6 Spectrum sensing and cognitive radio

6.1 Introduction

Cognitive radio is a technology which is being developed to bring greater efficiency, speed and reliability to users of wireless devices. The number of high powered wireless devices coming on to the market is increasing exponentially placing an unprecedented demand on the limited radio spectrum. Cognitive radio technology is seen as a potential solution to this problem as it identifies unused frequencies in a local area and switches a device to this temporarily to provide users with uninterrupted and faster mobile services.

In the following, CRS refers to Cognitive Radio Systems. One typical example of usage of CRS is in the so called “white spaces” (WS), which refers to frequency spectrum which is potentially available at a given time for further

utilisation within frequency spectrum originally planned another service (e.g. Broadcasting). Devices operating in the white spaces using cognitive radio features are called White Space Devices (WSD) [14].

6.2 Simulating spectrum sensing

The manual sets out how SEAMCAT can be used for spectrum sensing where the interfering devices (ILT) try to detect the presence of protected services (e.g. the VLT) transmitting in each of the potentially available channels. Spectrum sensing essentially involves conducting a measurement within a candidate channel to determine whether any protected service is present and transmitting. When a channel is determined to be vacant, sensing is typically applied to adjacent channels to identify what constraints there might be on transmission power, if any.

A key parameter for spectrum sensing is the detection threshold that is used by a cognitive device to detect the presence or the absence of a protected service's transmission. If it detects no emission above this threshold in a channel, the white space device (WSD, i.e. the It) is allowed to transmit, otherwise the WSD keeps silent or look into other channels. You can study this phenomenon in SEAMCAT, which enables multiple cognitive radio systems. The cognitive radio feature mainly introduces the detection threshold and the selection of the operating frequency of the WSD.

In SEAMCAT, the CRSs are assumed to be the interferers. A SEAMCAT workspace will contain only 1 victim system and 1 or many interferers. It is possible to assess the aggregated impact of interferers that can be either CR devices or not. The scenario allows the impact of spectrum sensing to be investigated where a cognitive radio device is activated nearby a victim system. Both the victim and the interfering dialogue interface should be filled to enable spectrum sensing in SEAMCAT. Figure 157 illustrates that the introduction of spectrum sensing requires an extra budget link called sensing Received Signal Strength (sRSS) which represents the signal which is transmitted by the VLT and is sensed by the It. Note that the It acts as a transceiver, meaning that when the energy is sensed though the bandwidth of the sensing device (i.e. the It), it is acting as a receiving device.

The sRSS (considering the unwanted mask of the DTT) at the channel *m* is calculated as described in ANNEX 6:.

It is assumed that the frequency of the interfering cognitive radio device is dependent on the frequency range defined for the victim. This means that when the CR module is activated, the interfering frequency function dialogue box is de-activated (#4 of Figure 231). Depending on how the victim frequency is defined (i.e. constant, discrete or distributed between f_{min} and f_{max}). SEAMCAT only allows the use of the following distributions: Constant, User defined, Uniform, User defined (stair).

