Advanced statistical techniques for spectrum engineering analysis

SEAMCAT: a European experience

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ISART – May 12, 2015
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Agenda

- Introduction to SEAMCAT
- Principle of Monte Carlo
- SEAMCAT at a glance
- Modelling Unwanted and Blocking interference
- Setting Emission and Blocking mask
- Overview of System Creation
- Overview of CDMA/OFDMA
Advanced Statistical Techniques for Spectrum Engineering Analysis

A SEAMCAT view

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Outline
Introduction to SEAMCAT

Spectrum Engineering

SEAMCAT

Conclusions
Spectrum engineering challenges

Increasing penetration of the existing radio applications

Introduction of new radio applications

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

Regulatory

Technological

Economic considerations

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Spectrum engineering challenges

Increasing penetration of the existing radio applications

Introduction of new radio applications

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

Regulatory

Technological

Economic considerations
Need for spectrum sharing

• 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”
Need for spectrum sharing

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- 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”
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
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

• 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

- **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)

- As an agreed work platform within 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 worldwide

Source: google analytics on the [www.seamcat.org](http://www.seamcat.org) download page in 2014. 2014 survey: about 800 people downloaded SEAMCAT.
Installing SEAMCAT
(administrative right needed)

**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)

- 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
Thank you - Any questions?
Principle of Monte-Carlo in a SEAMCAT environment

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Outline

- Sharing/Compatibility studies
- MCL vs Monte-carlo approach
- Event generation
- Conclusion
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

<table>
<thead>
<tr>
<th>Region 1</th>
<th>Region 2</th>
<th>Region 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 675-1 690</td>
<td>METEOROLOGICAL AIDS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FIXED</td>
<td></td>
</tr>
<tr>
<td></td>
<td>METEOROLOGICAL-SATELLITE (space-to-Earth)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MOBILE except aeronautical mobile</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5.341</td>
<td></td>
</tr>
<tr>
<td>1 690-1 700</td>
<td>METEOROLOGICAL AIDS</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Fixed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mobile except aeronautical mobile</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5.289 5.341 5.382</td>
<td></td>
</tr>
<tr>
<td>1 700-1 710</td>
<td>FIXED</td>
<td></td>
</tr>
<tr>
<td></td>
<td>METEOROLOGICAL-SATELLITE (space-to-Earth)</td>
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<td></td>
<td>MOBILE except aeronautical mobile</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5.289 5.341</td>
<td></td>
</tr>
</tbody>
</table>
Interference criteria

• 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**: Boltzmann 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

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

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

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

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

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

- Example: I/N = -6 dB

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

- But also, capacity loss or bit rate loss
The MCL approach

- The stationary worst-case is assumed

D_{\text{min}}, or minimum frequency separation for D=0

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

- Random generation of transceivers
- Link budget
- Signal values

- **Only 1 victim link**

- **MANY** interfering links
  ... or interfering systems

example for one event
... after 1000 Events

Positioning of transceivers for 1000 events
How event generation works*

- Succession of snapshots...

1) Calculate $d$, $P_{tx}$, $G_{Tx}$, $G_{Rx}$, $L$
2) Calculate $d_{RSS}$

(*) Except CDMA/OFDMA systems
Results of event generation

- Vectors for useful and interfering signals:
  - dRSS
  - iRSS
Evaluating probability of interference

- For each random event where $dRSS > \text{sensitivity}$:

\[\text{Desired signal value (dBm)} \quad \text{Interfering signal (dBm)} \quad \frac{C/I_{\text{trial}}}{C/I_{\text{target}}} > ? \quad \text{Interference (dB)} \quad \text{Noise Floor (dBm)}\]

- If $C/I_{\text{trial}} > C/I_{\text{target}}$: “good” event
- If $C/I_{\text{trial}} < C/I_{\text{target}}$: “interfered”

- Finally, after cycle of $N_{\text{all}}$ events:
  Overall $P_{\text{interference}} = 1 - \left(\frac{N_{\text{good}}}{N_{\text{all}}} \right)^{dRSS > \text{sens}}$
Event generation
Cellular system module

