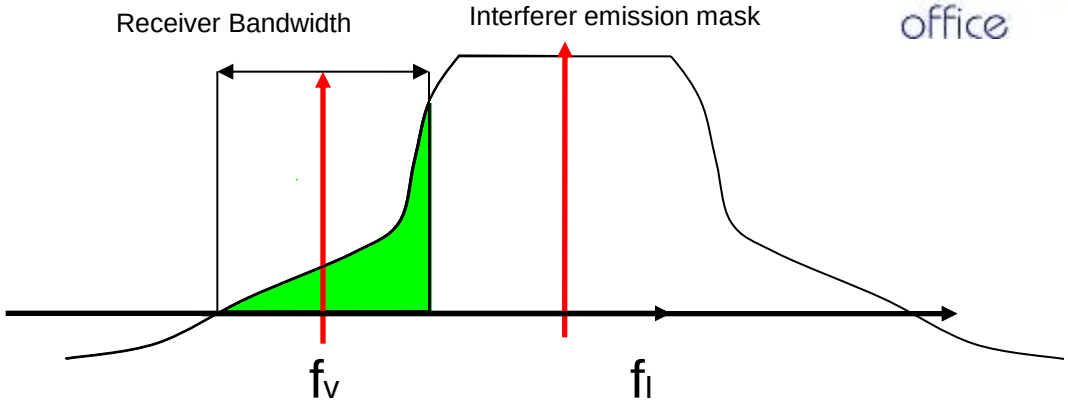
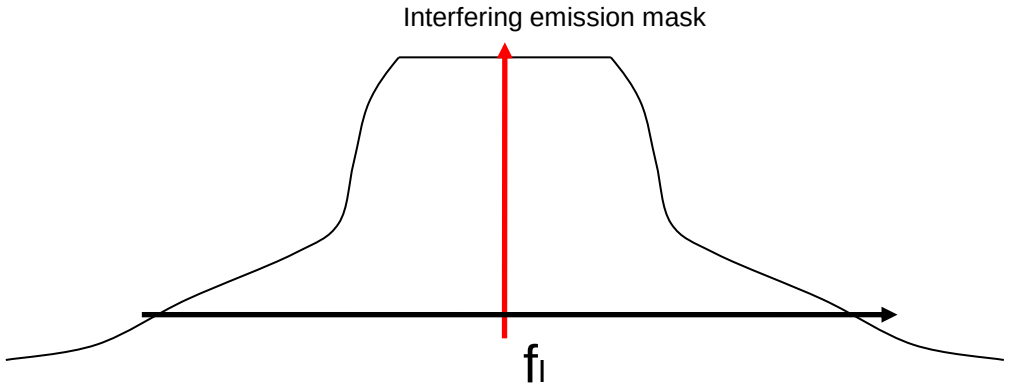
- *Victim*



- *Interfering System*



Exercise #1: Unwanted calculation

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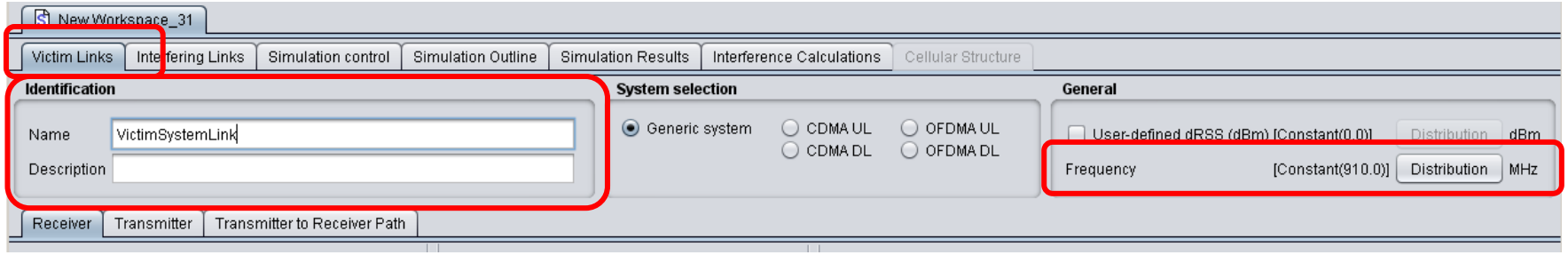
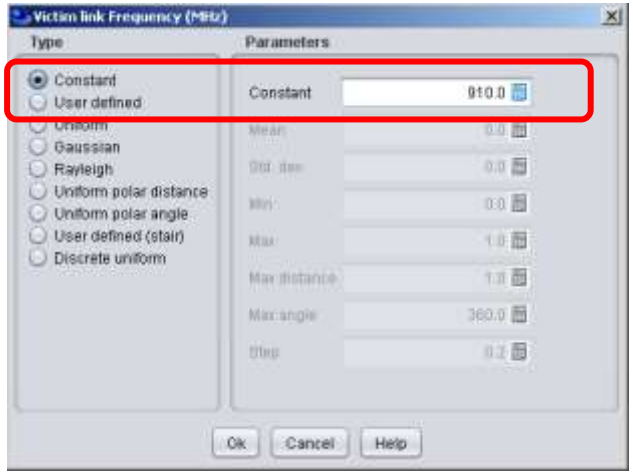
- Set victim link receiver (VLR)
  - Name: VLR Exercise #2
  - Frequency: 910 MHz
  - Interference criteria: I/N = 0
  - Noise level = -110
  - Bandwidth = 150 KHz
- Set interfering link transmitter (ILT)
  - Name: ILT Exercise #2
  - Frequency: 905 MHz
  - Power: 23 dBm
  - Emission mask: default mask

Offset	Mask	Ref. BW
-10	0	1,250
10	0	1,250

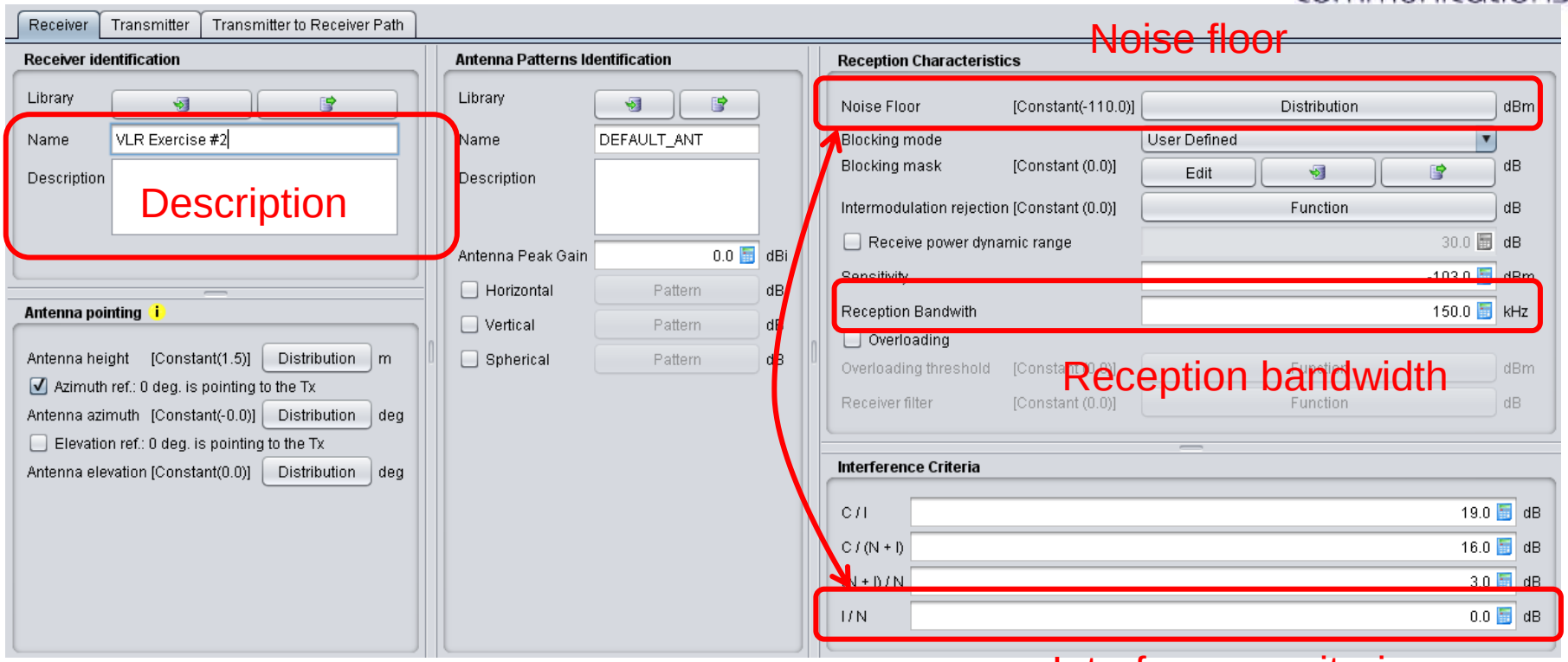
- Path between VLR with ILT
  - Propagation model:free space (no variation)
  - Position (x,y): fixed, 10km apart

Victim link

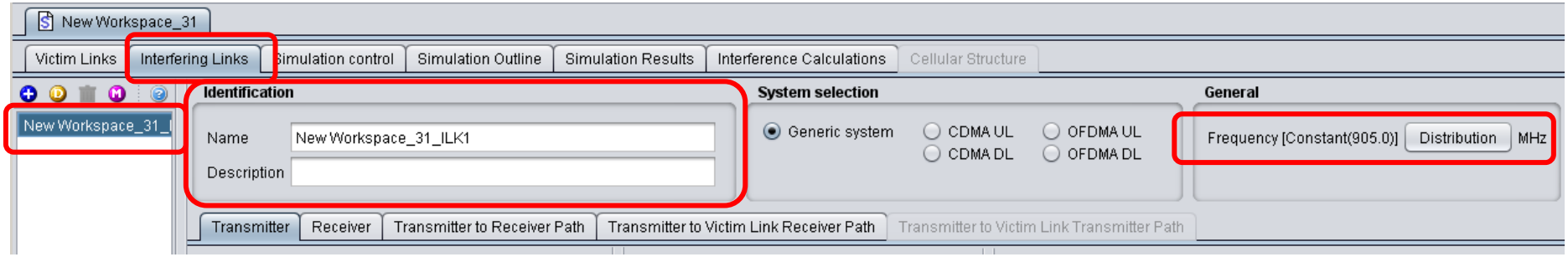

New Workspace_31
Victim Links
Interfering Links
Simulation control
Simulation Outline
Simulation Results
Interference Calculations
Cellular Structure
Identification
Name
VictimSystemLink
Description
System selection
Generic system
CDMA UL
CDMA DL
OFDMA UL
OFDMA DL
General
User-defined dRSS (dBm) [Constant(0.0)]
Distribution
dBm
Frequency
[Constant(910.0)]
Distribution
MHz
Receiver
Transmitter
Transmitter to Receiver Path


Victim link Frequency (MHz)
Type
Parameters
Constant
User defined
Gaussian
Rayleigh
Uniform polar distance
Uniform polar angle
User defined (stair)
Discrete uniform
Constant
910.0
Ok
Cancel
Help

Victim Link Receiver



Interfering Link



Interfering Link Transmitter

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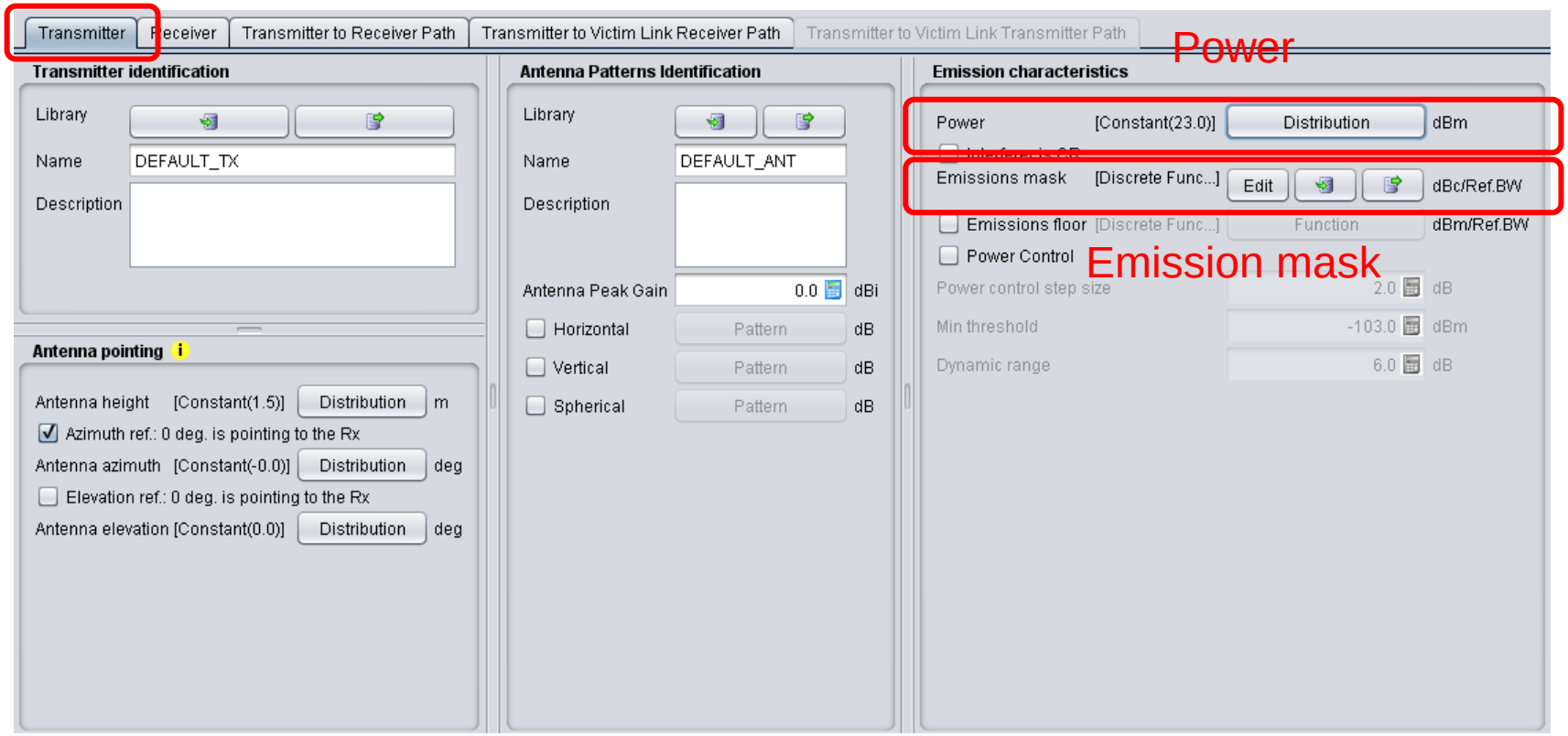
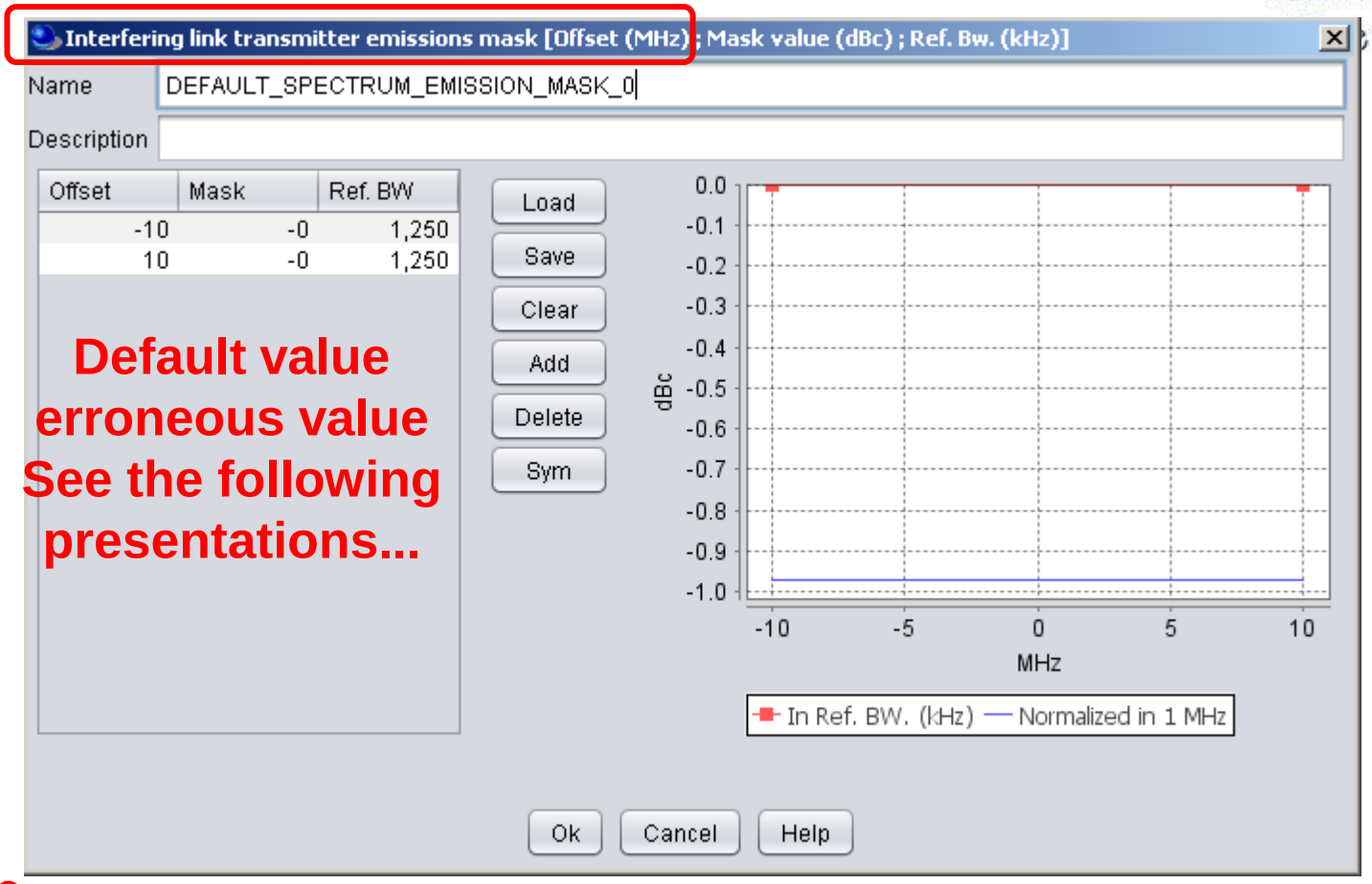
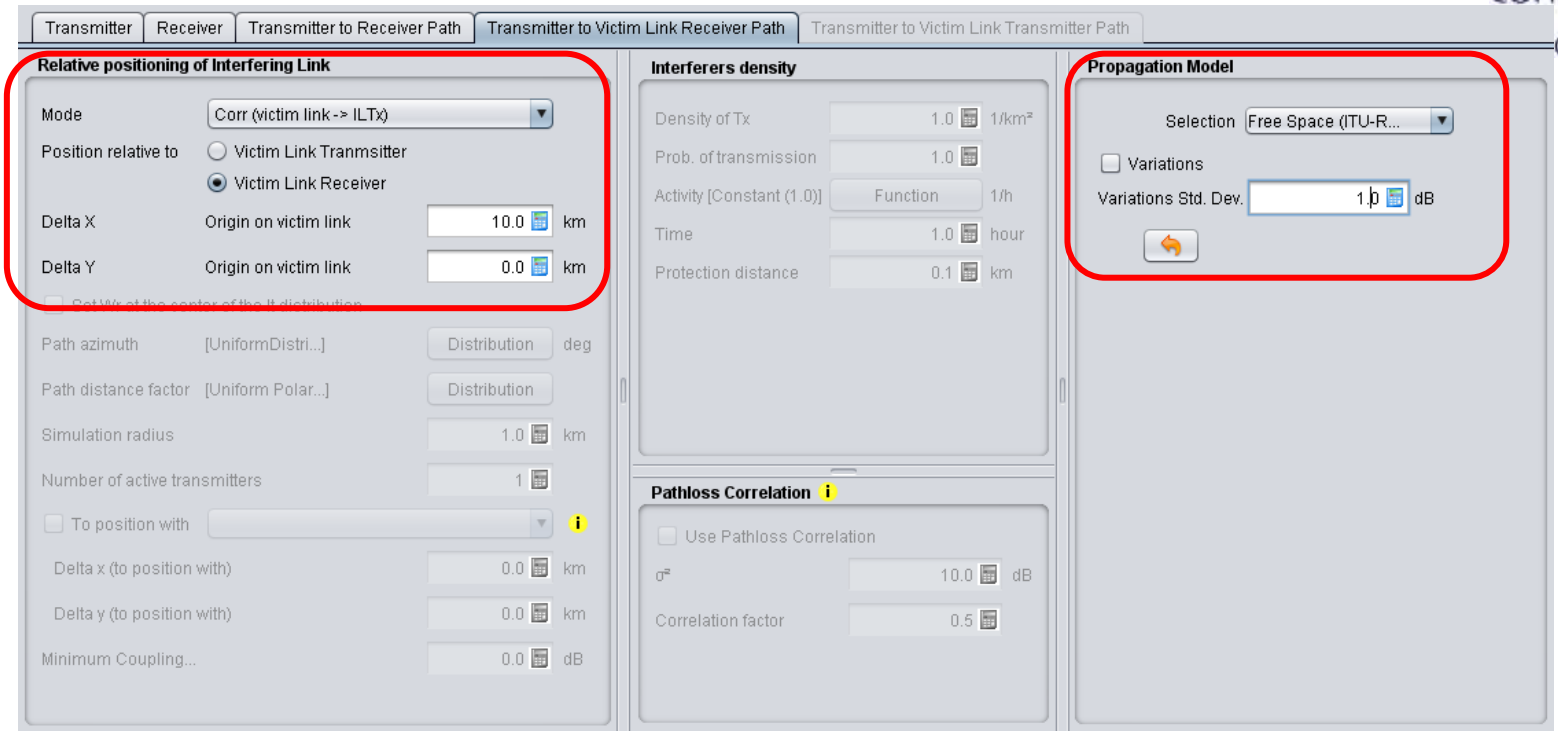


Unwanted emissions mask



ILT → VLR Path



Att = 32.44 + 20 x log (f (MHz)) + 20 x log (d (km))
Att = 32.44 + 20 x log (905 MHz) + 20 x log (10 km)
Att = 111.57 dB

Simulations...