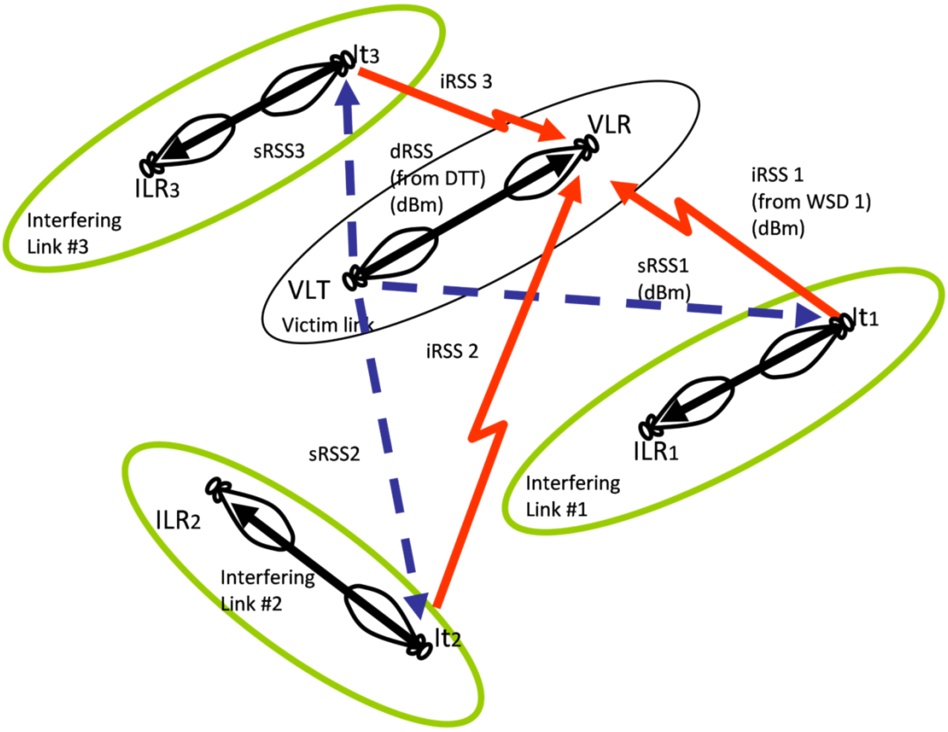


Figure 157: Illustration of 3 cognitive radio systems (WSD) and a victim system (sRSS is in blue)

6.3 Input system parameters

For the sensing feature to be activated, both the victim and interferer transmitters have to have the “interferer is CR” selected (Figure 158). This will activate the spectrum sensing algorithm (see ANNEX 16:) and will allow you to set the transmitting characteristic of the victim link transmitter, i.e. the energy that the cognitive radio spectrum sensing device is to sense. You will be able to set the emission mask and the emission floor.

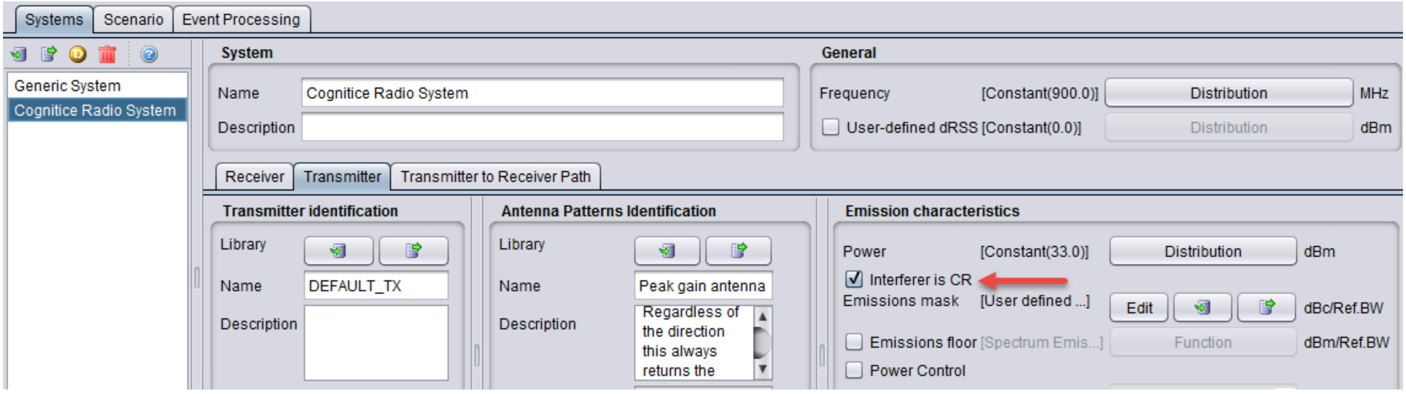


Figure 158: Selection of the CR algorithm

Table 20: Victim Link transmitter

Description	Symbol	Type	Unit	Comments
Interferer is CR		switch		When the CR button is checked then it allows to set the emission characteristics of the VLT (used for the sRSS calculation only)

Emission mask: Unwanted signal level (VLT)		Function (X,Y) (MHz)	dBm/reference bandw. (MHz)	Define the mask of the transmitter, in the emission bandwidth and out of the emission bandwidth. Negative values in the relative mask should be chosen in a way that the integration over the emission bandwidth results in the total emitted power. If constant mask, there is no emission outside of the bandwidth.
Unwanted emissions floor: Noise floor signal level		Function (X,Y) (MHz)	dBm/ reference bandw. (MHz)	Define the minimum strength of the unwanted emissions. So the unwanted emissions equal to Max(Pwt + Unwanted emission, Unwanted emissions floor)

Note that the settings of the emissions mask and the emission floor is the same as for the interfering link (i.e. same units).