- 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

<table>
<thead>
<tr>
<th>Victim system</th>
<th>Interference criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classical (generic module i.e. non CDMA/OFDMA module)</td>
<td>Probability of interference based on $C/I$, $C/(I+N)$, $(N+I)/N$, $I/N$</td>
</tr>
<tr>
<td>CDMA</td>
<td>Capacity loss: number of voice users being dropped</td>
</tr>
<tr>
<td>OFDMA</td>
<td>Bitrate loss: number of bit rate lossed compared to a non interfered victim network</td>
</tr>
</tbody>
</table>
Extra - Reminder

- \( \log_{10}(1) = 0 \)
  \( 10 \log_{10}(1) = 0 \)
- \( \log_{10}(2) = 0.3 \)
  \( 10 \log_{10}(2) = 3 \)
- \( \log_{10}(10) = 1 \)
  \( 10 \log_{10}(10) = 10 \)
- \( \log_{10}(100) = \log(10^2) = 2 \log_{10}(10) = 2 \)
  \( 10 \log_{10}(100) = 20 \)
- \( 10 \log_{10}(25) = 10 \log_{10}(100/4) = 10 \log_{10}(100) - 10 \log(4) \)
  = \( 10 \log_{10}(10^2) - 10 \log_{10}(2^2) \)
  = \( 2 \log_{10}(10) - 20 \log_{10}(2) \)
  = \( 2 \times 10 - 2 \times 3 =14 \text{dB} \)
- \( 10 \log_{10}(2500) = 10 \log_{10}(25 \times 100) \)
  = \( 10 \log_{10}(25) + 10 \log(100) = 14 \text{dB} + 20 \text{dB} = 34 \text{dB} \)
Thank you - Any questions?
A glance at the tool

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Outline

Architecture
Graphic Interface
Libraries and Batch
Plugin
Multiple vector display
Compare propagation model
....
Main interface

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

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

**Simulation controls:**
- Number of events etc..

**Simulation results:**
- dRSS/iRSS vectors, **Pinterference**, Cellular structure
Data exchange via XML

Physically a .zip file with “sws” extension including XML files for the scenario and the results.
Graphic interface (1/1)

Comparison of workspaces

View of parameters at a glance

Graphical reminders (tooltip)
Scenario parameters

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

Distribution

Pattern

Double / integer field

Function
Graphic interface (1/2)

Intuitive check of simulation scenario

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

Overview of results (dRSS, iRSS)
Libraries and Batch

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

- Easy to run sequentially workspaces
  - **Batch** operation
  - Intuitive use
Welcome + News

- Welcome + News

History

- History
• 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

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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
Thank you - Any questions?
Modelling of Unwanted and Blocking Interference Modes

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Outline

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

### Interfering Modes
- **Compatibility**
- **Translation**
- **Unwanted**
- **Blocking**
- **Overloading**
- **Intermodulation**

### Interference Criteria
- **C/I**
- **C/[I+N]**
- **(N+I)/N**
- **I/N**

---

## Unwanted and Blocking Signals
Unwanted Emissions

- **Victim**

- **Interfering System**
Exercise #1: Unwanted calculation

- 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

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

<table>
<thead>
<tr>
<th>Identification</th>
<th>System selection</th>
<th>General</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Victim SystemLink</td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Frequency**
- Type: Constant
- Value: 10.0 MHz
# Victim Link Receiver

## Description

- **Name**: VLR Exercise #1
- **Description**: [Blank]

## Antenna Characteristics

- **Antenna Pointing**
  - Antenna height: [Constant(1.5) Distribution]
  - Azimuth ref. 0 deg is pointing to the Tx
  - Elevation ref. 0 deg is pointing to the Tx

## Reception Bandwidth

- **Reception Bandwidth**: 150.0 kHz

## Noise Floor

- **Noise Floor**: [Constant(110.0)]

## Interference Criteria

<table>
<thead>
<tr>
<th>Interference</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>C/I</td>
<td>19.0 dB</td>
</tr>
<tr>
<td>C/N + I</td>
<td>16.0 dB</td>
</tr>
<tr>
<td>I/N</td>
<td>0.0 dB</td>
</tr>
</tbody>
</table>
### Interfering Link

