2.25 Considering time domain Tx activity

Consideration of time-domain activity of transmissions in SEAMCAT simulation for Generic and Cellular systems

When using SEAMCAT for simulation of networks in compatibility and sharing studies, sometimes users face questions about how to simulate transmitters which are not active all the time. This corresponds to the terms/parameters Duty cycle, Activity factor, Activity ratio, Probability of transmission, BS/UE TDD ratio and similar terms, depending on type of equipment used, or a combination of these.

As this is a common question raised, this annex presents some of the solutions which can be used to simulate transmitters taking into account non-continuous transmitting behaviour. This is a non-exhaustive list and there are other possible ways to achieve similar outcomes. Which method is to be used depends on the specific scenario.

These methods are mainly targeted towards time-domain activity on the interfering system link, however some of these could also be applied to the victim system if relevant.

Different methods to consider transmitters which are not active all the time in interference calculations:

- Tx power distribution
- Additional Loss distribution
- Setting Uniform (and Closest interferer) mode of simulation together with Transmitter density and Traffic
- Adjusting Tx power to average power
- Conditional probability formula & law of total probability
- Separate activity vector combined with extracted results vectors
- Reduce the number of active Tx to simulate

- Methods for applying time-domain activity of transmissions in SEAMCAT simulation

Methods for applying time-domain activity of transmissions in SEAMCAT simulation

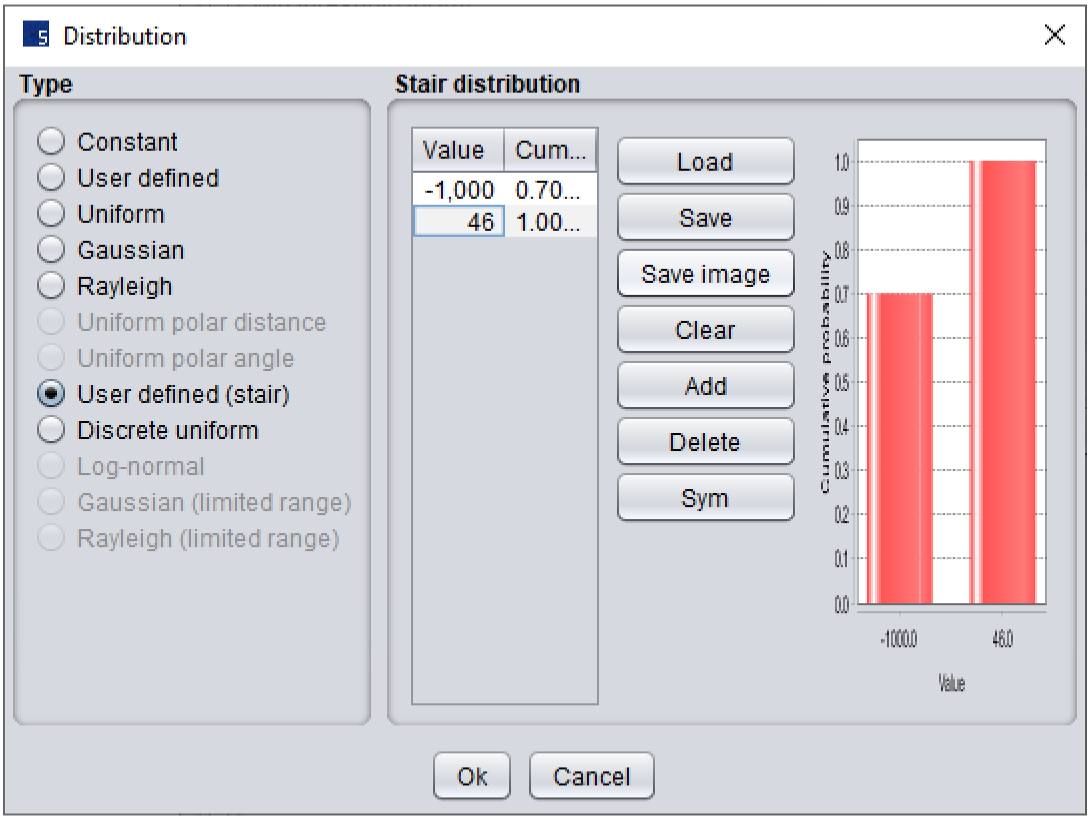
1. **Tx power Distribution**

- *Applicability: cellular or generic systems with multiple interferers where individual transmitters exhibit independent random time domain behaviour (e.g. mobile networks, SRDs)*

The user can set User defined (Stair) distribution where for the active state the actual power of transmitter is simulated, and for the non -active state set an arbitrarily low Tx power (e.g. -1000 dBm) is assumed, effectively simulating an “off” transmitter.