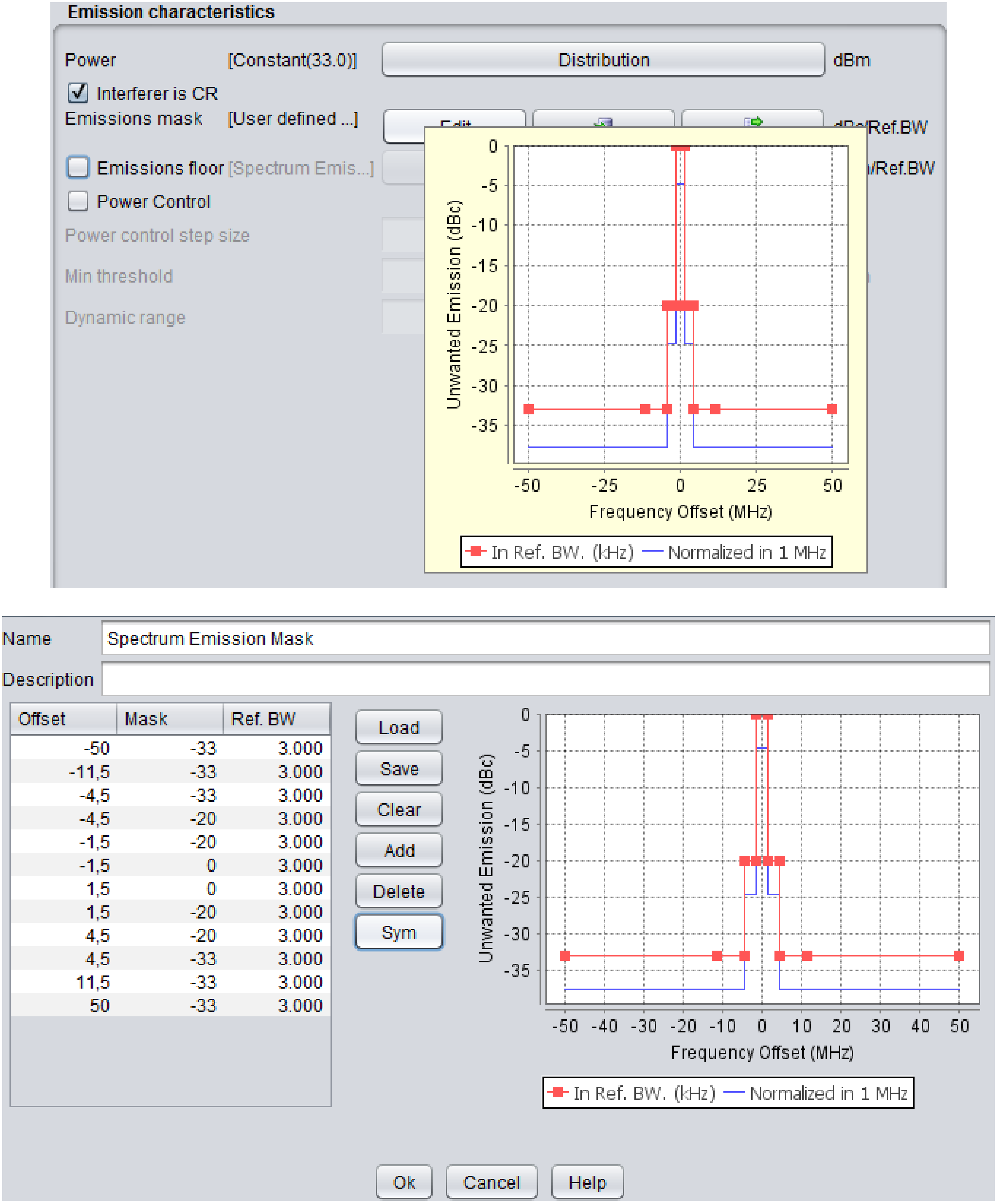


Figure 159: Activate the CR in the VLT (Victim Link) to consider its emission characteristics
(i.e. used in the sRSS calculation)

6.4 Scenario parameters

In addidtion to the input system parameters, you also need to set charateristics of the spectrum sensing algorithm as described in Section 10.4.