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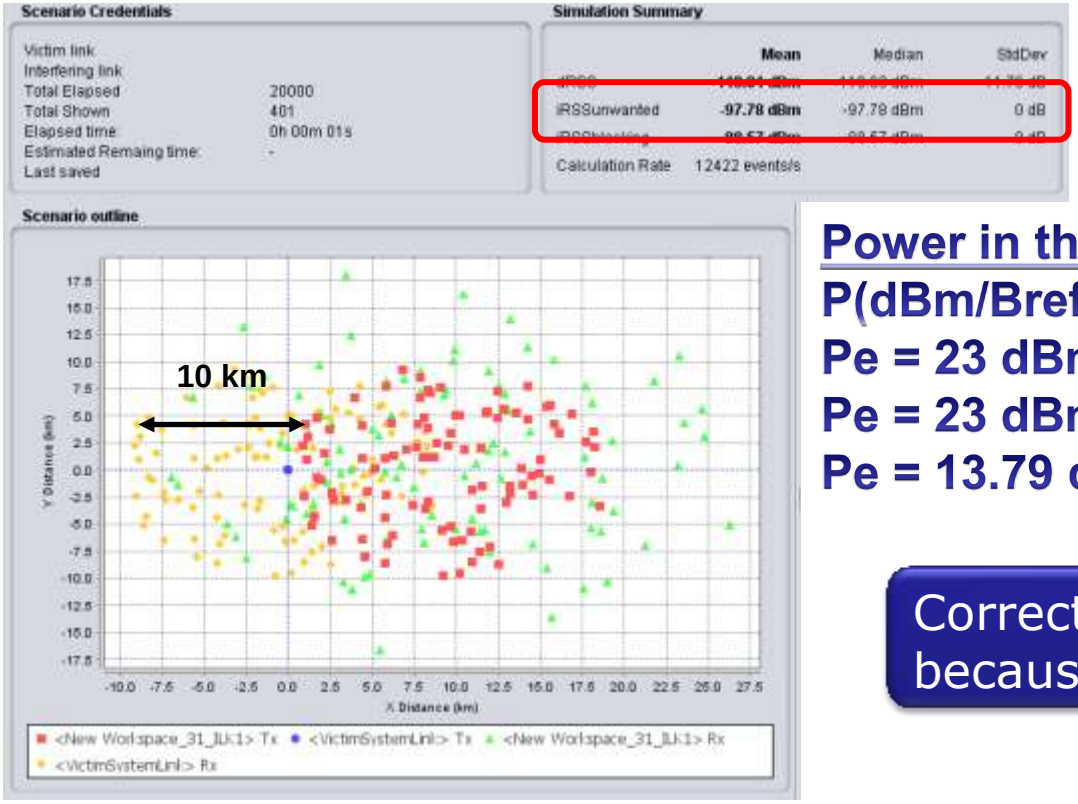


Power in the victim bandwidth:

P(dBm/Bref) = Pe(dBm) + att(dBc/Bref) + CF

Pe = 23 dBm + 0 + 10*log(150/1250)

Pe = 23 dBm + 0 - 9.21dBm

Pe = 13.79 dBm

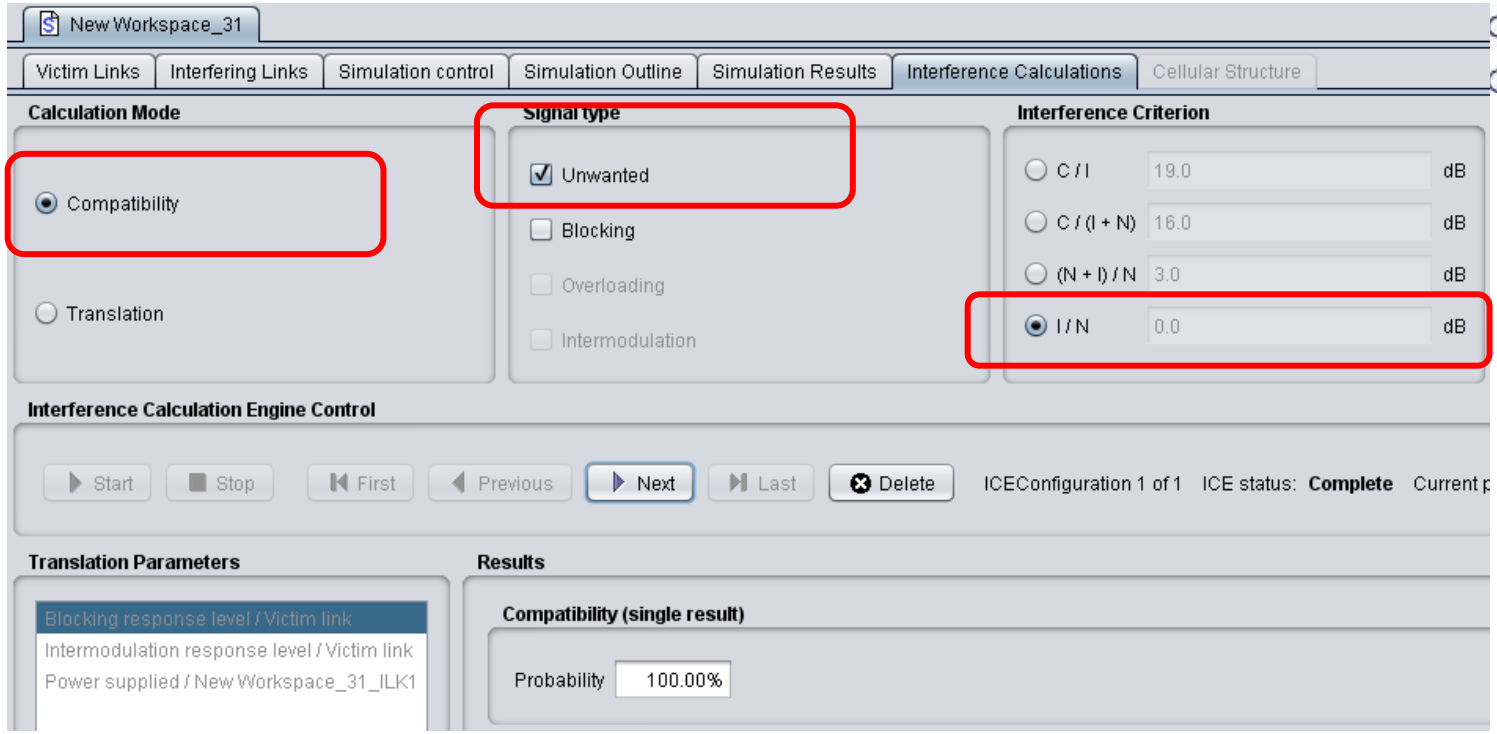
Correction Factor (CF) needed because Vr BW < It BW

IRSS Unwanted = Pe + Ge + Gr – Att (free space)

IRSS Unwanted = 13.79 dBm + 0 dB + 0 dB – 111.57 dB

IRSS Unwanted = - 97.78 dBm

Results



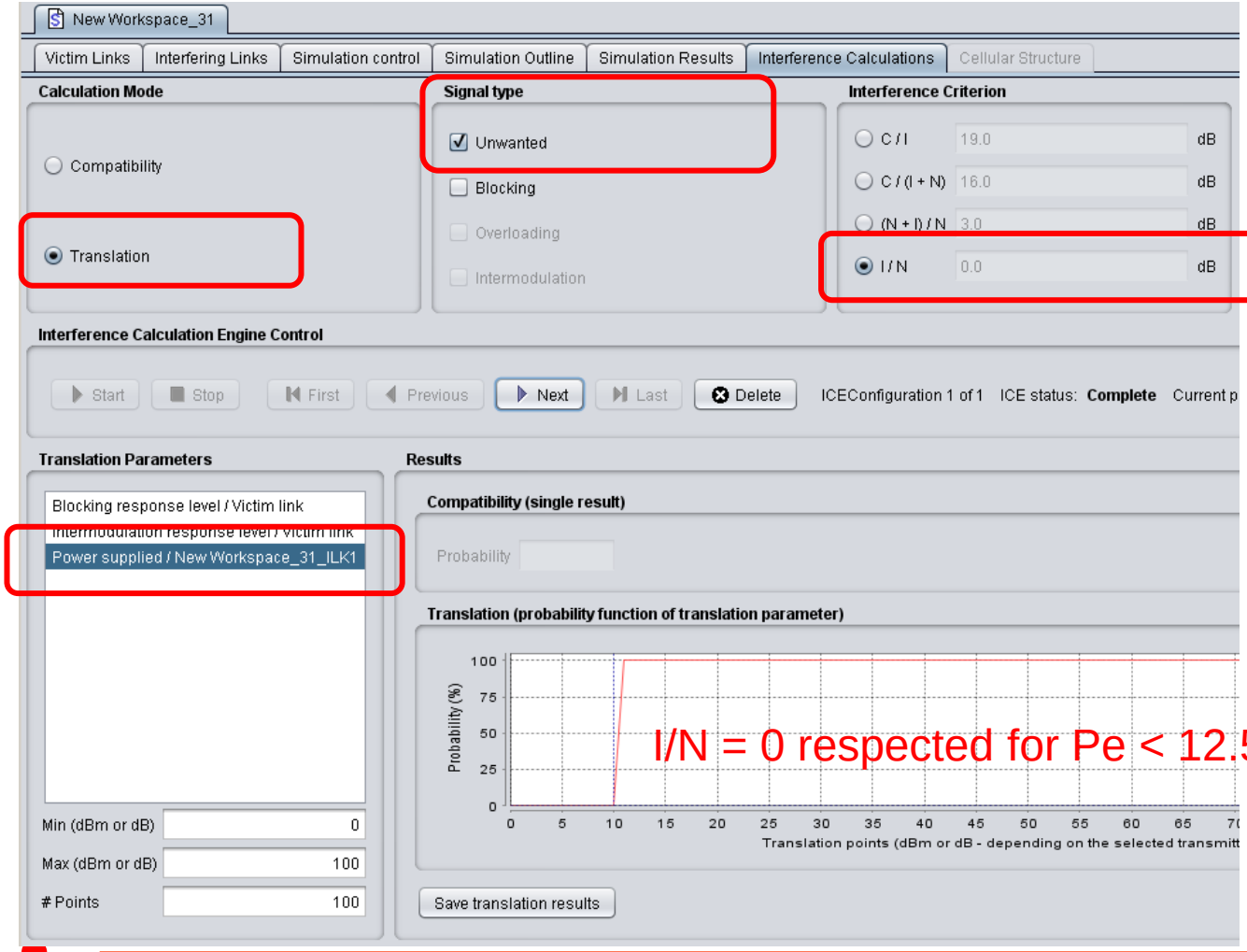
N = -110 dBm

IRSS Unwanted = - 97.78 dBm

I/N = - 97.78 – (-110) = 12.21 dB (→ Calculated by SEAMCAT)

Interference Criterion was: I/N = 0 (→ Input to SEAMCAT)

Results...

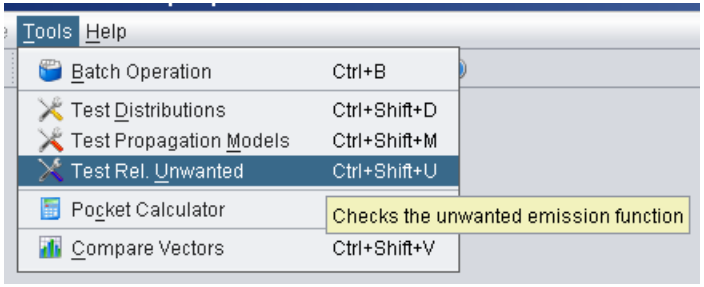


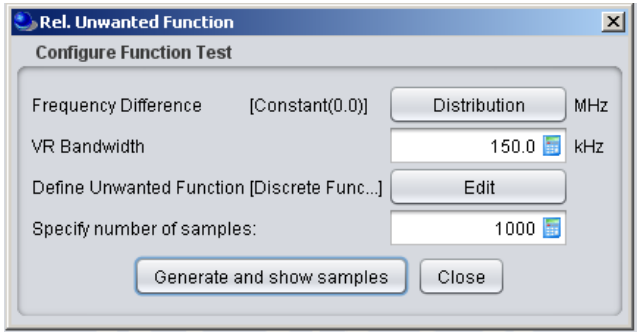
I/N = 0 respected for Pe < 12.5 dB at 50%

Exercise #2: SEM calculation

How to check that the Spectrum Emission Mask is properly calculated?

- Easy tool in SEAMCAT → "Test Rel. unwanted" tool
  - Launch the "Test Rel. unwanted" tool





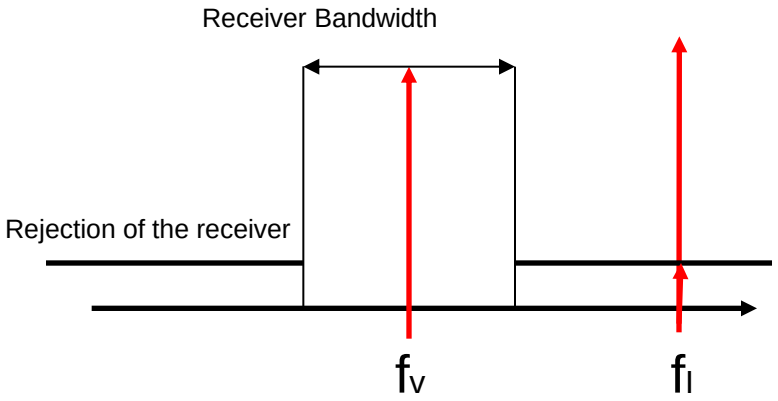
- $\Delta f = fi - fv = 0$
- Vr BW = 150 kHz
- SEM: same as in Exercise #1

Offset	Mask	Ref. BW
-10	0	1,250
10	0	1,250

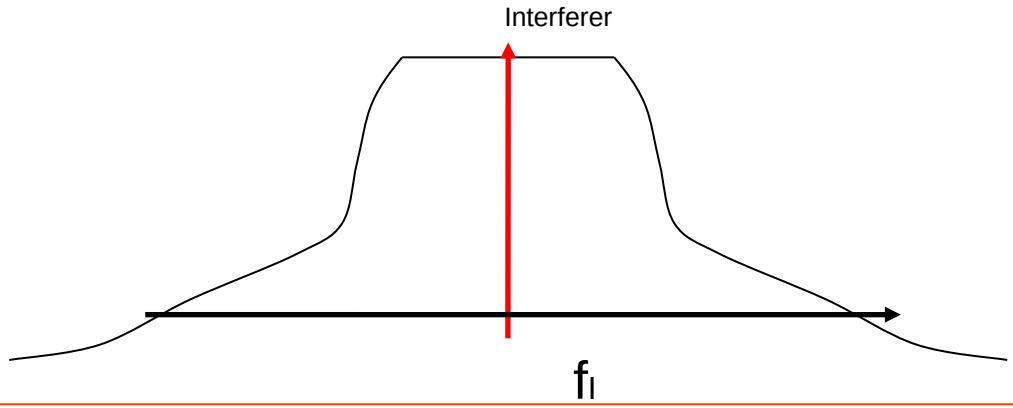
- Results: -9.21 dBm

Blocking

- *Victim*



- *Interfering System*



Blocking: 3 Modes

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User Defined (dB): Rejection at the receiver

$$Att_{Blocking} = Block_{UD}$$

Protection Ratio (dB):