In the System settings under Transmitter / Power, the user needs to select Distribution, select User defined (stair) and input a cdf function. This is particularly useful for cases where a scenario needs to simulate on and off periods such as with Duty cycle or similar. For example, if a Tx is working with 46 dBm power which is transmitted for 30 % of time the settings would need to be as shown in the figure below.

In simulation, at each trial the Tx power will be generated with 30% probability to be 46 dBm. Please note that in this case 70% of events will be non-interfered from this transmitter and depending on the scenario, the number of events might need to be adjusted to obtain a sufficient number of relevant interfering cases.



Distribution

Type

○ Constant
○ User defined
○ Uniform
○ Gaussian
○ Rayleigh
○ Uniform polar distance
○ Uniform polar angle
● User defined (stair)
○ Discrete uniform
○ Log-normal
○ Gaussian (limited range)
○ Rayleigh (limited range)

Stair distribution

Value	Cum...
-1,000	0.70...
46	1.00...

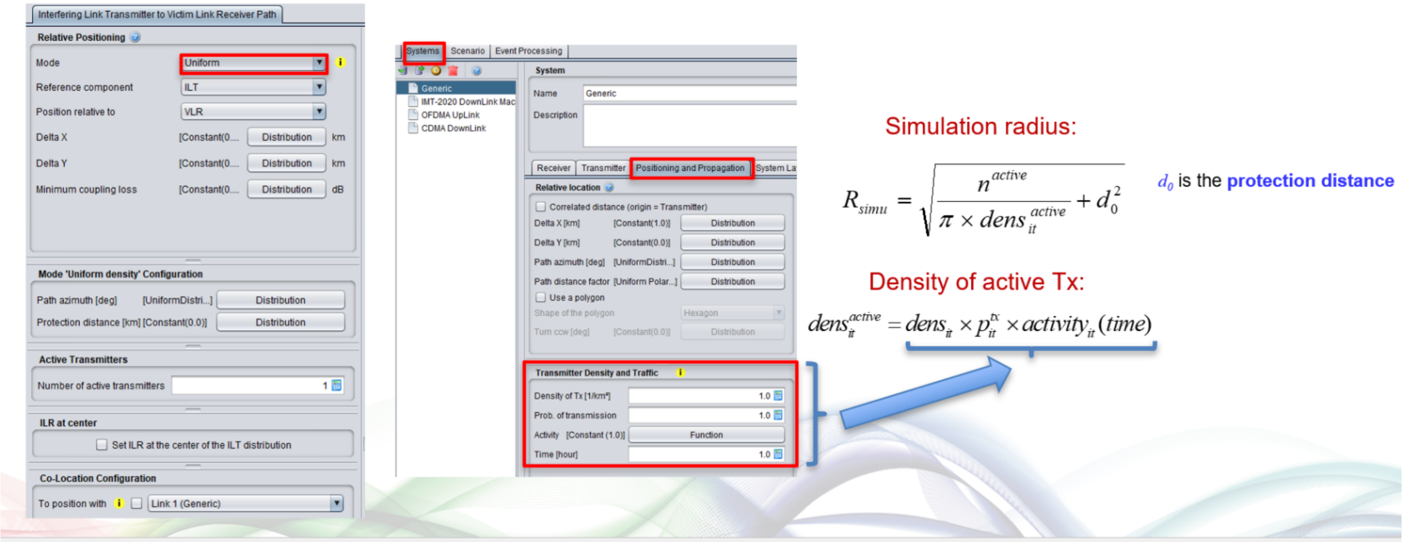
2. **Setting Uniform (and Closest interferer) mode of simulation together with Transmitter density and Traffic**

- *Applicability: Generic systems with multiple interferers of a specific density and random positioning, where individual transmitters exhibit independent random time domain behaviour (e.g. SRD)*

In Systems under Positioning and Propagation, the user can set Transmitter Density and Traffic parameters. This panel defines the parameters Transmitter density, Probability of transmission Activity and Time. With these parameters SEAMCAT calculates the density of active transmitters to simulate. To use these settings in the Scenario, the user needs to select Uniform mode and adjust the number of active transmitters and the protection distance (if relevant according to the scenario).