**Identification**

<table>
<thead>
<tr>
<th>Name</th>
<th>NewWorkspace_31_ILK1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td></td>
</tr>
</tbody>
</table>

**System Selection**

- Generic system
- CDMA UL
- OFDMA UL
- CDMA DL
- OFDMA DL

**General**

- Frequency (Constant: 305.0 MHz)
- Distribution

---

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Interfering Link Transmitter

Power

Emission mask
Unwanted emissions mask

Default value erroneous value
See the following presentations...
Att = 32.44 + 20 \times \log (f \text{ (MHz)}) + 20 \times \log (d \text{ (km)})

Att = 32.44 + 20 \times \log (905 \text{ MHz}) + 20 \times \log (10 \text{ km})

Att = 111.57 \text{ dB}
Simulations...

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

<table>
<thead>
<tr>
<th>Calculation Mode</th>
<th>Signal Type</th>
<th>Interference Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compatibility</td>
<td>Unwanted</td>
<td>C/I 19.0 dB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C/I(1 + N) 16.0 dB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(N + l)/N 3.0 dB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I/N 0.0 dB</td>
</tr>
</tbody>
</table>

**Translation Parameters**

- **Blocking response level/Victim link**: Similar to the interference calculation
- **Intermodulation response level/Victim link**: Similar to the interference calculation
- **Power supplied/New Workspace_31_ILK1**: Similar to the interference calculation

**Results**

- **Compatibility (single result)**: Probability 100.00%

---

\[ N = -110 \text{ dBm} \]

\[ \text{IRSS Unwanted} = -97.78 \text{ dBm} \]

\[ I/N = -97.78 - (-110) = 12.21 \text{ dB} \] (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

- $\Delta f = f_i - f_v = 0$
- $V_r \cdot BW = 150 \text{ kHz}$
- SEM: same as in Exercise #1

- Results: $-9.21 \text{ dBm}$
**Blocking**

- **Victim**

![Diagram of a mobile phone with frequencies f_v and f_i representing the receiver bandwidth and rejection of the receiver.]

- **Interfering System**

![Diagram of an interferer with frequency f_i.]
Blocking: 3 Modes

User Defined (dB): Rejection at the receiver
\[ \text{Att}_{\text{Blocking}} = \text{Block}_{\text{UD}} \]

Protection Ratio (dB):
\[ \text{Att}_{\text{Blocking}} = \text{Block}_{\text{PR}} + \frac{C}{(N+I)} - \frac{I}{N} + \frac{(N+I)}{N} \]

Sensitivity Mode (dBm): Maximum Acceptable Value of Power
\[ \text{Att}_{\text{Blocking}} = \text{Block}_{\text{Sens}} \, (\text{dBm}) - \text{Sensitivity} \, (\text{dBm}) + \frac{C}{(N+I)} - \frac{I}{N} \]
S = -90 dBm
N = -110 dBm
I/N = -6 dB
I_{max} = -40 dBm

Avr = 76 dB
Protection ratio = 49 dB

for the simulation of a 'real' system also the noise figure has to be considered
Exercise # 3: blocking calculation

• 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

• Set interfering link transmitter (ILT)
  • No change

• Path between VLR with ILT
  • No change
Victim link
VLR Blocking Mask

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

Should be defined at the frequency of the Interferer
IRSS Blocking = \( P_e + G_e + G_r - Att\ (free\ space) - Att\ block \)
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?

- **2 Interference Criteria / 2 runs**

![Diagram showing two interference criteria with options for Signal Type and Interference Criterion. The Interference Criteria table shows values for C/I, C/(I+N), (N+I)/N, and I/N in dB.]
Question: Can I run simulations for unwanted and blocking in the same workspace in a single run?

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

• 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 than one interference criteria are used, you need to check that they are consistent

• Understand what the tool compute
Thank you - Any Questions?
Setting Emission and Blocking masks

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Outline

- Using library
- Emission Mask
- OFDMA example
- Emission floor
- ACLR
- Blocking Mask / ACS
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 symmetric 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 **saved** as .txt file
- it can be reused for other workspaces using **load** buttons.