$$Att_{Blocking} = Block_{PR} + C/(N+I) - I/N + (N+I)/N$$

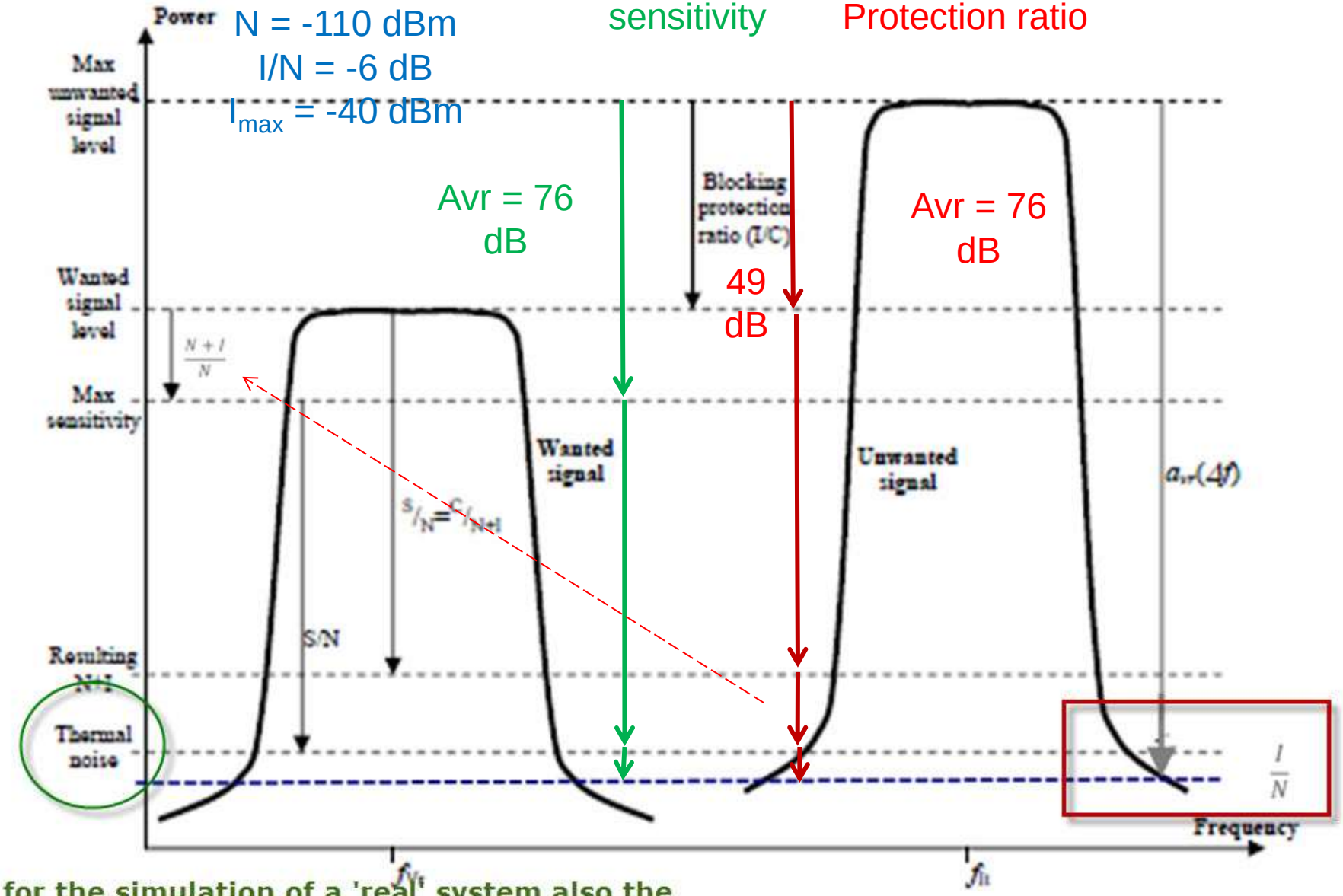
Sensitivity Mode (dBm): Maximum Acceptable Value of Power

$$Att_{Blocking} = Block_{Sens}\ (dBm) - Sensitivity\ (dBm) + C/(N+I) - I/N$$

S = -90 dBm
N = -110 dBm
I/N = -6 dB
I_{max} = -40 dBm

sensitivity

Protection ratio



for the simulation of a 'real' system also the noise figure has to be considered

Relationship between signal levels

Exercise # 3: blocking calculation

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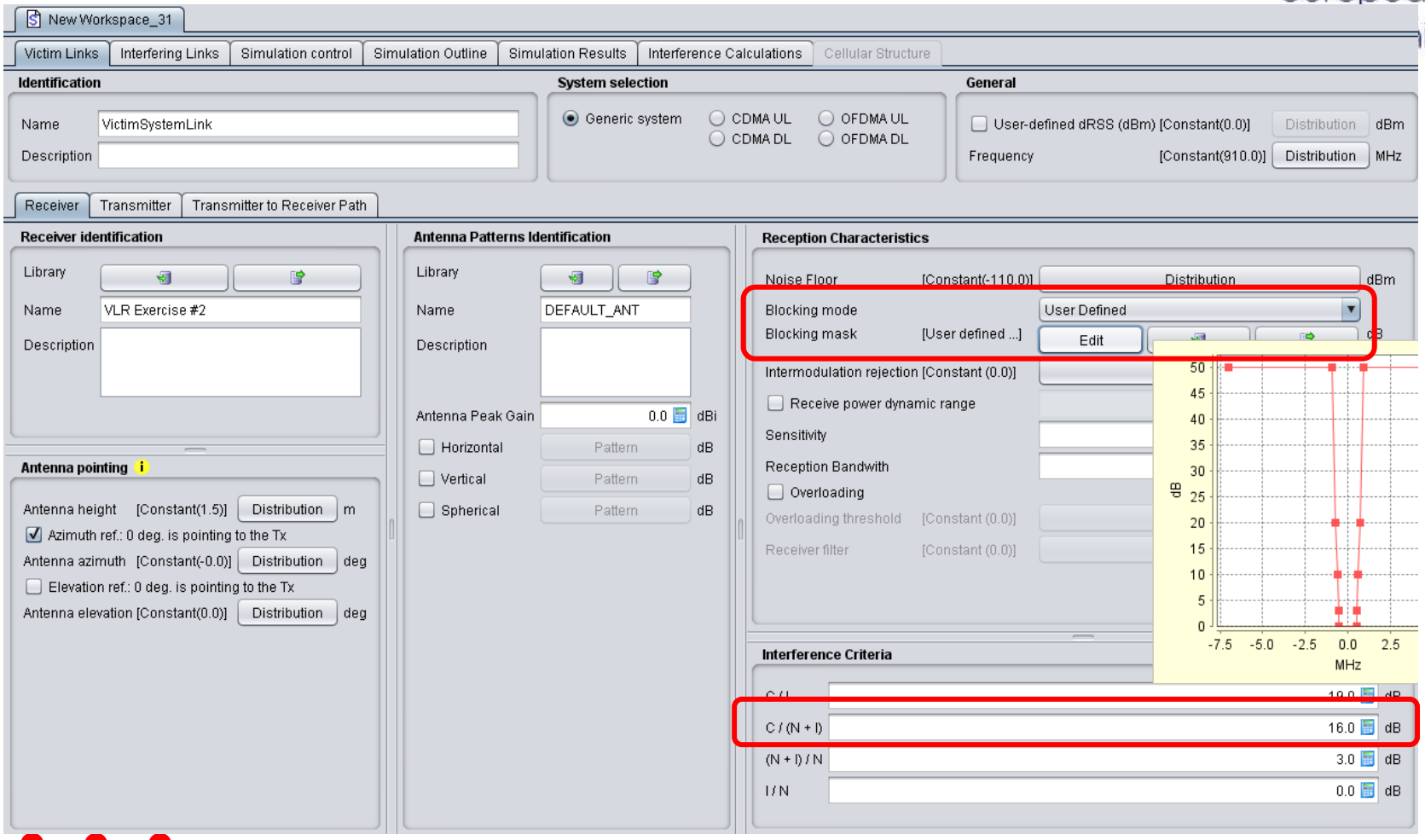
- Set victim link receiver (VLR)
  - Blocking mode: user defined
  - Blocking response: function

  (Load the ”example of a blocking mask.txt” file)
  - Interference criteria: I/N = 0
  - Noise level = -110

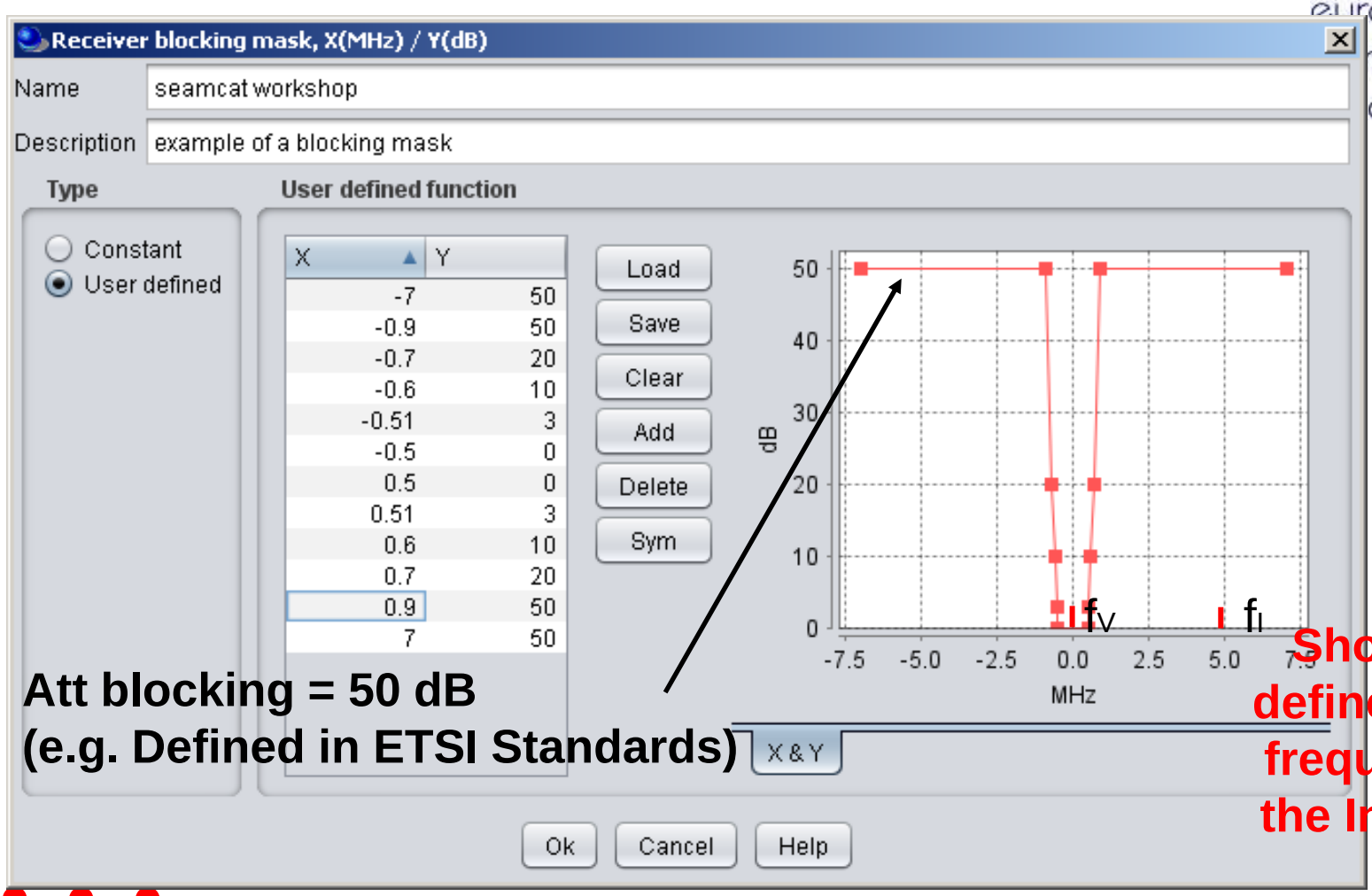
X	Y
-7	50
-0.9	50
-0.7	20
-0.6	10
-0.51	3
-0.5	0
0.5	0
0.51	3
0.6	10
0.7	20
0.9	50
7	50

- Set interfering link transmitter (ILT)
  - No change
- Path between VLR with ILT
  - No change

Victim link


New Workspace_31
Victim Links
Interfering Links
Simulation control
Simulation Outline
Simulation Results
Interference Calculations
Cellular Structure
Identification
Name
VictimSystemLink
Description
System selection
Generic system
CDMA UL
CDMA DL
OFDMA UL
OFDMA DL
General
User-defined dRSS (dBm) [Constant(0.0)]
Distribution
dBm
Frequency
[Constant(910.0)]
Distribution
MHz
Receiver
Transmitter
Transmitter to Receiver Path
Receiver identification
Library
Name
VLR Exercise #2
Description
Antenna Patterns Identification
Library
Name
DEFAULT_ANT
Description
Antenna Peak Gain
0.0
dBi
Horizontal
Vertical
Spherical
Pattern
dB
Reception Characteristics
Noise Floor
[Constant(-110.0)]
Distribution
dBm
Blocking mode
User Defined
Blocking mask
[User defined ...]
Edit
Intermodulation rejection [Constant (0.0)]
Receive power dynamic range
Sensitivity
Reception Bandwith
Overloading
Overloading threshold
[Constant (0.0)]
Receiver filter
[Constant (0.0)]
Antenna pointing
Antenna height
[Constant(1.5)]
Distribution
m
Azimuth ref.: 0 deg. is pointing to the Tx
Antenna azimuth
[Constant(-0.0)]
Distribution
deg
Elevation ref.: 0 deg. is pointing to the Tx
Antenna elevation [Constant(0.0)]
Distribution
deg
Interference Criteria
C / (N + I)
16.0
dB
(N + I) / N
3.0
dB
I / N
0.0
dB
dB
MHz

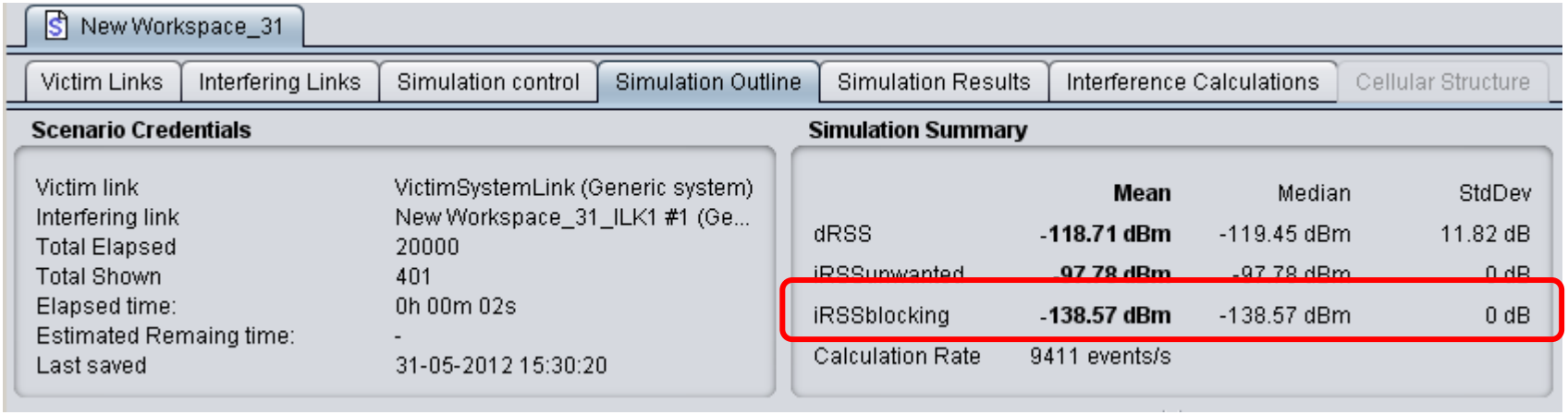
VLR Blocking Mask



Att blocking = 50 dB
(e.g. Defined in ETSI Standards)

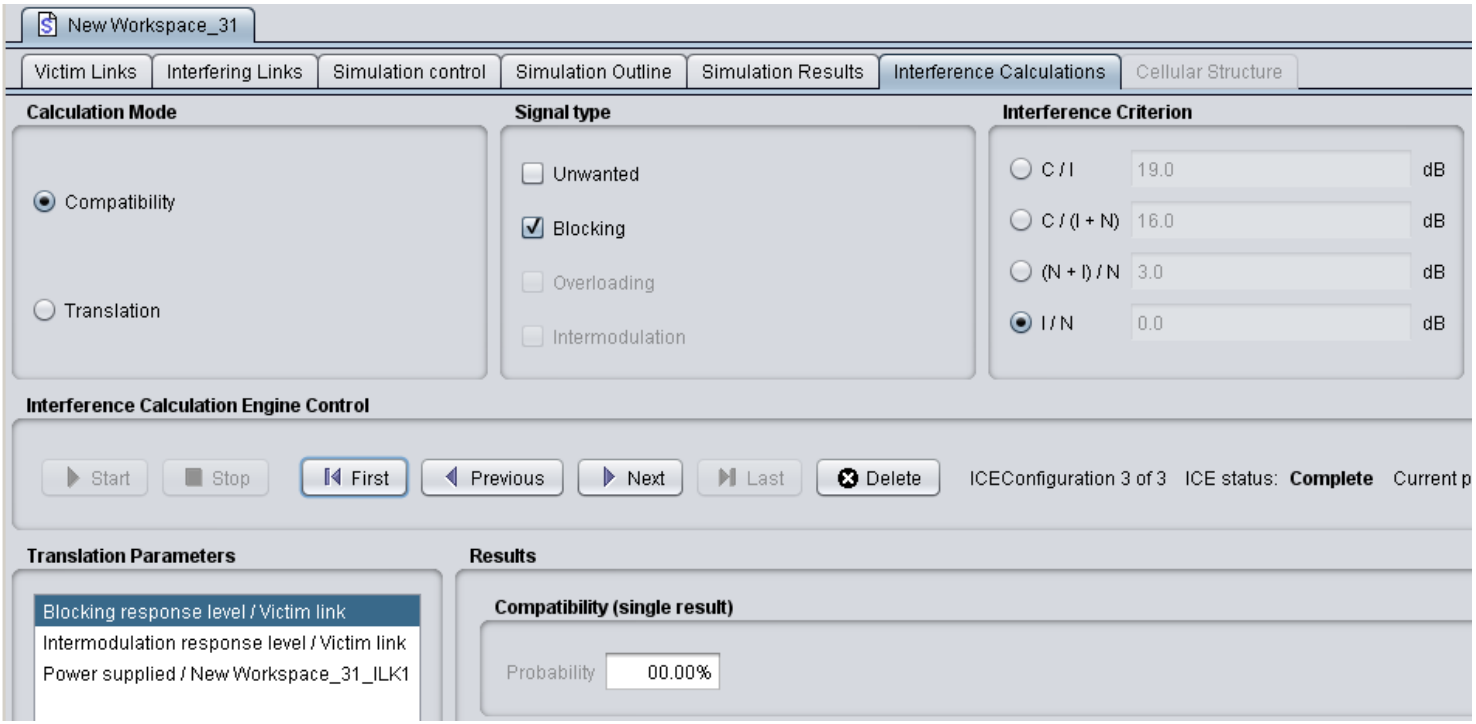
Should be defined at the frequency of the Interferer

Simulations



IRSS Blocking= Pe + Ge + Gr – Att (free space) – Att block
IRSS Blocking= 23 dBm + 0 dB + 0 dB – 111.57 dB – 50 dB
IRSS Blocking = - 138.57 dBm

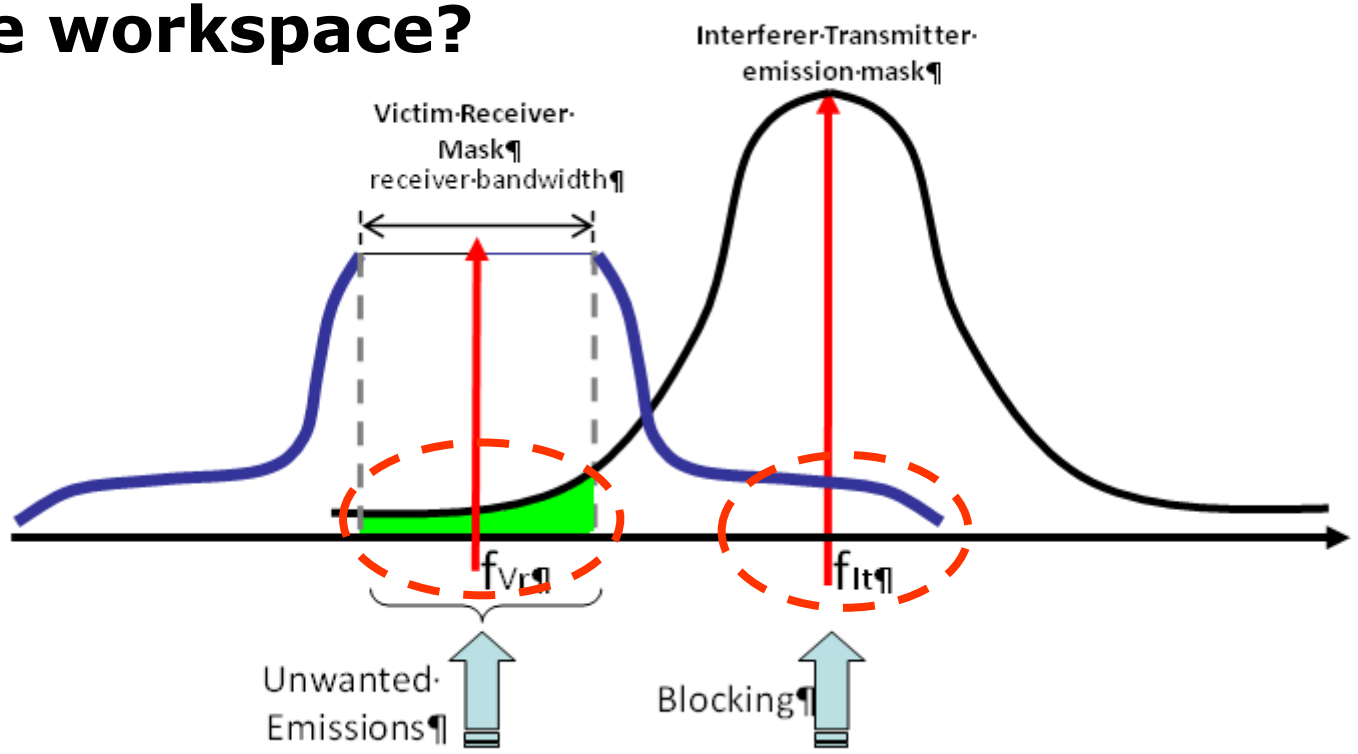
Results



IRSS Blocking Level = - 138.57 dBm
N = -110 dBm
I/N = 0 dB (Criterion) always met

Question?