6.5 Examples

At the end of the simulation, SEAMCAT provides a set of output vectors as presented in Section 12.4. The following subsections present examples on how to interpret the results.

6.5.1 All the channels are available

In such a scenario, the detection threshold is taken to a value of 0 dB (Figure 160) much higher than the sRSS level (average = -82.09 dBm) (Figure 161). Therefore, no victim system has been detected and the WSDs are allowed to transmit in any of the specified channels (Figure 162) per event.

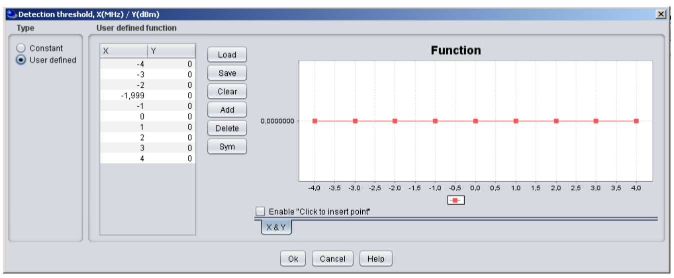


Figure 160: Selection of a high detection threshold

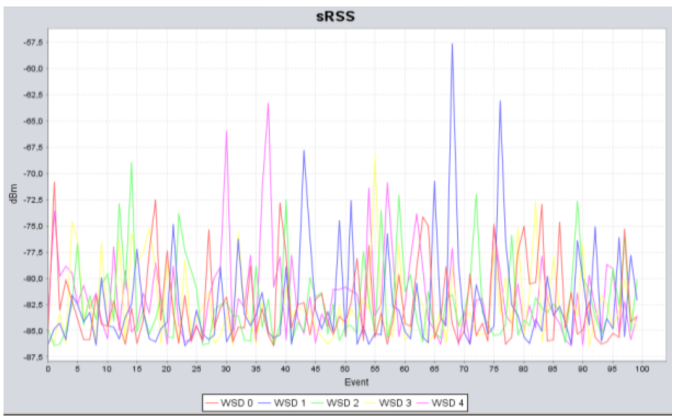


Figure 161: The sRSS values are well below the detection threshold, so no victim system have been detected

In such a case the e.i.r.p.used in the simulation is the Tx_{power} (=-33 dBm) + G_{max} (=0 dBi), meaning that the in-block e.i.r.p. limit does not apply. This means that whatever the frequency selected by the WSD its e.i.r.p.. is the same (Figure 164) (here assuming that the Power Control at the It is OFF).