The system then calculates an appropriate simulation radius so that the specified density of active Tx is fulfilled with the entered number of Active transmitters. In this case only transmitters which are active are simulated in the event and considered in calculation of Interference vectors. These settings are particularly useful when the transmitter density is known, as it is the case for many SRD devices.

The Closest interferer mode is similar, but it generates only one active transmitter which is closest to the victim under the given settings.



Interfering Link Transmitter to Victim Link Receiver Path

Relative Positioning

Mode: Uniform
Reference component: ILT
Position relative to: VLR
Delta X: [Constant(0.... km
Delta Y: [Constant(0.... km
Minimum coupling loss: [Constant(0.... dB

Mode 'Uniform density' Configuration

Path azimuth [deg]: [UniformDistri...]
Protection distance [km]: [Constant(0.0)]

Active Transmitters

Number of active transmitters: 1

ILR at center

☐ Set ILR at the center of the ILT distribution

Co-Location Configuration

To position with ☐ Link 1 (Generic)

Systems | Scenario | Event Processing

Generic
IMT-2020 DownLink Mac
OFDMA UpLink
CDMA DownLink

System

Name: Generic
Description:

Receiver | Transmitter | Positioning and Propagation | System La

Relative location

☐ Correlated distance (origin = Transmitter)
Delta X [km]: [Constant(1.0)]
Delta Y [km]: [Constant(0.0)]
Path azimuth [deg]: [UniformDistri...]
Path distance factor: [Uniform Polar...]
☐ Use a polygon
Shape of the polygon: Hexagon
Turn ccw [deg]: [Constant(0.0)]

Transmitter Density and Traffic

Density of Tx [1/km²]: 1.0
Prob. of transmission: 1.0
Activity: [Constant (1.0)]
Time [hour]: 1.0

Simulation radius:

$$R_{simu} = \sqrt{\frac{n^{active}}{\pi \times dens_{it}^{active}} + d_0^2}$$

d_0 is the **protection distance**

Density of active Tx:

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

3. **Adjusting Tx power to averaged power instead to actual power when working**

- *Applicability: Generic or cellular systems with a high number of interfering transmitters and a large separation distance to the victim receiver (e.g. satellite space station receiver)*

In some cases, the user is interested in the averaging effect of interference from a high number of Tx, so the effect of a proportion of Tx working with max power part of the time would be equivalent to all Tx working with average power all the time. In that way maximal power of the transmitter could be averaged.

For example, if we have a transmitter with an average transmit power, P= 15 dBm with an activity factor of 0.02, the average power can be calculated as:

- an average power to be used for each active user:

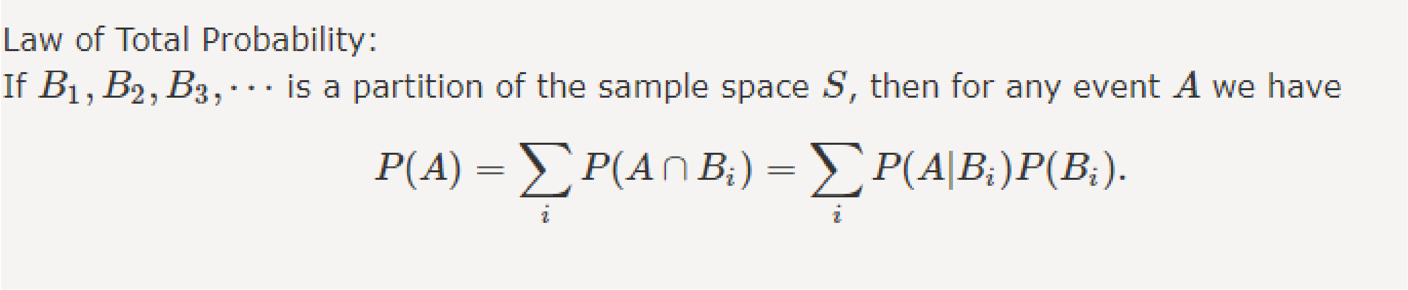
$$P_a = 15 + 10\log_{10}(0.02) = –2 \text{ dBm.}$$

This power can be set under System settings / Transmitter / Power settings of the Transmitter. An example of this usage for mobile terminals in cellular systems can be found in section 2.2.3.7 of Report ITU-R M.2241 and in Report ITU-R M.2292-0.