- **Can I make simulation for unwanted and blocking in the same workspace?**



Question: Can I make simulation for unwanted and blocking in the same workspace?

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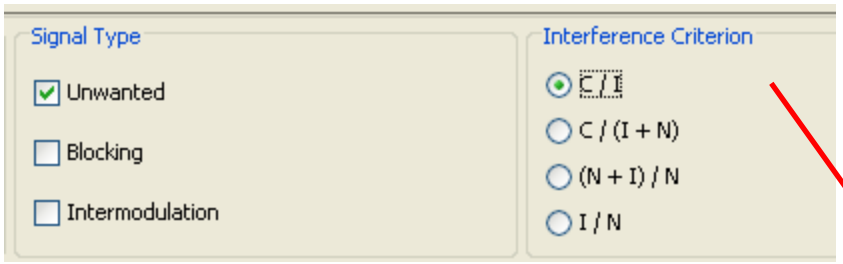
- **2 Interference Criteria / 2 runs**



Question: Can I run simulations for unwanted and blocking in the same workspace in a single run?

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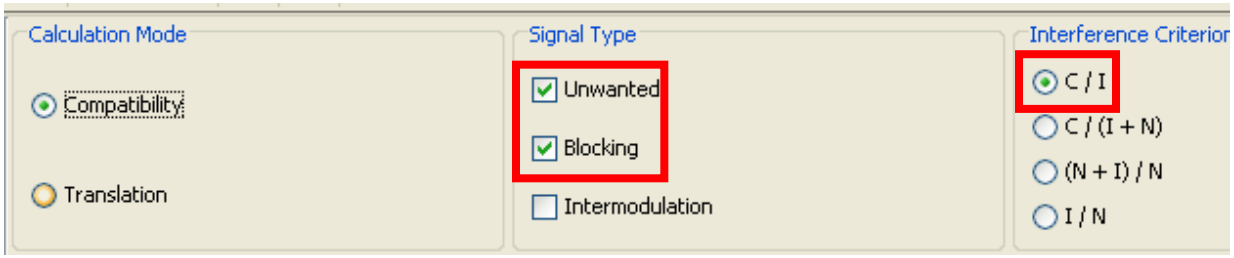
If the interference criteria are not the same...
You can compensate this when defining the mask (unwanted or blocking)



Assumptions: Blocking: PR mode + Criterion: C/I=0 dB
Unwanted: Criterion C/I=10 dB

Solution: Remove 10 dB from blocking mask (PR mode)
and use Criterion C/I=10 dB

Conclusion

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- Interference criteria allows:
  - To characterise the operation of a system
  - To define the technical sharing condition between systems in adjacent or co-channel scenario
- If more that one interference criteria are used, you need to check that they are consistent
- Understand what the tool compute

Thank you - Any Questions?

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Setting Emission and Blocking masks

European Communications Office
Jean-Philippe Kermoal (ECO)
ISART – May 12, 2015

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Web Site: http://www.cept.org/eco

Outline

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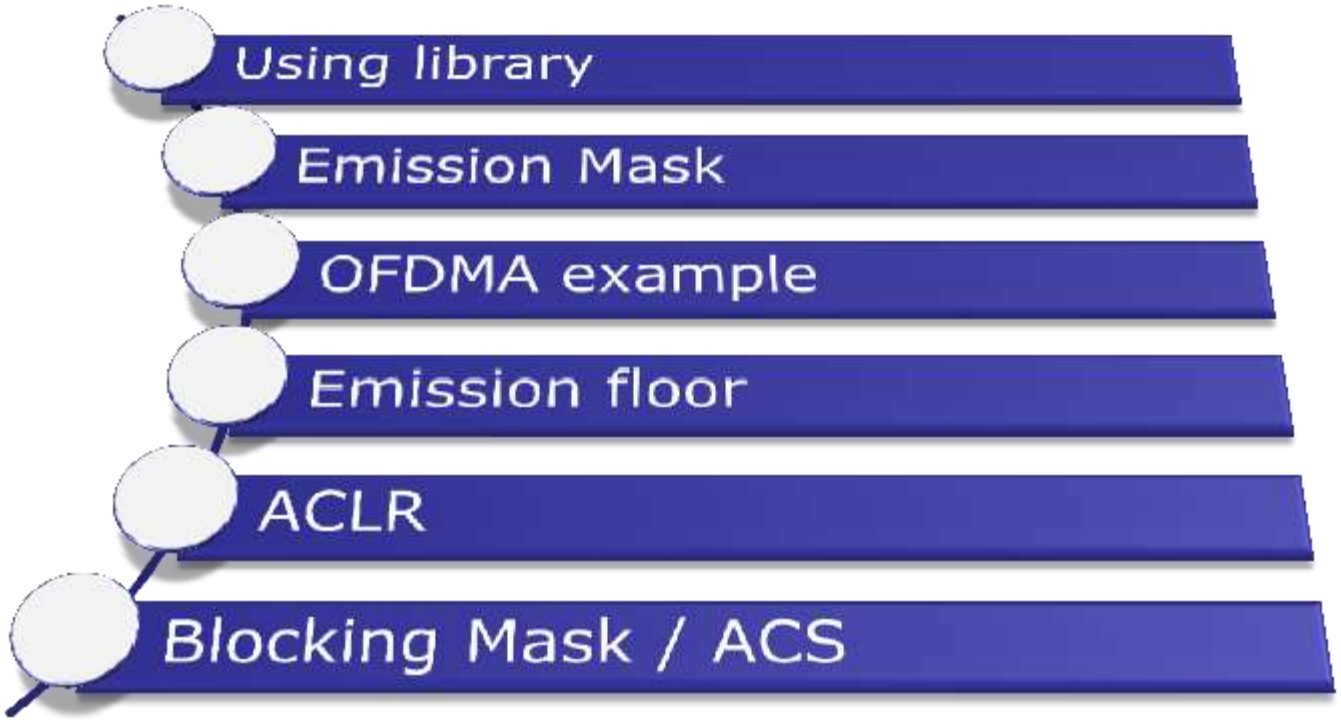
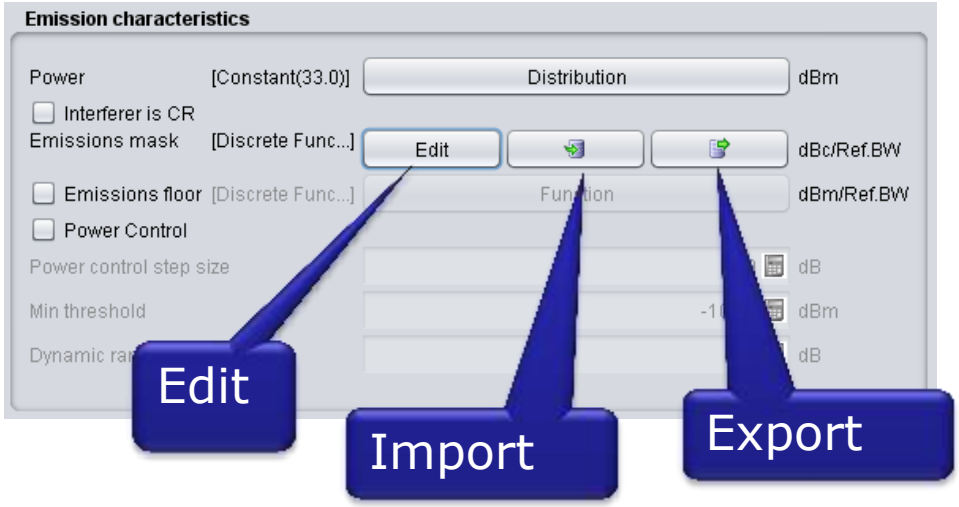
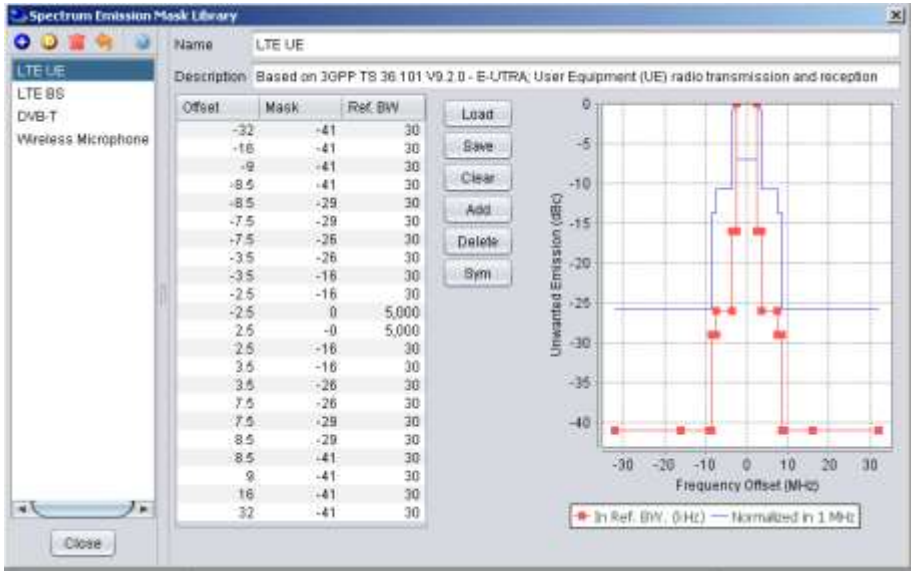


Using Library

- Edit
- Import from library
- Export to library

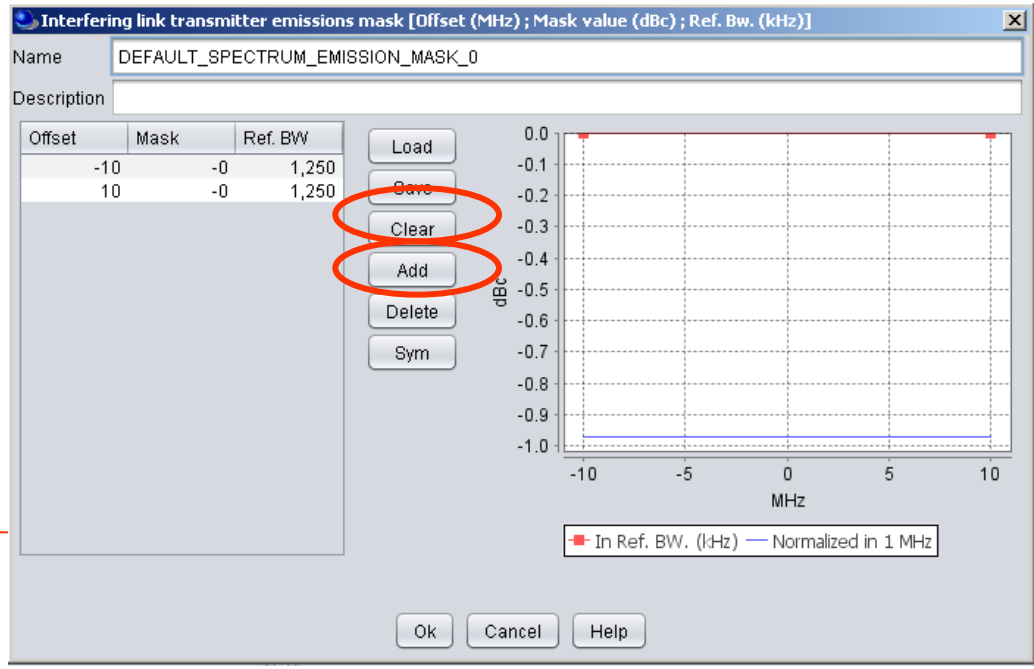




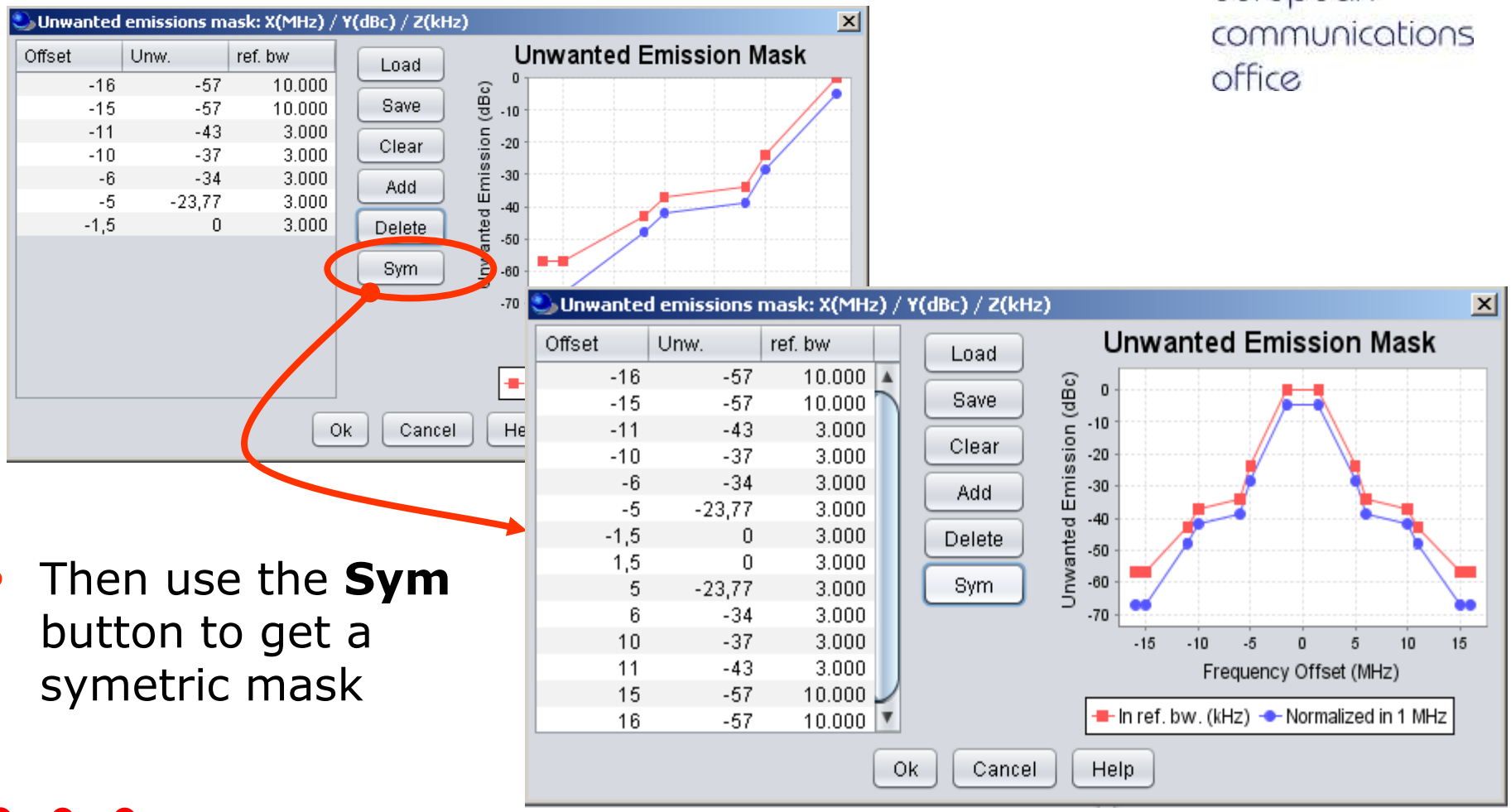
Technical specifications commonly extracted from ETSI (see http://www.etsi.org/WebSite/Standards/Standard.aspx)

Editing the mask

- The emission mask defaults value
- Remove the default using the **Clear** button.
- Then use the **add** button to add the enough blank rows for half of the emission mask.
- Note the format of the data:
  - Offset = MHz
  - Unwanted = dBc
  - Reference bandwidth = kHz



Symmetry

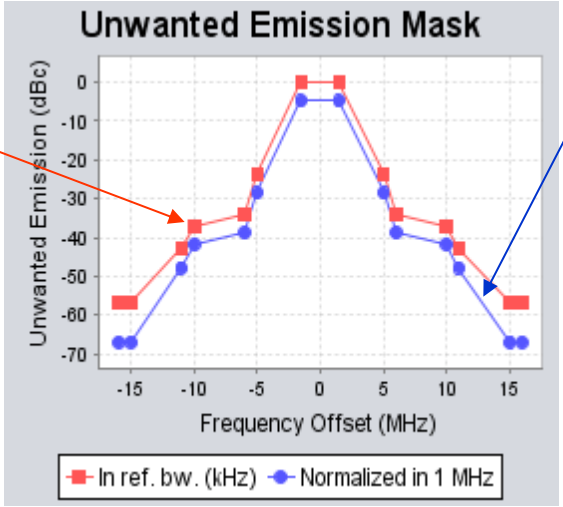


- Then use the **Sym** button to get a symetric mask

Reference/normalised bandwidth

- Once SEAMCAT has generated the whole mask, first check that the values are in the correct order.
- The unwanted emission diagram shows two masks

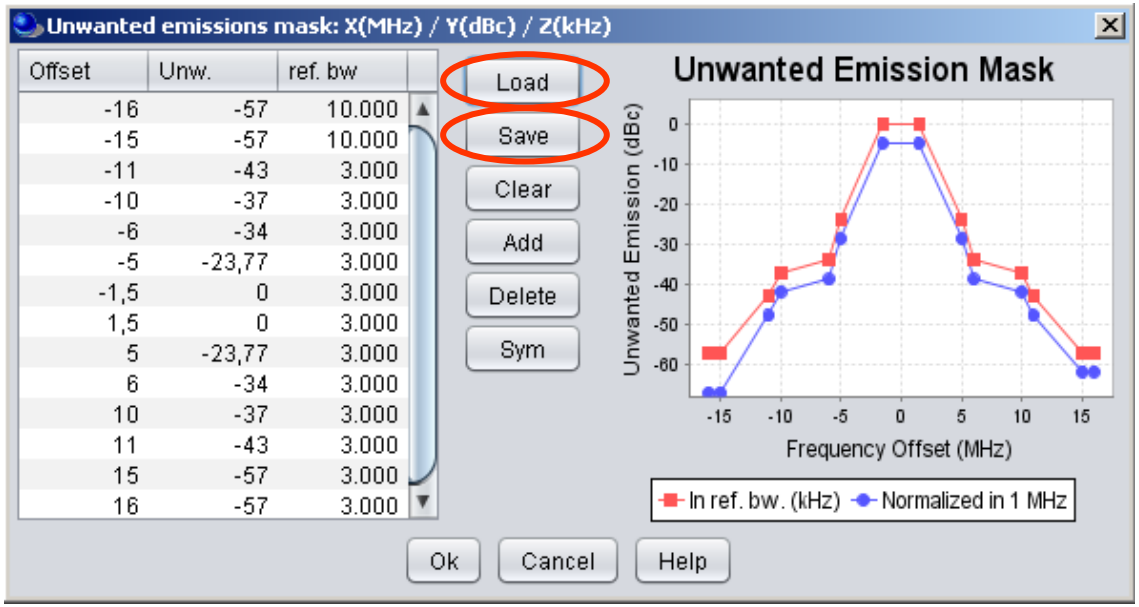
The red mask is the representation using the user defined reference bandwidth.