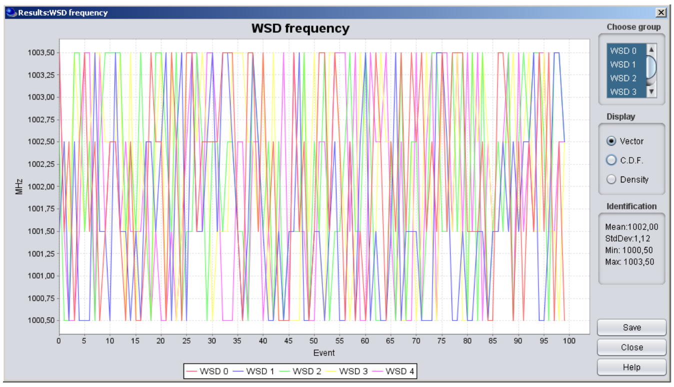


Figure 162: The WSD can transmit anywhere in the victim frequency range

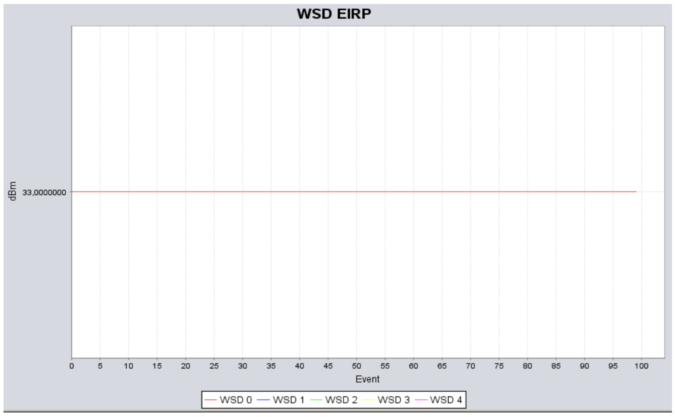


Figure 163: e.i.r.p. set to -33 dBm as set in the It, i.e.
Txpower (=-33 dBm) + Gmax (=0 dBi), meaning that there were no limit applied to the It Tx power

Figure 165 illustrates that on average there are 1.17 WSDs active at 1000.5 MHz per event, 1.23 WSDs in 1001.5 MHz, 1.34 WSDs in 1002.5 MHz and 1.26 WSDs in 1003.5 MHz for the same out of 5 which were input to the simulation. In this case all the WSDs were active (but in different frequencies) since the sum equal to 5 (i.e. none of the WSDs have been turned off).

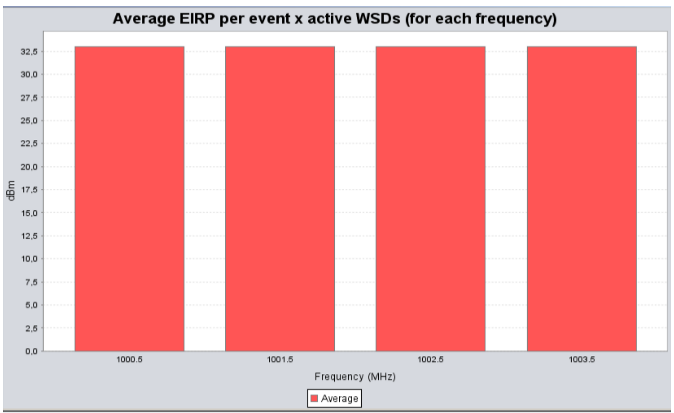


Figure 164: e.i.r.p. is the same irrespective of the frequency

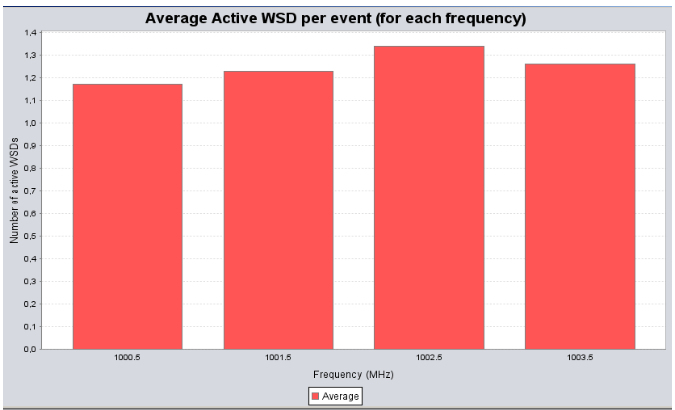


Figure 165: Illustration of the number of WSDs per frequency

6.5.2 All the channels are blocked

In such a scenario, the detection threshold is taken to a lower value compared to the sRSS and none of the WSDs are transmitting. In SEAMCAT, the Tx power is set to -1000 dBm (Figure 166). The WSD frequency is the same as the victim frequency per event.