4. **Conditional probability formula & law of total probability**

- *Applicability: Scenarios with a single interferer with time-dependent transmission, or multiple time-synchronised transmitters (e.g. TDD cellular networks)*

In some cases, it is appropriate to use a conditional probability formula to post-process the SEAMCAT probability results. In this case the SEAMCAT simulation is run with max power and a fully loaded system, and the resulting probability is combined with a conditional probability to calculate the probability of interference according to the Law of total probability.



Law of Total Probability:
If $B_1, B_2, B_3, \cdots$ is a partition of the sample space S, then for any event A we have

$$P(A) = \sum_i P(A \cap B_i) = \sum_i P(A|B_i)P(B_i).$$

For example if it is assumed that Tx is active 30% of time then the total probability of interference can be calculated as:

P(Interf) = P(Interf /Active)*P(Active)+P(Interf/non_active)*P(non_active)

P(Interf) = P(interf /Active)*0.3 + P(interf/non_active)*0.7 = P(interf /Active)*0.3 + 0

In this method it is assumed that the proportion of time when the Tx is not active is equivalent to adding an equivalent proportion of additional non-interfered events into the simulation. This approach has the benefit of not using additional computational resources to simulate events for which probability of interference is zero, and instead account for these cases by simple post-processing.

This approach can also be extended to combine results of TDD cellular network interference from separate simulations of downlink (DL) and uplink (UL) according to:

$$p_{total} = p_{DL} * R_{DL} + p_{UL} * R_{UL}$$

where:

p_{total} is the total interference probability

p_{DL}, p_{uL} are the individual results of probability of interference from DL and UL respectively, calculated in separate workspaces

R_{DL}, R_{UL} are the DL and uplink TDD ratios

For example, for a typical case of a TDD DL/UL split of 75%/25%:

$$p_{total} = p_{DL} * 0.75 + p_{UL} * 0.25$$

5. **Separate activity vector combined with extracted results vectors**

- *Applicability: where detailed event level results are needed, or post-processing of cellular capacity results taking into account time-dependent activity (e.g. cellular victim systems with time-dependent interferers)*

In some cases, it is necessary to extract vectors of wanted (dRSS) and interfering signals (iRSS), or other results such as cellular capacity, for post-processing. These vectors can be extracted and combined with time-dependent activity as follow:

- Create SEAMCAT workspace and run simulation assuming full power and fully loaded systems
- Export desired vectors for VSL and all ISL
- In external software, generate a random activity function which results in 1 with probability according to the specified activity factor and 0 otherwise; produce as many vectors as needed of this function.
- Multiply the relevant signal vector from SEAMCAT with the activity vector (note that iRSS $_{\text{unwanted}}$ and iRSS$_{\text{blocking}}$ coming from same interferer needs to be multiplied with the same activity vector)
- Use these multiplied vectors for calculation of interference or further post-processing as needed.

6. **Reduce the number of active Tx to simulate**

- *Applicability: allow to reduce computation time by reducing the number of active Tx to simulate.*

For a fixed simulation radius and a fixed density of Tx, assuming a certain duty cycle of x% for instance means that x% of the Tx interferer is “ON” (i.e. active) and “OFF” the rest of the time. So for that simulation radius, and fixed density, it is not needed to simulate the Tx that are “OFF”. This is similar to the option 1 “**Tx power Distribution**”, but faster. Simulating x% of Tx that are active (at full power) reduces computation time.

- For fixed simulation radius and fixed density of interfering transmitter, calculate the number of total interfering transmitter. Apply the duty cycle ratio to calculate the number of active transmitters.
- In SEAMCAT workspace, select the mode “none” (or “standard” in new version), set the “simulation radius” and set the “number of active transmitters”.