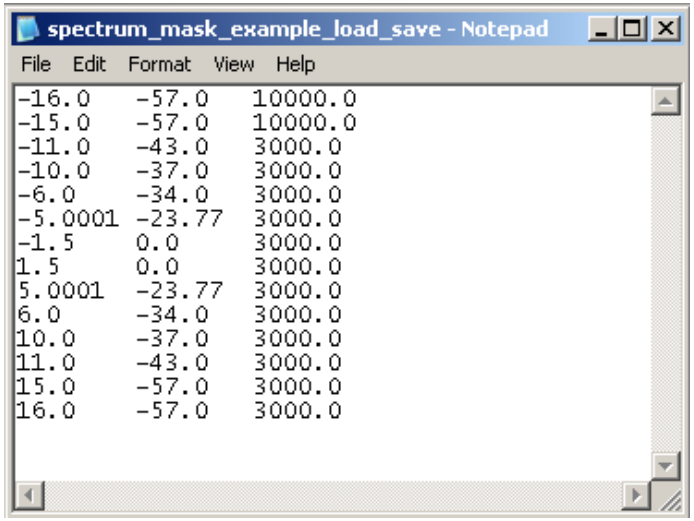


The blue mask is normalised to 1MHz measurement bandwidth.
The user may normalise his input to 1MHz bandwidth but it can be useful to input the mask in the bandwidth defined in the standard and allow SEAMCAT to create normalised mask.

Store your mask on disk

- Spectrum mask can be **save**d as .txt file
- it can be reused for other workspaces using **load** buttons.





- Or use the **import/export** library feature

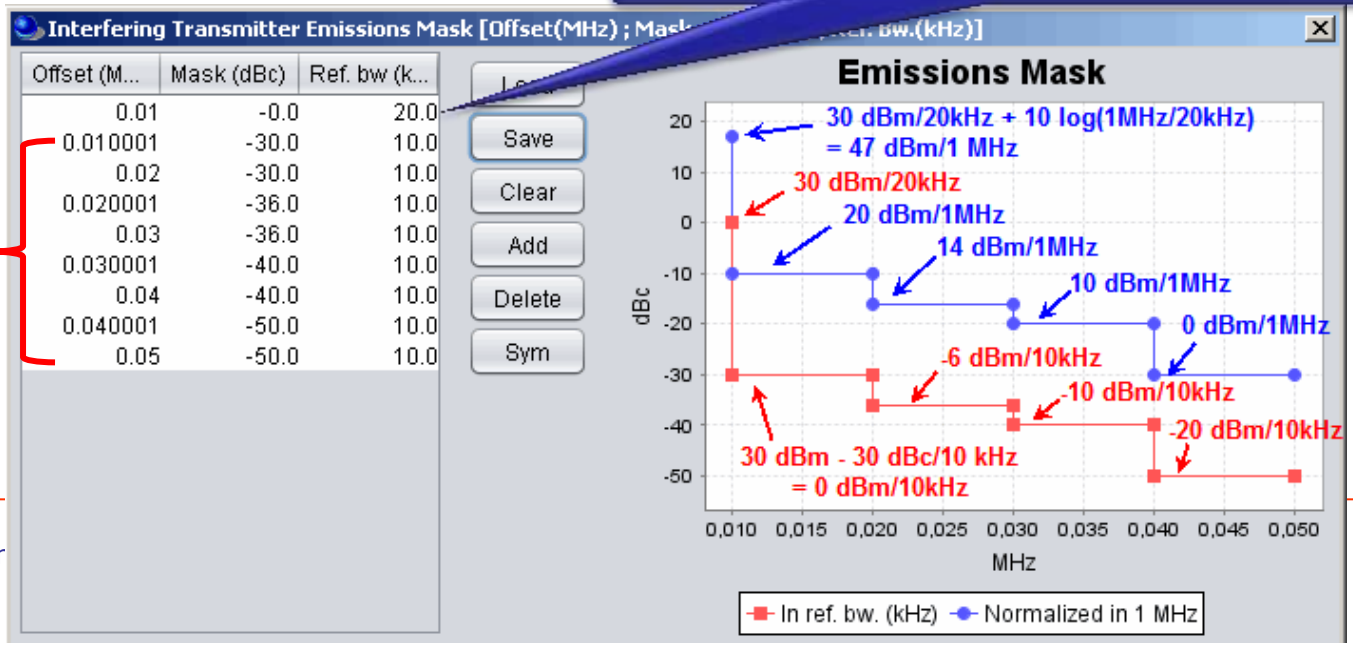
General

Frequency offset	Attenuation in dBc	Attenuation in dBc	Attenuation in dBc in SEAMCAT mask
0 to 10 kHz	0	0 dBc	0 dBc
10 to less than 20 kHz	Min (p(dBW)+30, 36)	30 dBc	-30 dBc
20 to less than 30 kHz	Min (p(dBW) + 40, 36)	36 dBc	-36 dBc
30 to less than 40 kHz	Min (p(dBW) + 45, 40)	40 dBc	-40 dBc
40 to less than 50 kHz	50	50 dBc	-50 dBc

System with 30 dBm in a emission bandwidth of 20 KHz

Emission BW = Ref. BW = 20 KHz

Ref. BW 10 KHz



OFDMA emission mask - UE example

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- SEAMCAT calculates the absolute unwanted power in taking account of the bandwidth of the VLR and the Ref. BW defined with the mask by integrating the relative power and considering then the total transmitted power.

- In case the limits are given as absolute power in dBm (as with this example) the values of the Mask are given by the difference of the limit and the total power,
  e.g. -15 dBm -23 dBm = -38 dBc

Table 6.6.2.1.1-1: General E-UTRA spectrum emission mask

Spectrum emission limit (dBm) / Channel bandwidth							
Δf_{OOB} (MHz)	1.4 MHz	3.0 MHz	5 MHz	10 MHz	15 MHz	20 MHz	Measurement bandwidth
± 0-1	-10	-13	-15	-18	-20	-21	30 kHz
± 1-2.5	-10	-10	-10	-10	-10	-10	1 MHz
± 2.5-2.8	-25	-10	-10	-10	-10	-10	1 MHz
± 2.8-5		-10	-10	-10	-10	-10	1 MHz
± 5-6		-25	-13	-13	-13	-13	1 MHz
± 6-10			-25	-13	-13	-13	1 MHz
± 10-15				-25	-13	-13	1 MHz
± 15-20					-25	-13	1 MHz
± 20-25						-25	1 MHz

total power = 23 dBm

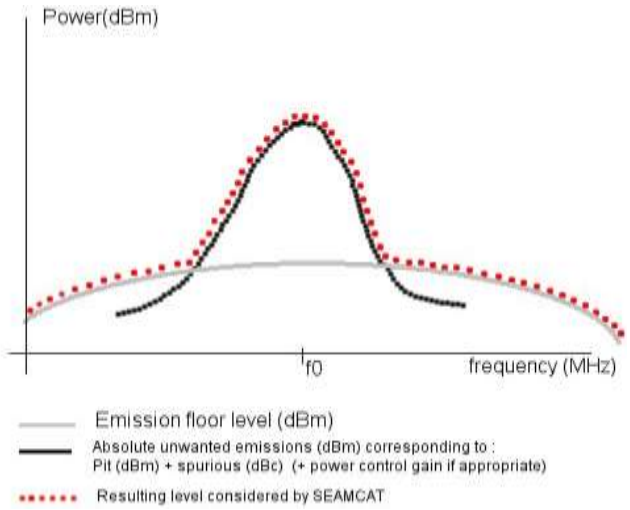
Table 6.6.3.1-2: Spurious emissions limits

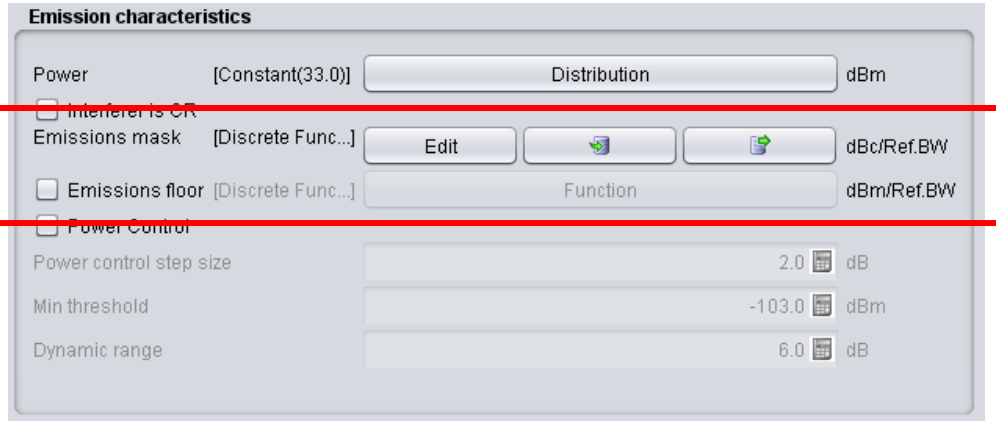
Frequency Range	Maximum Level	Measurement Bandwidth	Notes
9 kHz ≤ f < 150 kHz	-36 dBm	1 kHz	
150 kHz ≤ f < 30 MHz	-36 dBm	10 kHz	
30 MHz ≤ f < 1000 MHz	-36 dBm	100 kHz	
1 GHz ≤ f < 12.75 GHz	-30 dBm	1 MHz	
12.75 GHz ≤ f < 19 GHz	-30 dBm	1 MHz	Note 1
Note 1: Applies for Band 22, Band 42 and Band 43			

Emission Floor

- Useful when power control is used

$$emission_{it} = \max(emission\_rel_{it} + p_{it}^{supplied} + g_{it}^{PC}, emission\_floor_{it})$$





- This emission floor mask (frequency offset (MHz), emission floor (dBm), reference bandwidth (MHz)).

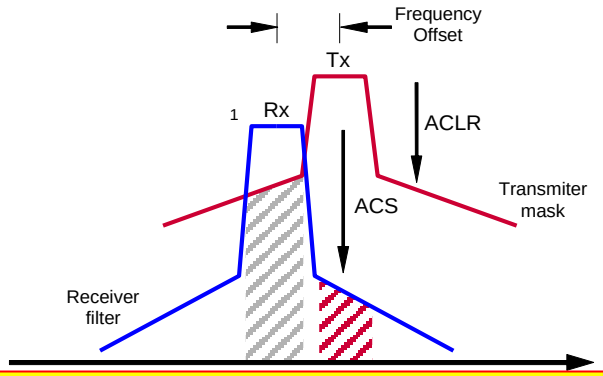
ACIR = f(ACLR, ACS)

- ACIR = adjacent-channel interference ratio

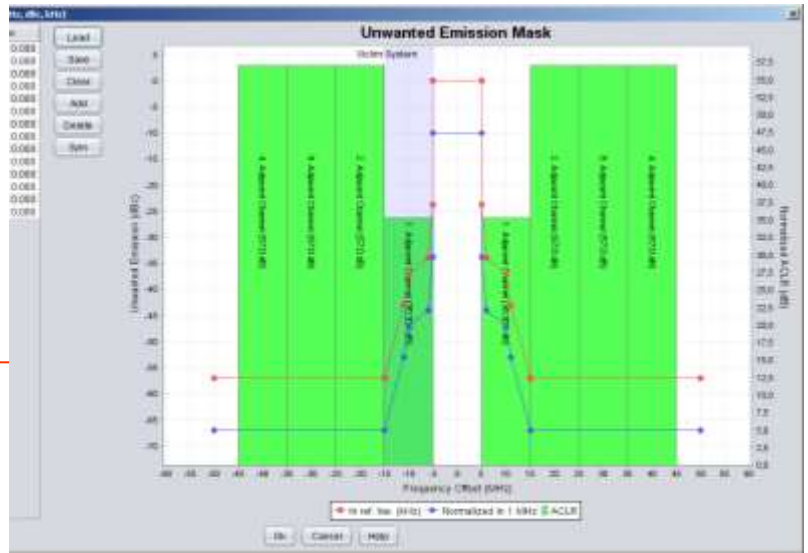
$$ACIR = \frac{1}{\frac{1}{ACLR} + \frac{1}{ACS}}$$

- In UL (reverse link), the dominant part of ACIR is due to the UE **adjacent channel leakage** (ACLR) i.e. ACS_{BS} is very large compare to $ACLR_{UE}$ and ACIR ≈ $ACLR_{UE}$.

- In DL (forward link), the dominant part of ACIR is due to the UE **frequency selectivity** (ACS) i.e. $ACLR_{BS}$ is very large compare to ACS_{UE} and ACIR ≈ ACS_{UE}

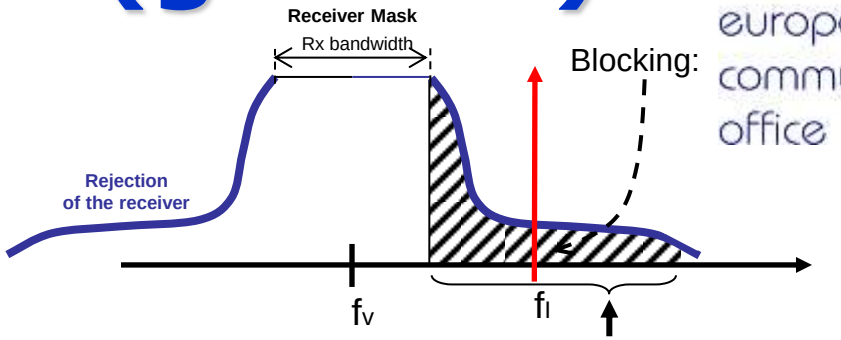


No use of the ACLR value directly. Emission spectrum Mask is used

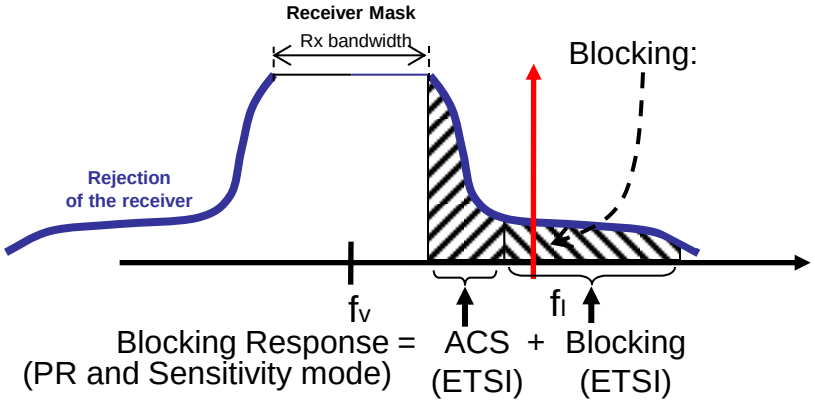


Blocking Mask (generic)

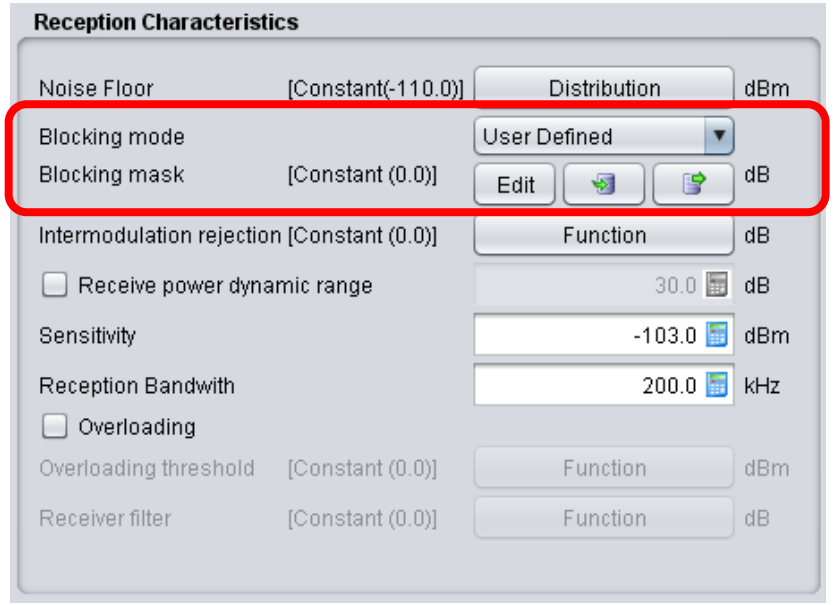
- User-defined mode
- Protection ratio
- Sensitivity modes



Blocking Response = filtering (user defined mode)



Blocking Response = ACS + Blocking
(PR and Sensitivity mode) (ETSI) (ETSI)



CDMA and OFDMA ACS

- ACS (Adjacent channel selectivity) is the same as the blocking attenuation input

OFDMA BS blocking Mask example

- Extract from CEPT Report 40 (ITU-R Report M2039)

6.1 BS Receiver rejection derived from narrow band blocking

The BS receiver rejections at 300 kHz frequency offset from channel edge derived from the narrow for UMTS, LTE, and WiMAX are given in Table 7.

BS	Frequency offset (kHz)	ACS test	Rejection (dB)	I
UTRA-FDD (5MHz)	300	-47 dBm	51.4	GSM
LTE(1.4 MHz)	252.5	-49 dBm	54.9	LTE 1 RB
LTE(3 MHz)	247.5	-49 dBm	50.9	LTE 1 RB
LTE(5 MHz)	342.5	-49 dBm	48.7	LTE 1 RB
LTE(10 MHz)	347.5	-49 dBm	48.7	LTE 1 RB
LTE(15 MHz)	362.5	-49 dBm	48.7	LTE 1 RB
LTE(20 MHz)	342.5	-49 dBm	48.7	LTE 1 RB
WiMAX (5 MHz)	300	-53 dBm	44.4	GSM
WiMAX (10 MHz)	300	-50 dBm	44.4	GSM

Table 7: BS receiver rejection at 300 kHz frequency offset derived from narrow band blocking

Note 1: the values of BS receiver rejection are calculated on the basis of the following formula:

$$ACS\_relative = ACS\_test - Noise\_floor - 10*\log_{10}(10^{M/10}-1)$$

where:

M is the desensitisation defined in the narrow band blocking test (6 dB is taken), the noise floor is calculated with bandwidths given in section 3 and 4 for LTE and WiMAX.

Table 7.5.1-1: Narrowband blocking requirement

	Wanted signal mean power [dBm]	Interfering signal mean power [dBm]	Type of interfering signal
Wide Area BS	$P_{REFSENS}$ + 6dB*	-49	See Table 7.5.1-2
Local Area BS	$P_{REFSENS}$ + 6dB**	-41	See Table 7.5.1-2
Home BS	$P_{REFSENS}$ + 14dB***	-33	See Table 7.5.1-2

Note*: $P_{REFSENS}$ depends on the channel bandwidth as specified in Table 7.2.1-1.
Note**: $P_{REFSENS}$ depends on the channel bandwidth as specified in Table 7.2.1-2
Note***: $P_{REFSENS}$ depends on the channel bandwidth as specified in Table 7.2.1-3.