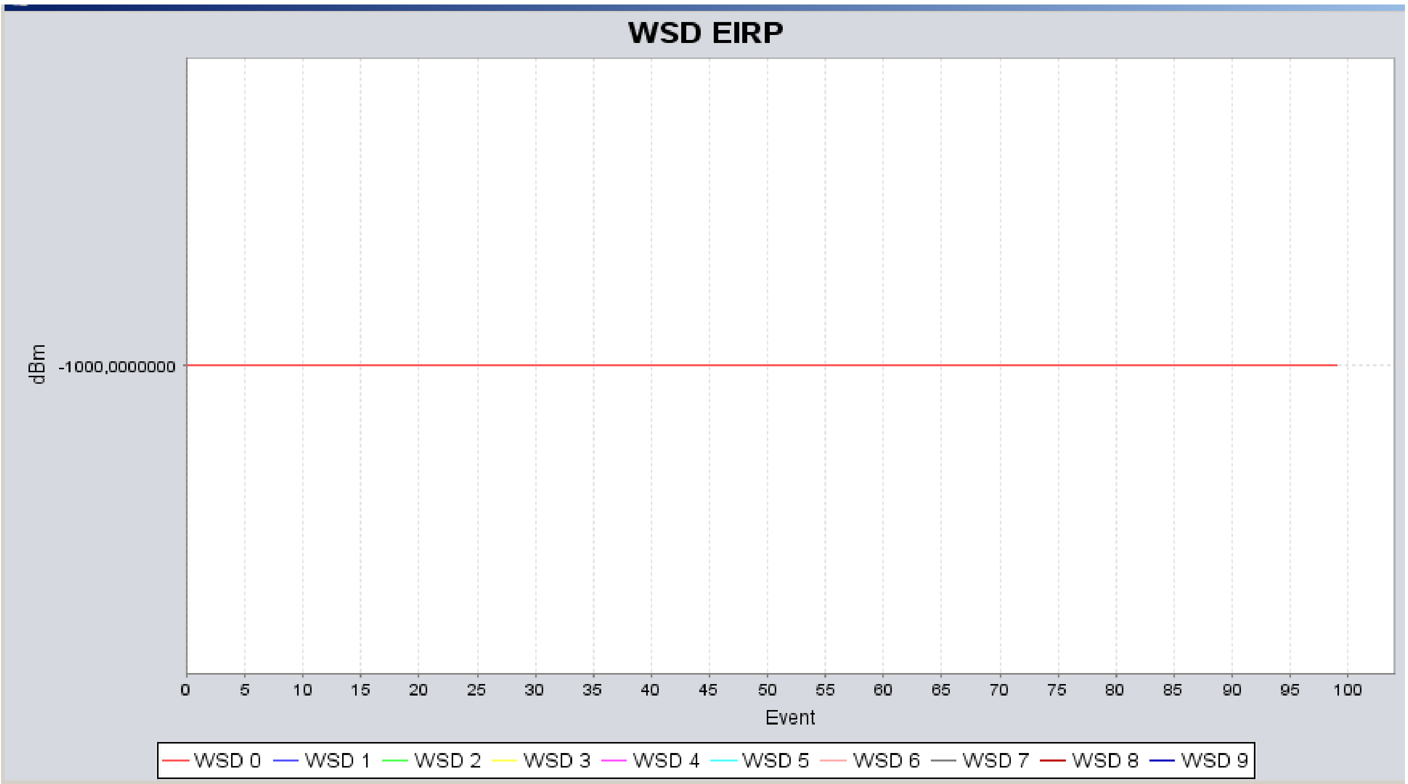


Figure 166: all the WSDs are off i.e. -1000 dBm

Note that in this specific case, the average e.i.r.p. and average WSDs per frequency can not be calculated and therefore can not be displayed as shown in Figure 168.

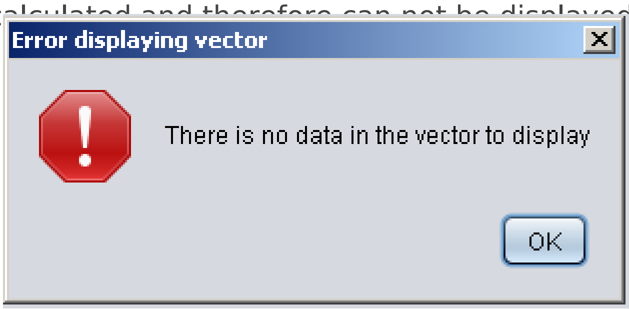


Figure 167: All the WSDs are off i.e. -1000 dBm

6.5.3 Some of the channels are blocked and some are available

This is a typical example. In such a scenario, the detection threshold is taken to a value of -80 dB (flat over the frequency range). This mean that when considering the sRSS of Figure 168, for some of the events, the sRSS will be above that threshold and therefore some WSDs will be considered as off (which explains the -1000 dBm value in Figure 169 (b)) and the WSD frequencies are randomly distributed.