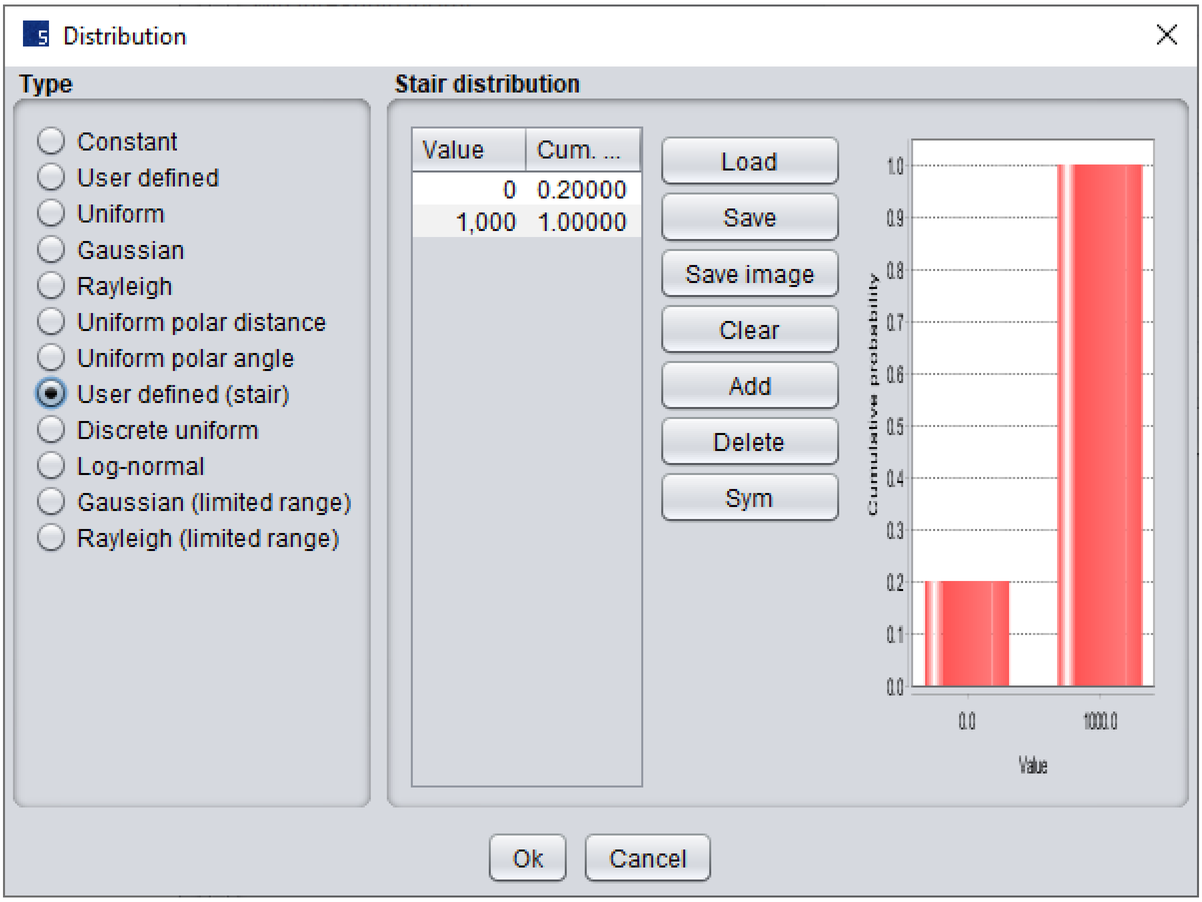
1. **Additional Loss Distribution**

- *Applicability: cellular or generic systems with multiple interferers where individual transmitters exhibit independent random time domain behaviour (e.g. mobile networks, SRDs)*

Another solution without the need for normalise and could work with Power lock / unlock distribution is to take activity into Additional loss. It can be set at terminal level and is embedded in calculation or received level (either dRSS or iRSS) whatever is needed. I tested – it works like that.

Settings:

- Power – applying distribution with power distribution requested (if needs locking in time elements – possible to do that)
- Have Additional loss as distribution = 1000 dB – 80% and 0 dB – 20 % (this will add 1000 dB of loss to the link in 80% of time – i.e. like this terminal is not active)



Distribution

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○ Constant
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○ Gaussian
○ Rayleigh
○ Uniform polar distance
○ Uniform polar angle
● User defined (stair)
○ Discrete uniform
○ Log-normal
○ Gaussian (limited range)
○ Rayleigh (limited range)

Stair distribution

Value	Cum. ...
0	0.20000
1,000	1.00000