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

<table>
<thead>
<tr>
<th>Frequency offset</th>
<th>Attenuation in dBC</th>
<th>Attenuation in dBC</th>
<th>Attenuation in dBC in SEAMCAT mask</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 10 kHz</td>
<td>0</td>
<td>0 dBC</td>
<td>0 dBC</td>
</tr>
<tr>
<td>10 to less than 20 kHz</td>
<td>Min (p(dBW) +30, 36)</td>
<td>30 dBC</td>
<td>-30 dBC</td>
</tr>
<tr>
<td>20 to less than 30 kHz</td>
<td>Min (p(dBW) + 40, 36)</td>
<td>36 dBC</td>
<td>-36 dBC</td>
</tr>
<tr>
<td>30 to less than 40 kHz</td>
<td>Min (p(dBW) + 45, 40)</td>
<td>40 dBC</td>
<td>-40 dBC</td>
</tr>
<tr>
<td>40 to less than 50 kHz</td>
<td>50</td>
<td>50 dBC</td>
<td>-50 dBC</td>
</tr>
</tbody>
</table>

System with 30 dBm in a emission bandwidth of 20 KHz

Emission BW = Ref. BW = 20 KHz

Ref. BW 10 KHz

Jean-Philippe Kermoal
OFDMA emission mask - UE example

- 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. $-15 \text{ dBm} - 23 \text{ dBm} = -38 \text{ dBc}$
Emission Floor

- Useful when power control is used

\[
\text{emission}_{\text{it}} = \max\left(\text{emission}_{\text{relit}} + p_{\text{it}}^{\text{supplied}} + g_{\text{it}}^{\text{PC}}, \text{emission}_{\text{floorit}}\right)
\]

- This emission floor mask (frequency offset (MHz), emission floor (dBm), reference bandwidth (MHz)).
\[ \text{ACIR} = f(\text{ACLR}, \text{ACS}) \]

- ACIR = adjacent-channel interference ratio
  \[ ACIR = \frac{1}{\frac{1}{\text{ACLR}} + \frac{1}{\text{ACS}}} \]

- 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 \approx 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 \approx 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 = (PR and Sensitivity mode) + Blocking (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.

<table>
<thead>
<tr>
<th>BS</th>
<th>Frequency offset (kHz)</th>
<th>ACS test</th>
<th>Rejection (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UTRA-FDD (5MHz)</td>
<td>300</td>
<td>-47 dBm</td>
<td>51.4</td>
</tr>
<tr>
<td>LTE(1.4 MHz)</td>
<td>252.5</td>
<td>-49 dBm</td>
<td>54.9</td>
</tr>
<tr>
<td>LTE(3 MHz)</td>
<td>247.5</td>
<td>-49 dBm</td>
<td>50.9</td>
</tr>
<tr>
<td>LTE(5 MHz)</td>
<td>342.5</td>
<td>-49 dBm</td>
<td>48.7</td>
</tr>
<tr>
<td>LTE(10 MHz)</td>
<td>347.5</td>
<td>-49 dBm</td>
<td>48.7</td>
</tr>
<tr>
<td>LTE(15 MHz)</td>
<td>362.5</td>
<td>-49 dBm</td>
<td>48.7</td>
</tr>
<tr>
<td>LTE(20 MHz)</td>
<td>342.5</td>
<td>-49 dBm</td>
<td>48.7</td>
</tr>
<tr>
<td>WiMAX (5 MHz)</td>
<td>300</td>
<td>-53 dBm</td>
<td>44.4</td>
</tr>
<tr>
<td>WiMAX (10 MHz)</td>
<td>300</td>
<td>-50 dBm</td>
<td>44.4</td>
</tr>
</tbody>
</table>

**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:

\[
ACS_{relative} = ACS_{test} - Noise_{floor} - 10^{\frac{M}{10}} - 1
\]

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.