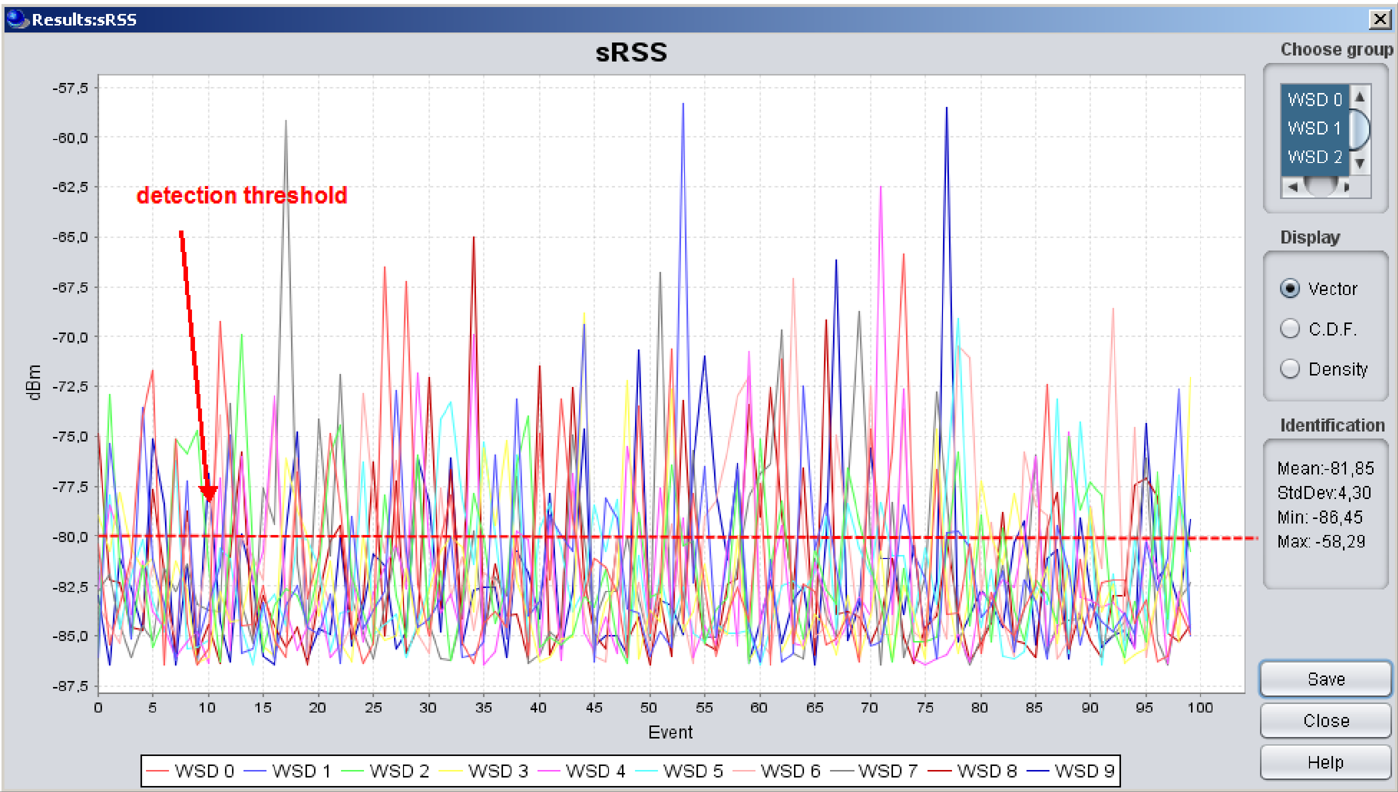
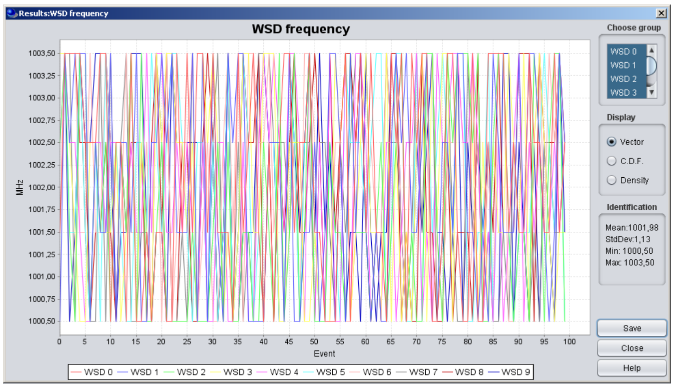
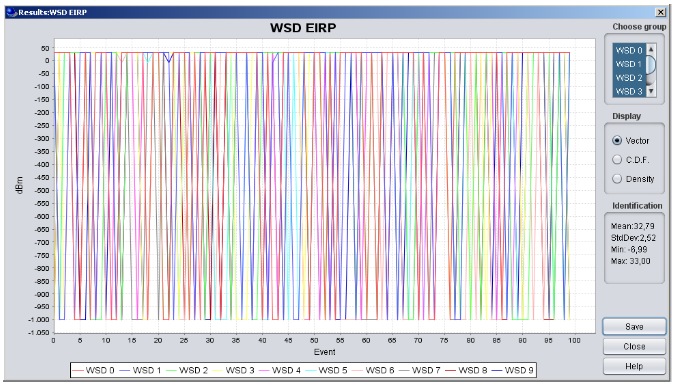