3GPP TS 36.104 V11.2.0 (2012-09)

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Thank you - Any Questions?

Overview of Systems in SEAMCAT

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ISART – May 12, 2015

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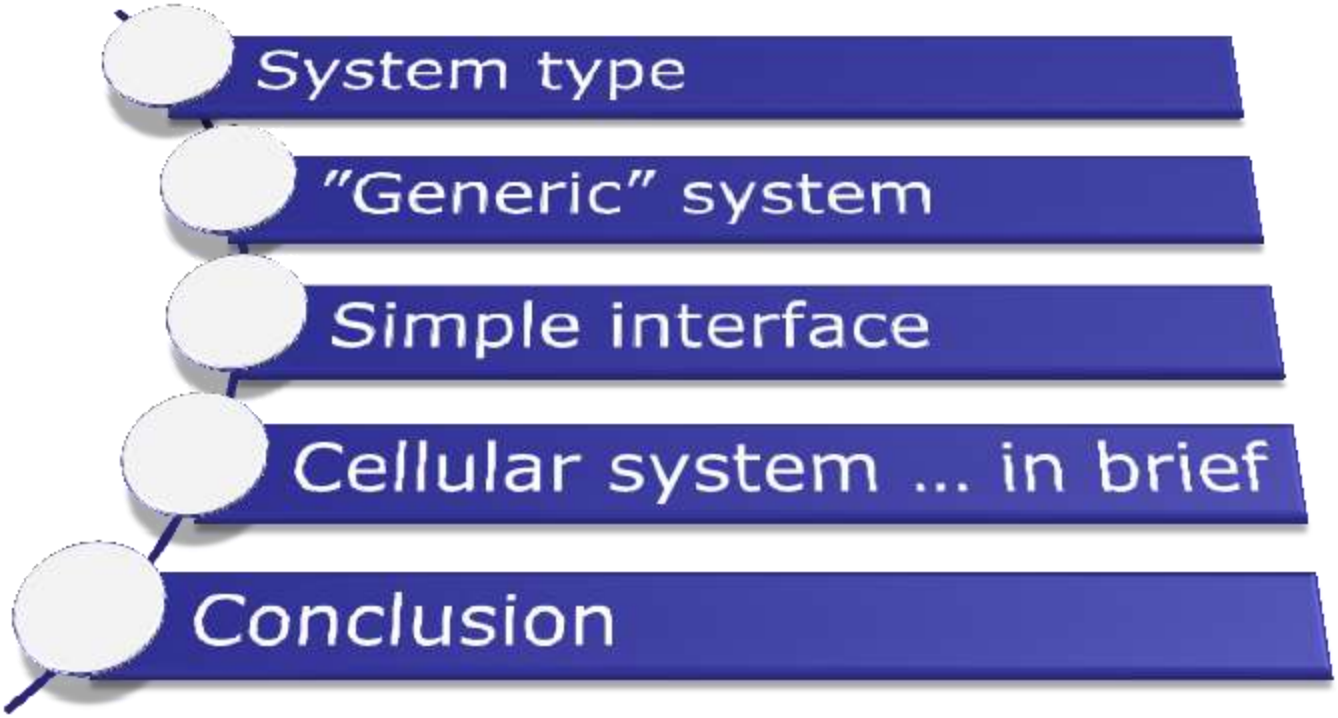
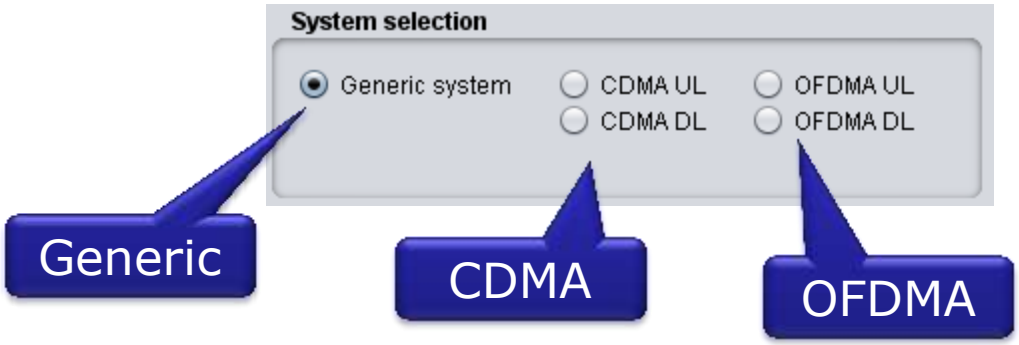
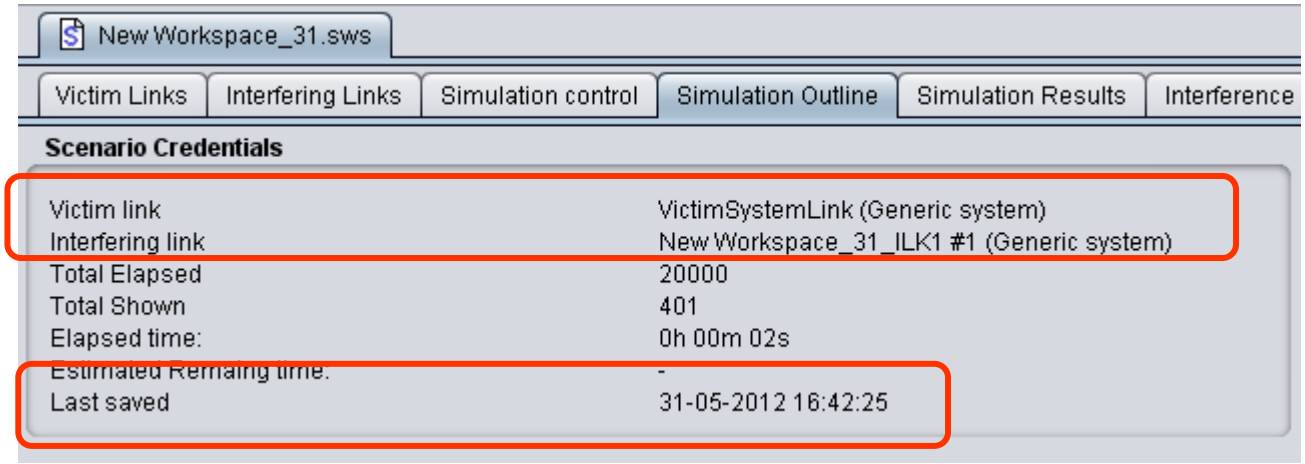
Outline

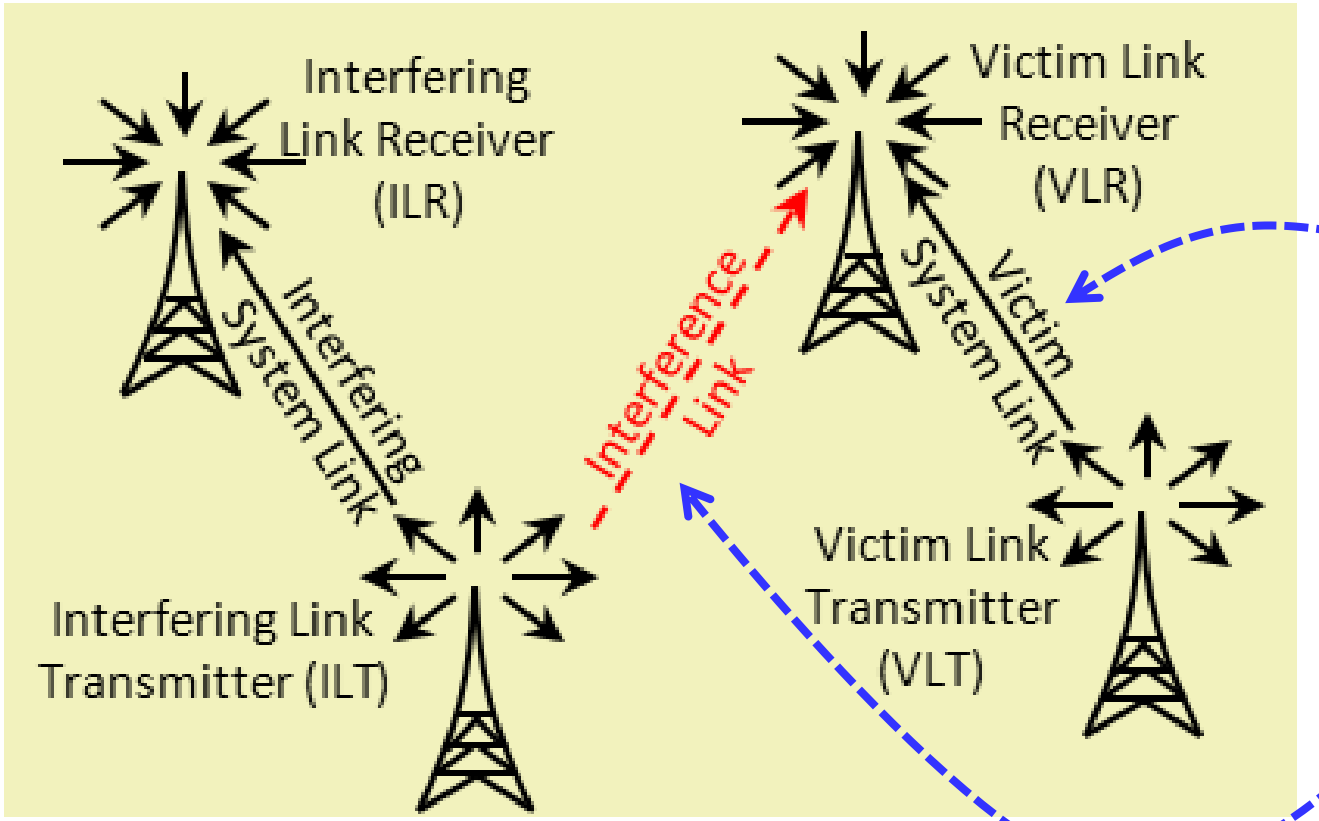

System type
"Generic" system
Simple interface
Cellular system ... in brief
Conclusion

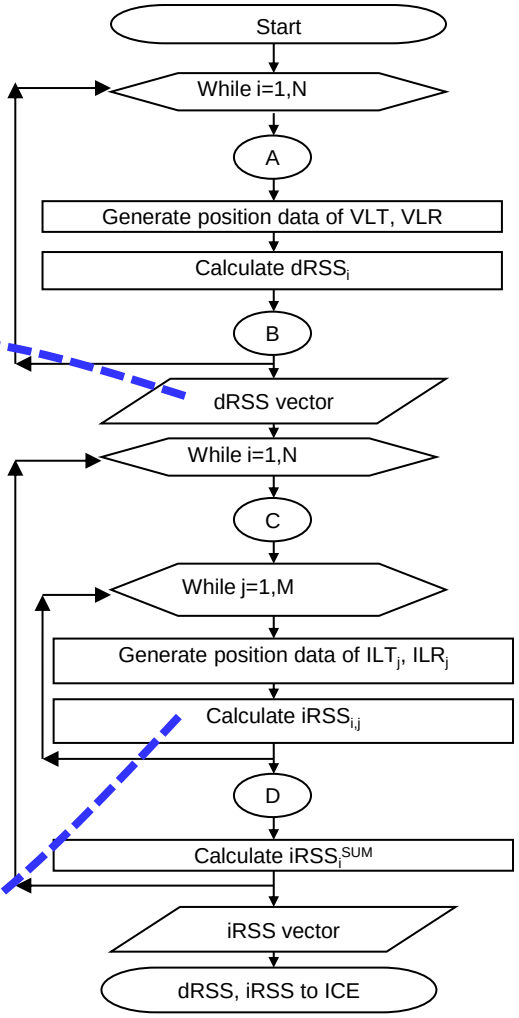
System type


System selection
Generic system
CDMA UL
CDMA DL
OFDMA UL
OFDMA DL
Generic
CDMA
OFDMA


New Workspace_31.sws
Victim Links
Interfering Links
Simulation control
Simulation Outline
Simulation Results
Interference
Scenario Credentials
Victim link
VictimSystemLink (Generic system)
Interfering link
New Workspace_31_ILK1 #1 (Generic system)
Total Elapsed
20000
Total Shown
401
Elapsed time:
0h 00m 02s
Last saved
31-05-2012 16:42:25

Generic system





Simple and harmonised interface

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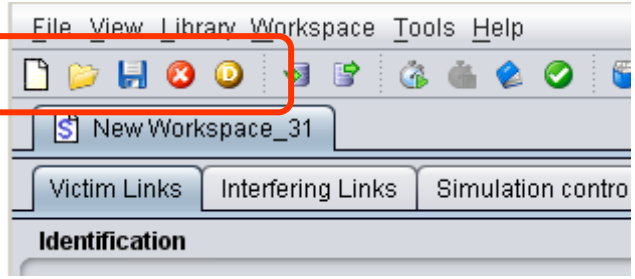
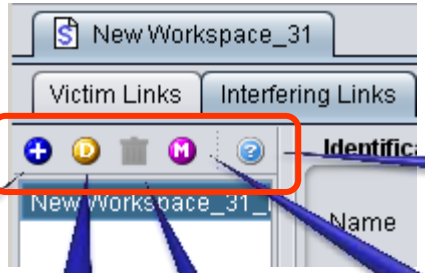
Workspaces



Interfering links



On-line Help

Add

Duplicate

Delete

Multiple interferer generation

Cellular modelling

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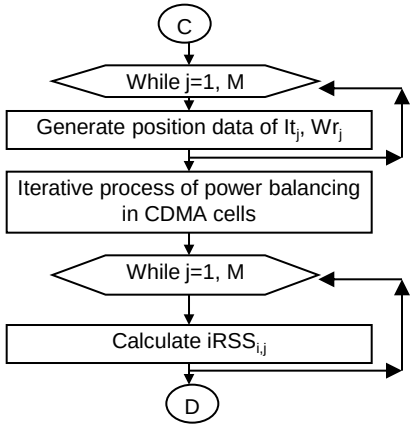
- Modelling of cellular systems as victim, interferer, or both:
  - Quasi-static time within a snapshot
  - One direction at a time (uplink or downlink)
- CDMA
  - Voice traffic only
  - Particular CDMA standard defined by setting Link Level Data (CDMA2000-1X, W-CDMA/UMTS)
- OFDMA
  - LTE

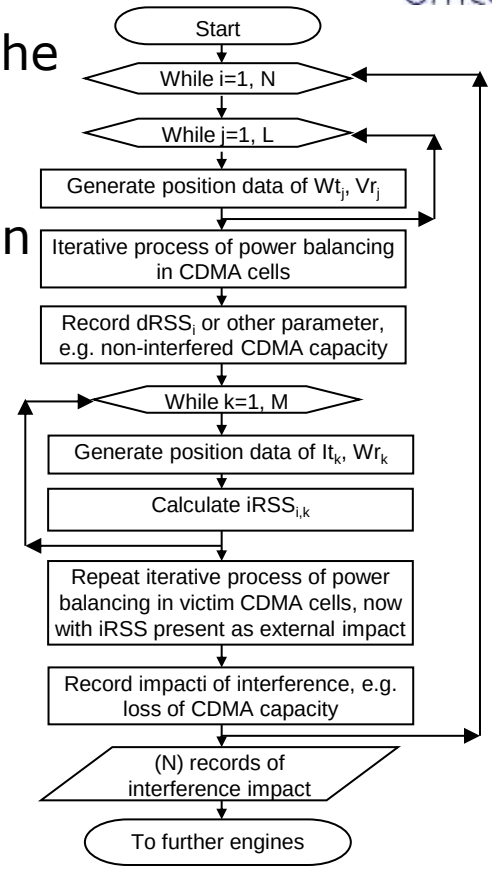
CDMA system modelling

- First a succession of snapshots are run without interference, gradually loading the system to find the target non-interfered capacity per cell
- apply interference and note the impact in terms of how many of initial users were disconnected

CDMA as interferer



CDMA as victim



CDMA vs OFDMA simulation

- OFDMA systems similar to CDMA systems
- Except: After the overall two-tiers cellular system structure (incl. wrap-around) is built and populated with mobiles

CDMA

- CDMA performs a power tuning process when surrounded by two tiers of auxiliary cells, and total cluster of 19.

OFDMA

- OFDMA performs an iterative process of assigning a variable number of traffic sub-carriers and calculating the overall carried traffic per base station.

Conclusions

- Harmonised interface between generic and CDMA/OFDMA modules
- Versatile tool to configure victim and interferer

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Thank you - Any questions?

Propagation model: Built-in and plug-in

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Outline

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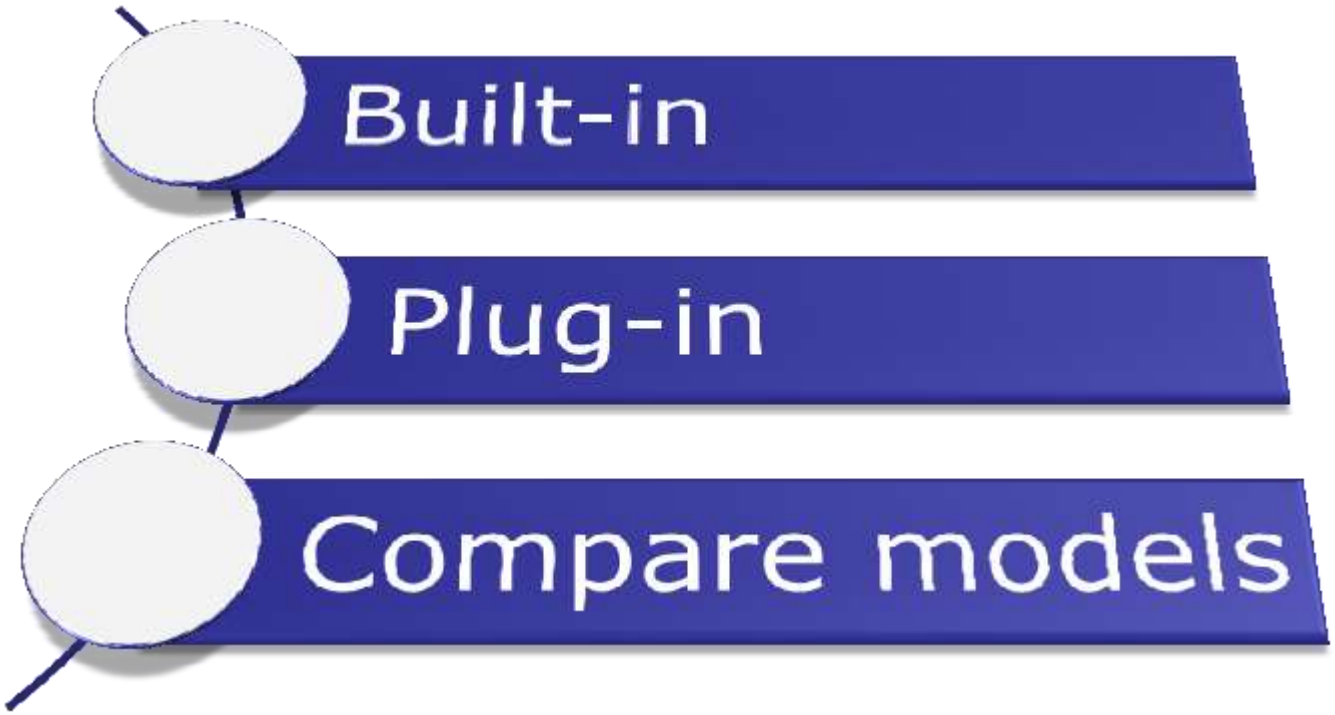