Source: 3GPP TS 36.104 V11.2.0 (2012-09)
Thank you - Any Questions?
Overview of Systems in SEAMCAT

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

System type

“Generic” system

Simple interface

Cellular system ... in brief

Conclusion
System type

- Generic
- CDMA
- OFDMA

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
- Estimated Remaining time: -
- Last saved: 31-05-2012 16:42:25
Generic system

While i=1,N
Generate position data of VLT, VLR
Calculate dRSS\textsubscript{i}

While j=1,M
Generate position data of ILT\textsubscript{j}, ILR\textsubscript{j}
Calculate iRSS\textsubscript{ij}

Calculate iRSS\textsubscript{SUM}
dRSS, iRSS to ICE
Simple and harmonised interface

Add
Duplicate
Delete

Workspaces

Interfering links

On-line Help
Multiple interferer generation
Cellular modelling

- 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
• 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 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
Thank you - Any questions?
Propagation model: Built-in and plug-in

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

- Built-in
- Plug-in
- Compare models
## Built-in model

- 6 models + plug-in

<table>
<thead>
<tr>
<th>Model</th>
<th>Frequency Range</th>
<th>Distance Range</th>
<th>Typical Application Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITU-R P.1546 model</td>
<td>30 MHz - 3 GHz</td>
<td>1-1000 km</td>
<td>Broadcasting and other terrestrial services, typically considered in cases with high mounted transmitter antenna (e.g. above 50-60 m)</td>
</tr>
<tr>
<td>Extended Hata model</td>
<td>30 MHz - 3 GHz</td>
<td>Up to 40 km</td>
<td>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.</td>
</tr>
<tr>
<td>Extended Hata-SRD model</td>
<td>30 MHz - 3 GHz</td>
<td>Up to 300 m</td>
<td>Short range links under direct-LOS assumption, important: antenna heights up to 3 m</td>
</tr>
<tr>
<td>Spherical diffraction (ITU-R P.452) model</td>
<td>Above 3 GHz</td>
<td>Up to and beyond radio horizon</td>
<td>Interference on terrestrial paths in predominantly open (e.g. rural) areas</td>
</tr>
<tr>
<td>Free space loss model</td>
<td>Above 30 MHz</td>
<td>LOS-limited</td>
<td>Fixed links and other systems/paths were direct-LOS could be assumed</td>
</tr>
<tr>
<td>ITU-R P.452-14 model</td>
<td>about 0.7 GHz to 50 GHz</td>
<td>up to a distance limit of 10 000 km</td>
<td>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.</td>
</tr>
<tr>
<td>User-defined model (Propagation plug-in)</td>
<td>model specific</td>
<td>model specific</td>
<td>model specific</td>
</tr>
</tbody>
</table>
Any propagation model plug-in is automatically integrated in the list of models available for your simulation.
Example: Extended Hata

Input parameters specific to the model

Frequency range:
30 MHz - 3 GHz

Distance range:
up to 40 km

Typical application area:
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.

Information:
Note that the Hata model assumes that the specified antenna heights of transmitter and receiver are heights above ground.
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

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

Remove
Example #10: Free Space

\[
L = 32.5 + 10 \log \left( \left( \frac{h_t - h_r}{1000} \right)^2 + d^2 \right) + 20 \log f
\]

- \( L = 32.5 + 10 \log(8) + 20 \log(1000) \)
- \( L = 101.5 \text{ dB} \)
Compare models

- 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
Thank you - Any Questions?
SEAMCAT Version 5.0.0

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

• 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.
The user will select whatever system for the victim and the interfering links.
Antenna plugins

- 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

- Black box disappear
- EPPs can extract intermediary results
- EPPs can further extend algorithm
- easy EPP plugins integration to the workspace
Thank you - Any questions?
US questions related to SEAMCAT

European Communications Office
Jean-Philippe Kermoal - SEAMCAT Manager (ECO)
ISART – May 12, 2015
(Jean-Philippe.Kermoal@eco.cept.org)
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

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.
     Occasionally 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

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 performed on more than 450 different workspaces

4. Open community – we promote feedback from users

5. Version 5.0.0 giving access to intermediary results
Thank you - Any questions?