Figure 168: sRSS for 5 WSDs per event



(a) WSD frequency

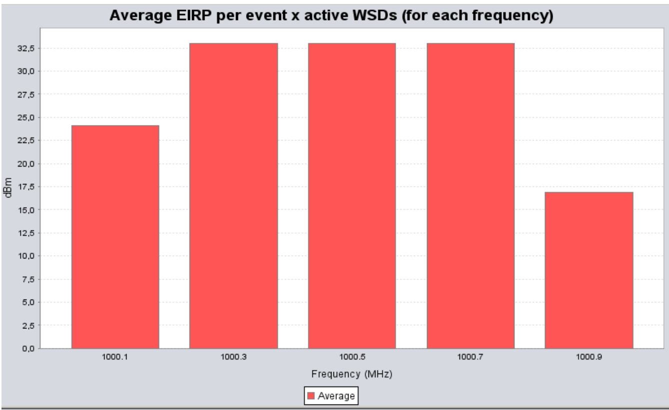


(b) WSD e.i.r.p.

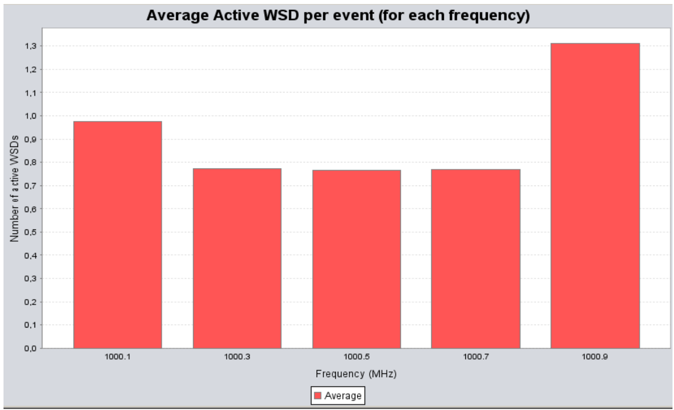
Figure 169: Output results of the WSD in (a) frequency and (b) e.i.r.p.

In this case, one can see that all the channels were occupied in Figure 170. The WSDs were allowed to transmit with an e.i.r.p. of 33 dBm in the 3 middle channels (1000.3 MHz to 1000.7 MHz) while for the side channels less power was allowed (i.e. 24 dBm for 1000.1 MHz and 16.89 dBm for 1000.9 MHz).

Figure 170 (b) also indicates that not all the simulated WSDs were active (those having an e.i.r.p. of -1000 dBm), and that per event about only 1 WSD was active.



(a) average e.i.r.p.



(b) average number of active WSDs

Figure 170: output results of the WSD in (a) frequency and (b) e.i.r.p.