Built-in model

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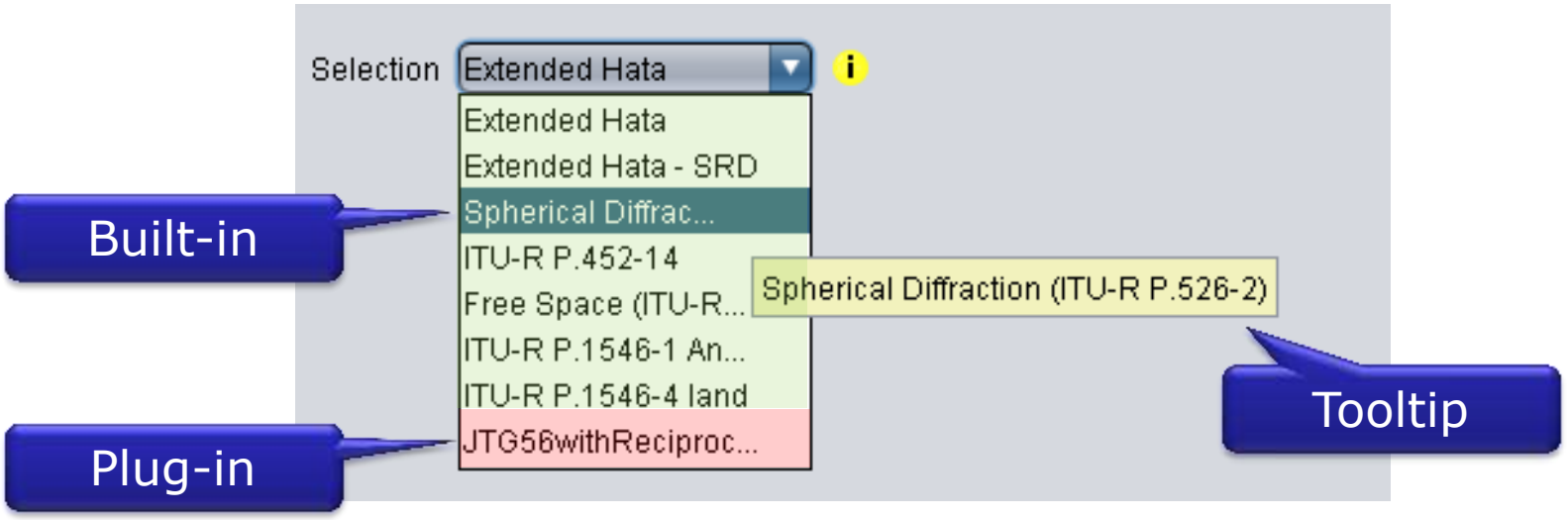
- 6 models + plug-in

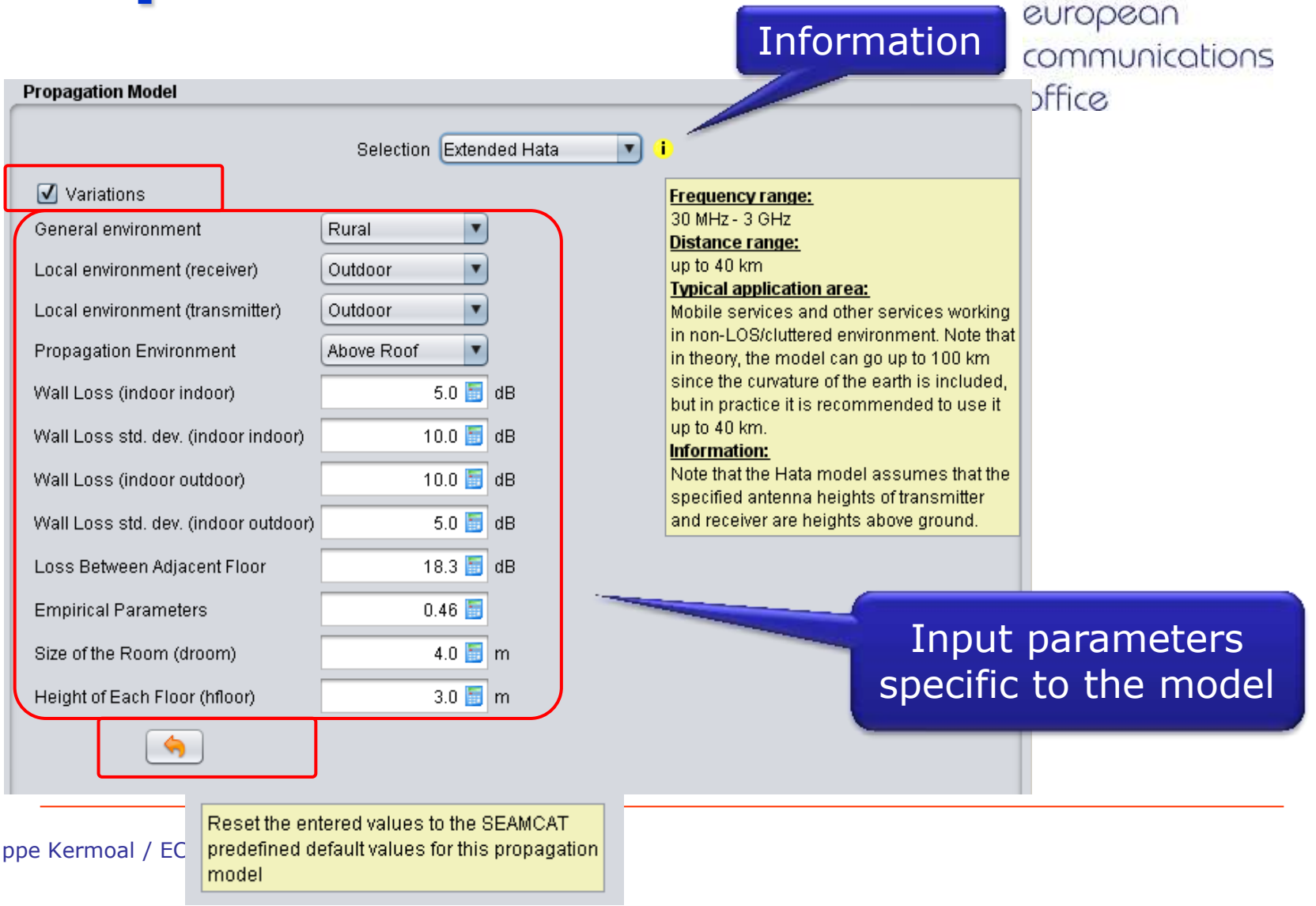
Model	Frequency Range	Distance Range	Typical Application Area
ITU-R P.1546 model	30 MHz - 3 GHz	1-1000 km	Broadcasting and other terrestrial services, typically considered in cases with high mounted transmitter anttena (e.g. above 50-60 m)
Extended Hata model	30 MHz - 3 GHz	Up to 40 km	Mobile services and other services working in non-LOS/cluttered environment . Note that in theory, the model can go up to 100 km since the curvature of the earth is included, but in practice it is recommended to use it up to 40 km.
Extended Hata-SRD model	30 MHz - 3 GHz	Up to 300 m	Short range links under direct-LOS assumption, **important: antenna heights up to 3 m**
Spherical diffraction (ITU-R P.452) model	Above 3 GHz	Up to and beyond radio horizon	Interference on terrestrial paths in predominantly open (e.g. rural) areas
Free space loss model	Above 30 MHz	LOS-limited	Fixed links and other systems/paths were direct-LOS could be assumed
ITU-R P.452-14 model	about 0.7 GHz to 50 GHz	up to a distance limit of 10 000 km	Prediction method for the evaluation of interference between stations on the surface of the Earth at frequencies above about 0.1 GHz, accounting for both clear-air and hydrometeor scattering interference mechanisms.
User-defined model (Propagation plug-in)	model specific	model specific	model specific

List selection



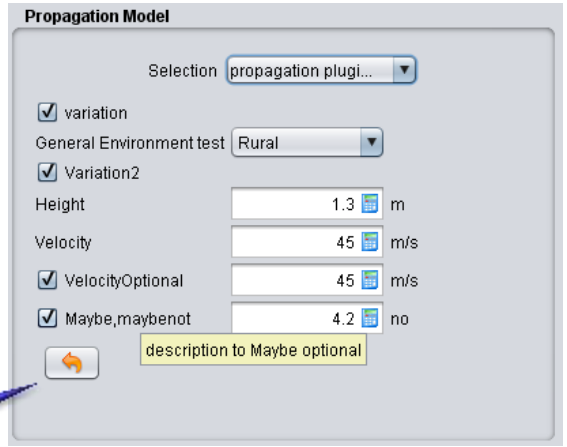
Any propagation model plug-in is automaticaly integrated in the list of models available for your simulation

Example: Extended Hata



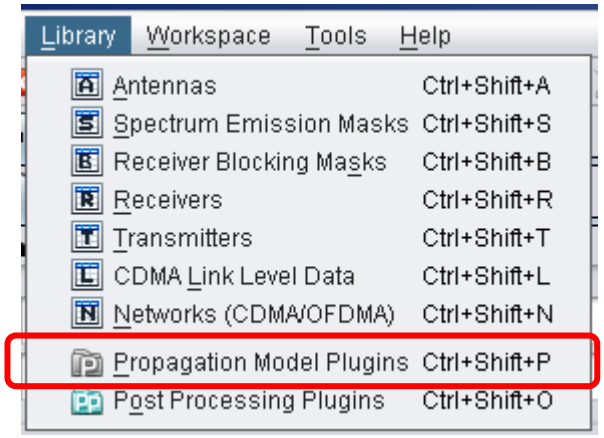
Propagation model plug-in

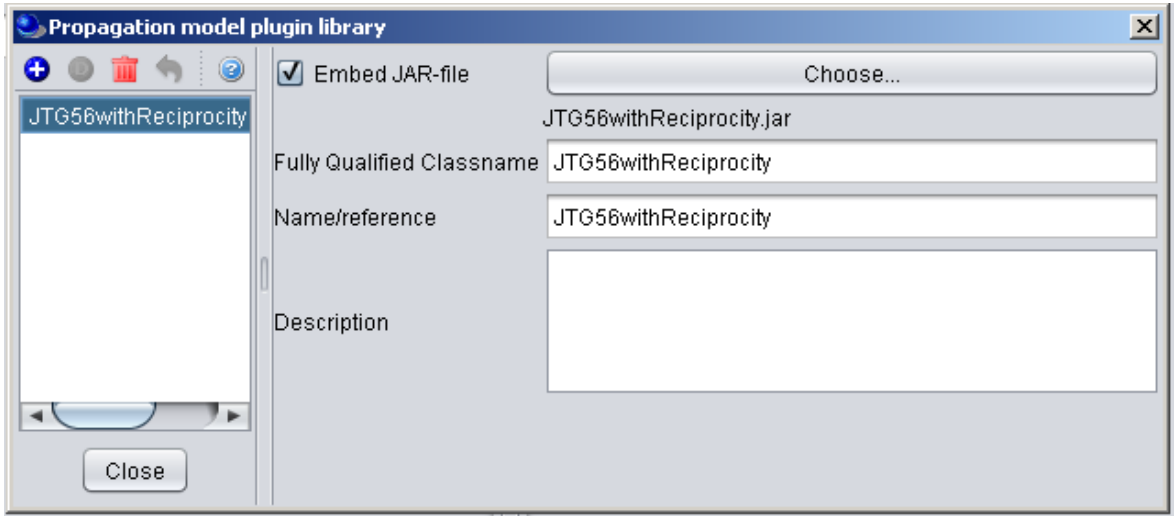
- This plug-in may be used to define **ANY** kind of propagation model
  - No complexity limit:
    double, dropdown, boolean
  - No limit to the inputs:
    unlimited number
  - Description of inputs:
    tooltip



- Can be used for any paths of your scenario

Plug-in





- 2 choices
  - .class file
  - .jar file (recommended) to allow embedement of the plugin in the workspace to allow easier dissemination of your workspace

Test or Compare

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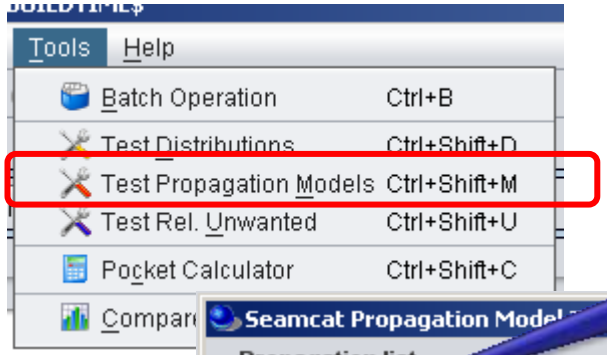
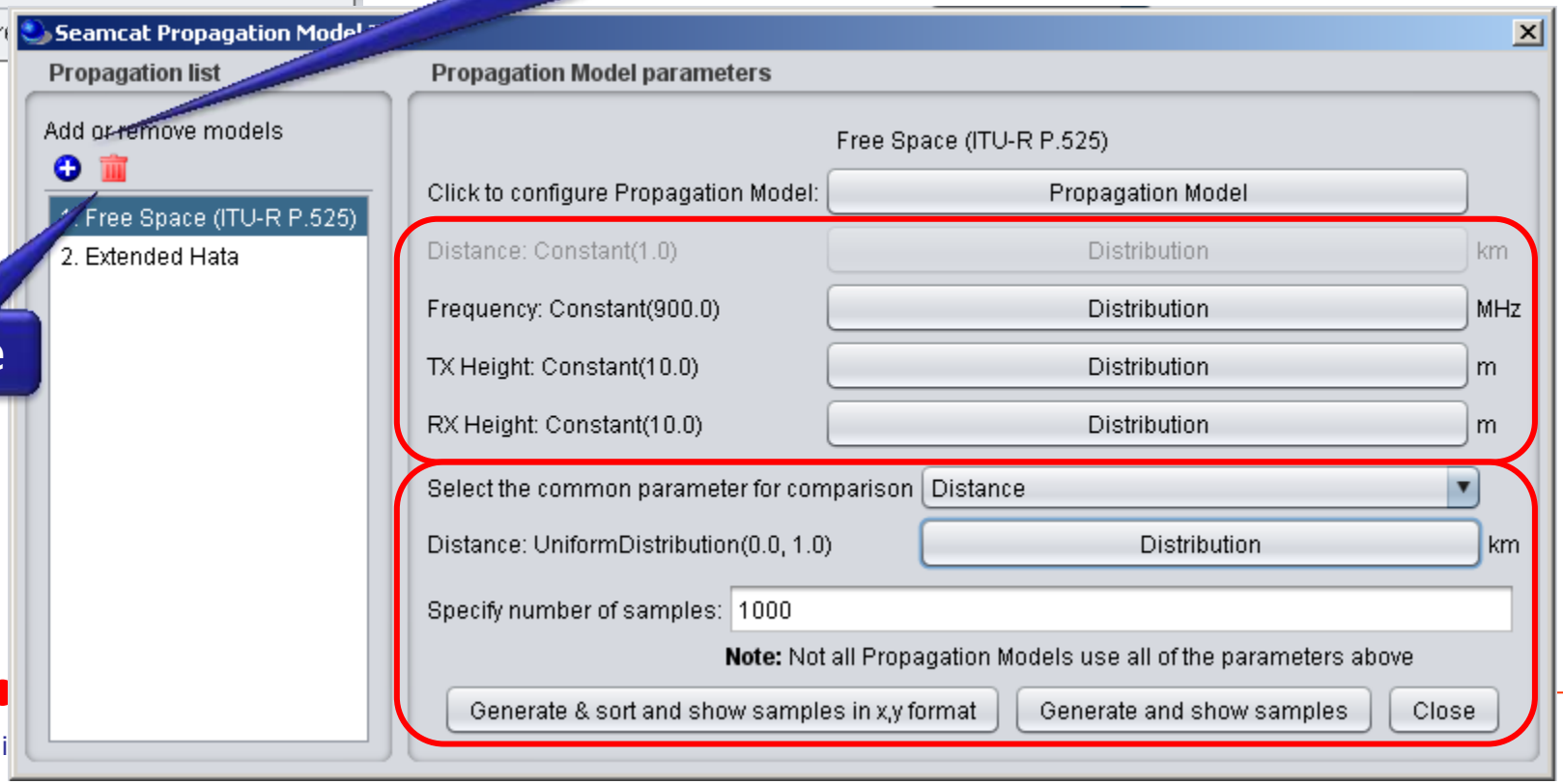


You can add any built-in OR plug-in model

Remove



Example #10: Free Space

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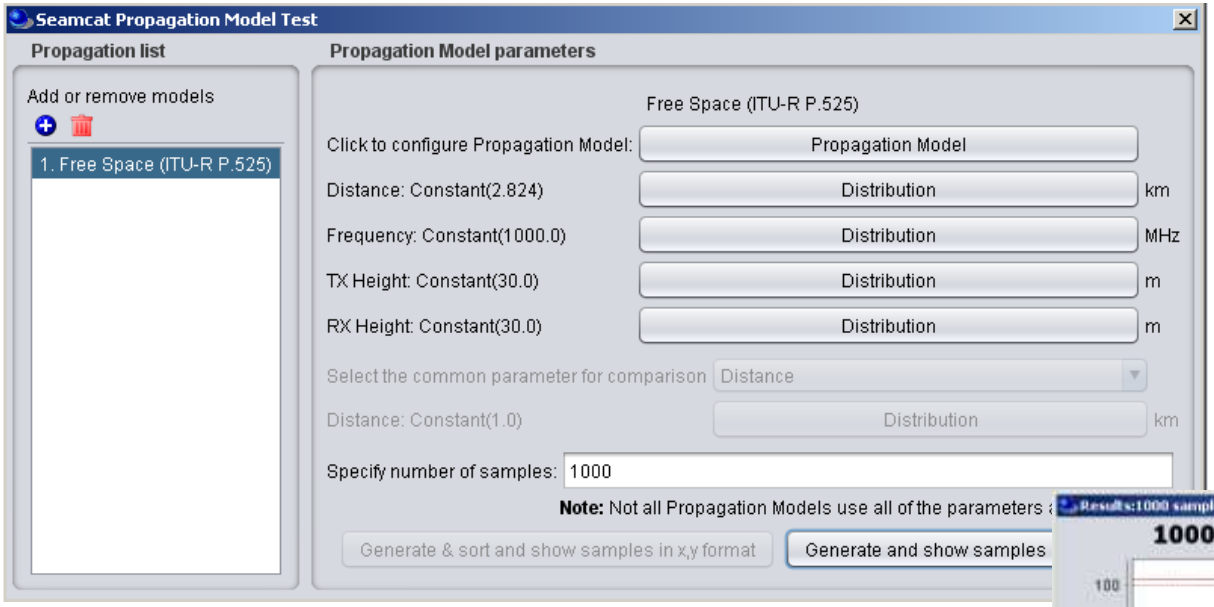

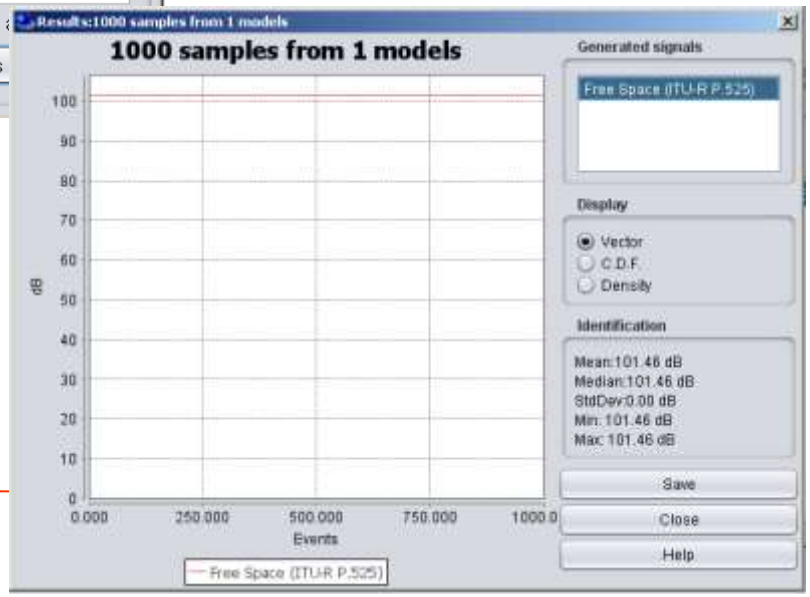

$$L=32.5+10\log\left(\left(\frac{(h_{tx}-h_{rx})}{1000}\right)^2+d^2\right)+20\log f$$

- L = 32.5+10log(8)+20log(1000))
- L = 101.5 dB

Compare models

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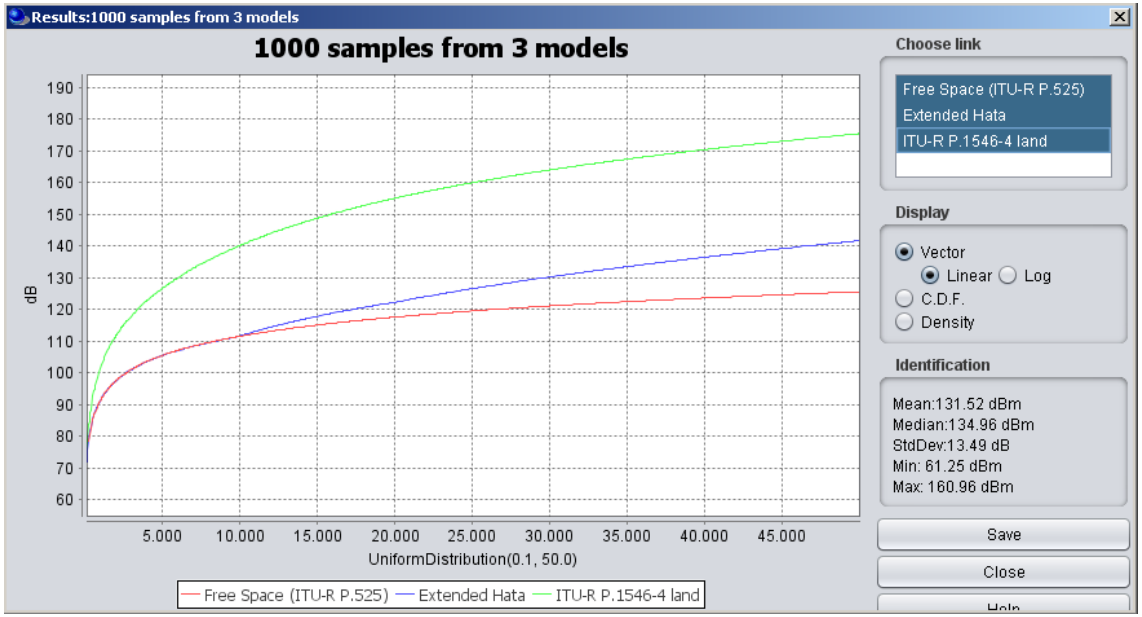
- Select 3 propagation models
  - Free space
  - Extended hata
  - ITU-R P.1546-4



- Assumptions
  - no variations
  - Tx: 30 m, Rx: 10 m
  - Distance from 100m to 50 km

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Thank you - Any Questions?

SEAMCAT Version 5.0.0

European Communications Office
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ISART – May 12, 2015

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Version 5.0.0

- The official version is 4.0.1
- New version 5.0.0 expected to be available in September 2015
- Currently in alpha testing phase

What's new in 5.0.0

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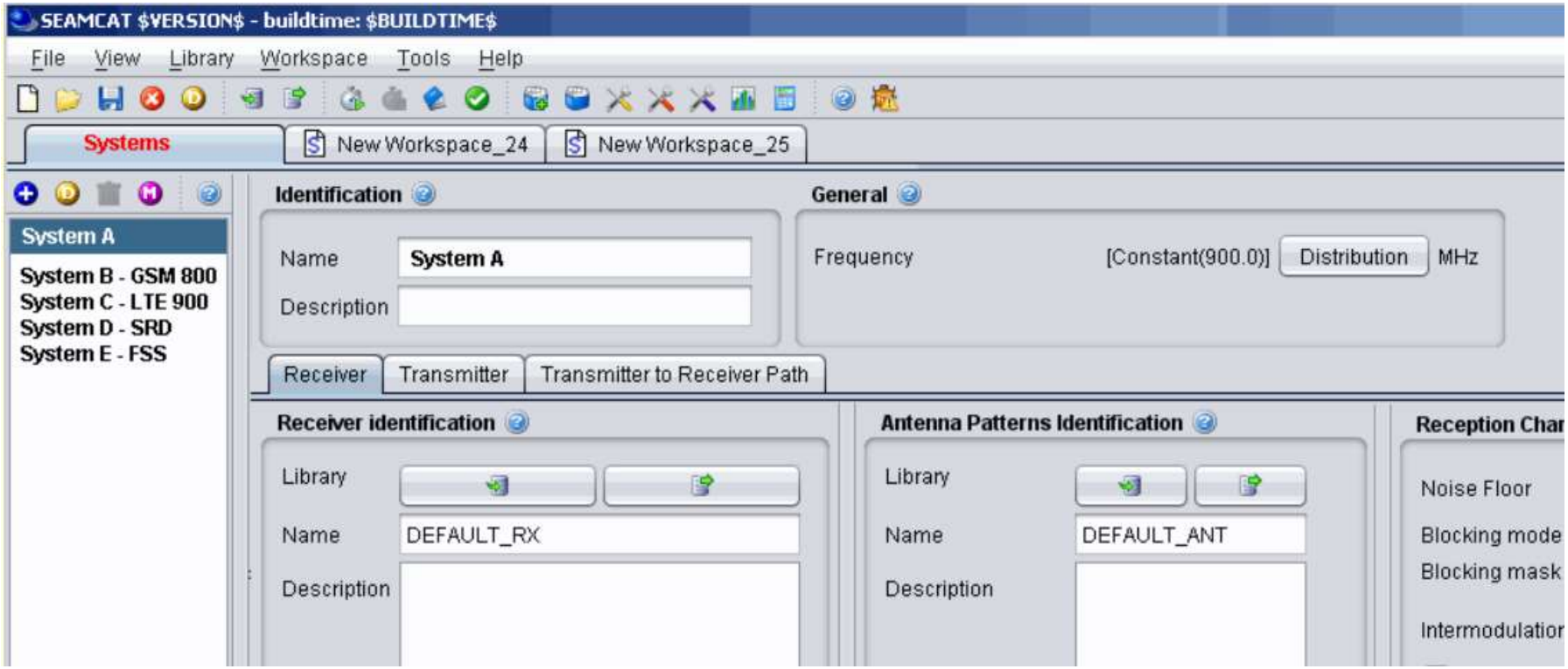
- Calculation unchanged (except bug fix)
- New .jar distribution
- System approach GUI
- Advanced plugins for antenna
- Introduction of EPP – Event Processing Plugins
- Parallel processing on multi-core machine

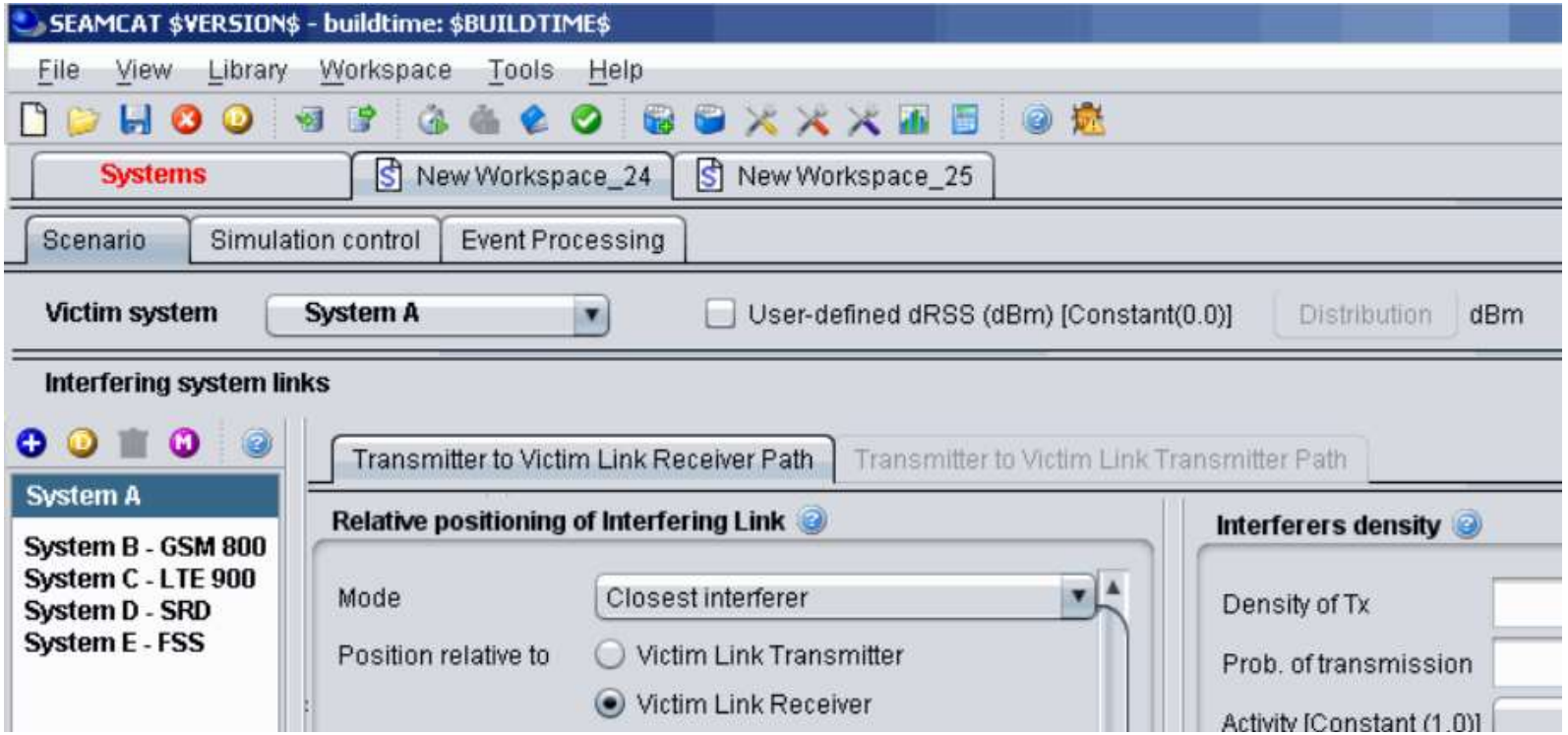
System approach GUI (1)

- New interface from a system perspective
- Systems defined by their Rx, Tx and Tx-Rx path or cellular settings.



System approach GUI (2)

- The user will select whatever system for the victim and the interfering links.



Antenna plugins

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- Antenna will be implemented in plugin
- Allow to introduce frequency etc.. into the antenna pattern computation
- Allows any implementation of ITU.R recommendation (e.g. ITU-R Rec. F.1336, ITU-R Rec. F.699 and ITU-R Rec. F. 1245 etc...)

Event Processing Plugins

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- Black box disappear
- EPPs can extract intermediary results
- EPPs can further extend algorithm
- easy EPP plugins integration to the workspace

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Thank you - Any questions?

US questions related to SEAMCAT

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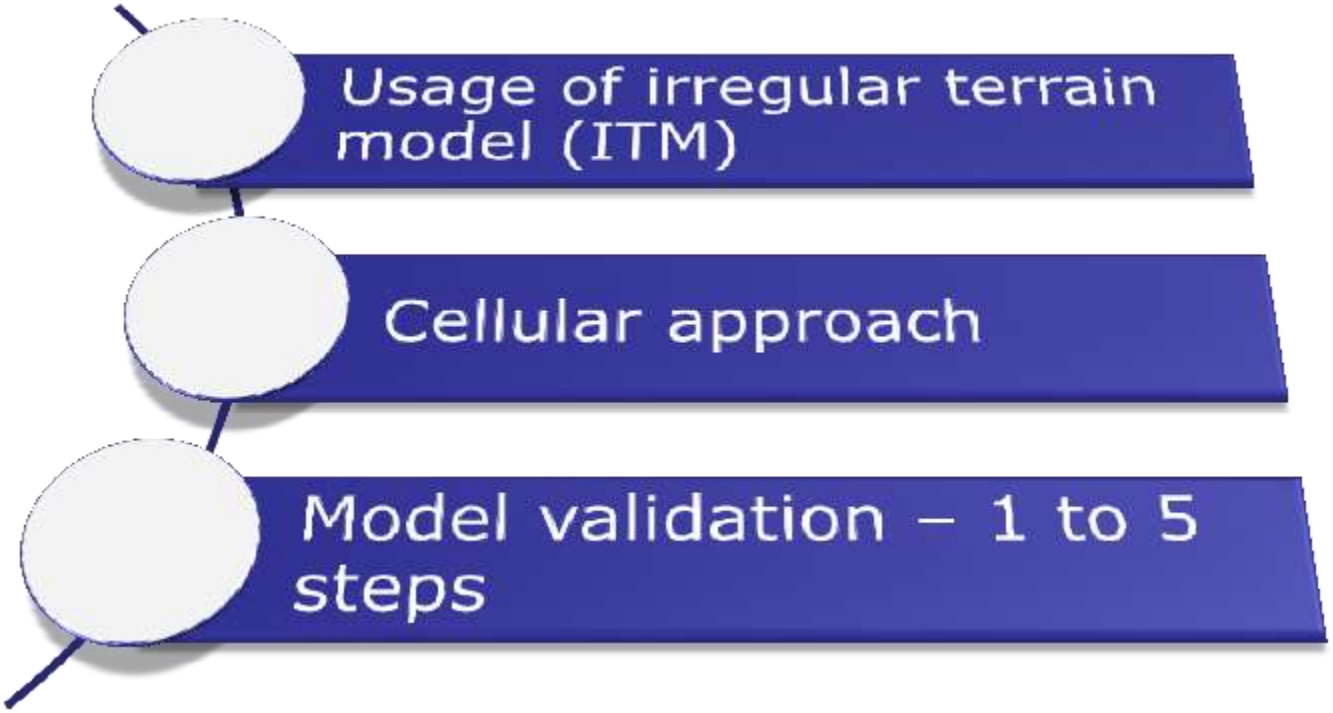
Outline


Usage of irregular terrain model (ITM)
Cellular approach
Model validation – 1 to 5 steps

Usage of irregular terrain model (ITM)

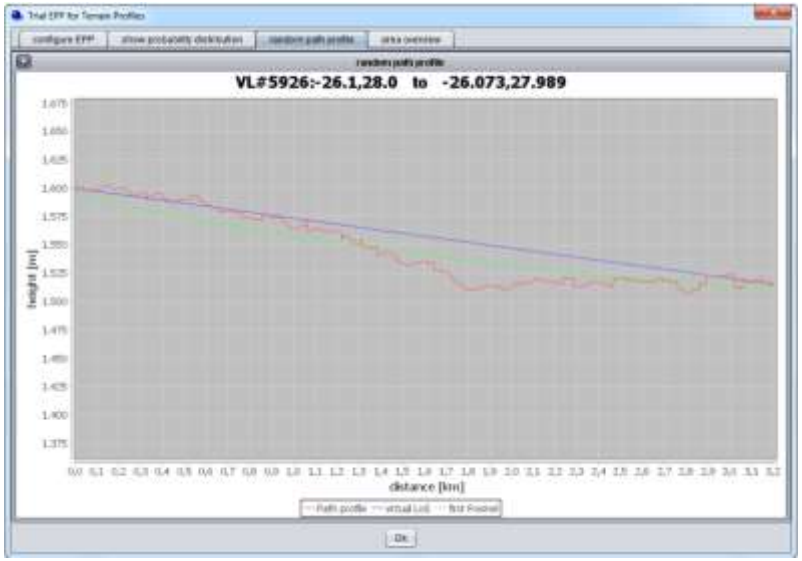
- Need to understand the European regulatory approach (Ex-Ante vs Ex-post)
  - Ex-Ante, European regulation (ECC) is based on compatibility studies that defines technical conditions
  - Later, comes the Harmonised Standard (ETSI) which establish the conformity requirement based on the ECPT work for the introduction of the equipment on the European Market (EU)
  - Ex-post is more of a national matter to ensure that there is no interference -> monitoring/market surveillance.

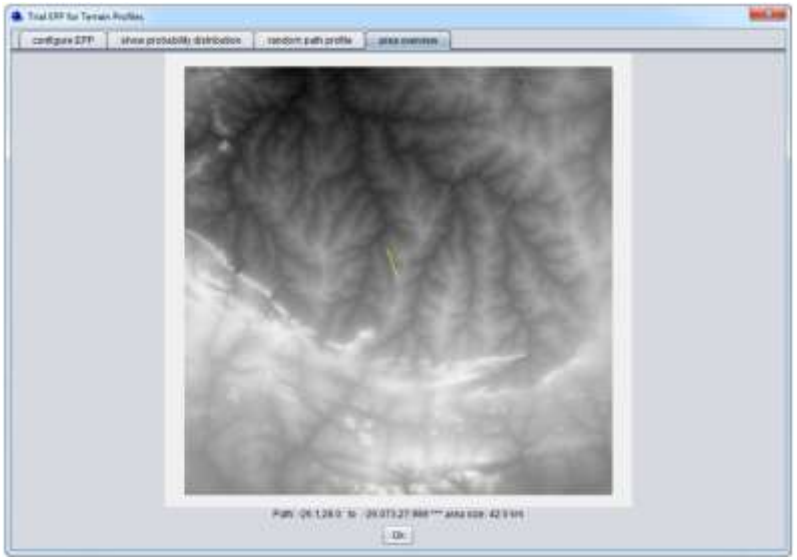
Therefore from an Ex-Ante perspective, the CEPT is more interested in generic study and the usage of terrain model for monte carlo simulation is questionable.

What about SEAMCAT?

- Studies in SEAMCAT are generic
- Assume flat terrain surface in version 4.1.0
- This is not a planning or a coordination tool

- Next generation of SEAMCAT (version 5.0.0)
  - Introduction of the Event Processing Plugin (EPP)
  - Allows terrain mapping
  - This is at the user responsibility to generate results





(source: STG(14)44 terrain profile draft)

Cellular approach

- LTE power control based on the 3GPP TR36.942
- Very generic model – result of a compromise at 3GPP when establishing LTE simulation between industry players
- Reality is particular to vendors product
- See presentation on the CDMA/OFDMA overview for details

Model validation
1 to 5 steps

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1. Is my model close to reality?
   - Propagation model

   Most of CEPT studies are based on model from the ITU-R P. Recommendation. So the ”validity” has been discussed at the ITU by propagation experts.

   Occasionaly other models are considered, then it is during the Project Team activity that agreement are reached to use one model or another. Project Team members consist of ALL stackeholders (Administrations, Industry) to ensure a balance in all the views.

   - LTE algorithm

   The 3GPP TR36.942 was generated with all the major mobile vendors and operators involved. They compared there various simulators and after convergence in their results provided some benchmarking results that was used to tune SEAMCAT.

Model validation 1 to 5 steps

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2. Is the implementation of model according to the specification?
   - Extensive testing based on specification received
   - Extensive usage in CEPT (easier to detect bugs)
3. How do we ensure that SEAMCAT ver(n+1) is in line with previous SEAMCAT ver(n)?
   - ~100.000 Lines of code
   - Automated benchmarking system has been established based on Junit test. (fixing seeds ☺)
   - Propagation models have specific test module
   - Before any release an integration test is perfomed on more than 450 different workspaces
4. Open community – we promote feedback from users
5. Version 5.0.0 giving access to intermediary results

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Thank you - Any questions?