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Simulation of Picocell Interference Scenario for Cognitive Radio

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Abstract – This article presents results of the Picocell mitigation interference simulation for implementation of cognitive radio. The simulations results have been taken by using the SEAMCAT software at 900 MHz with a 200 KHz reception bandwidth, considering both indoor and outdoor propagation environments. The results is the evaluation of the reduction of unwanted and blocking interference with increase in detection threshold value of cognitive radio technology in a picocell and macrocell network under different scenarios.

Keywords – Cognitive Radio, Unwanted interference, blocking interference, SEAMCAT.

INTRODUCTION

In today's wireless communication environment, the Radio Frequency (RF) spectrum has been occupied for different fields like cellular, military, Television, satellite or emergency communication. The RF spectrum used for wireless cellular communication is getting crowded day by day with the increasing number of user subscribers and the demand of high data rate for internet usage, but the use of frequency spectrum for other wireless communication and broadcast purpose is not utilized properly, like in Television broadcast band, at some instant the frequency spectrum remains vacant for particular period of time [1] [2]. This vacant spectrum can be used for cellular communication, means the frequency spectrum can be borrowed from Television Broadcast band and can be used for cellular communication. The use of spectrum of licensed frequency bands when primary user is absent, will improve the efficiency of spectrum utilization.

The Cognitive Radio (CR) technology imposed itself as a good key for increasing the spectrum utilization [3]. A new radio type has been developed "Cognitive Radio", it endowed with the intelligence that senses, shares and uses the spectrum opportunities of the pre-existing wireless networks, I.e. the channels which are not in any use by the licensed users.

The term "Cognitive Radio" was motivated by Joseph MitolaIII, is a radio that can borrow/use spectrum by sensing vacant or white space in spectrum from its surroundings, adapt it and can change frequency dynamically based on its location and other neighbour radios by learning their spectrum pattern [4].

The main proposed of this article is to use these concepts to simulate the interference in the picocell and macrocell in SEAMCAT tool.

SEAMCAT SIMULATION TOOL

SEAMCAT is the implementation of a Monte Carlo radio simulation model developed by the group of CEPT administrations, European Telecommunications Standards Institute (ETSI) members and international scientific bodies [5]. SEAMCAT tool has been invented to deal with a complex range of spectrum engineering and radio compatibility problems. The Monte Carlo method can address virtually all radio-interference scenarios. This flexibility is achieved by the way the parameters of the system are defined. The input form of each variable parameter (antenna pattern, radiated power, propagation path) is its statistical distribution function. It is therefore possible to model even very complex situations by relatively simple elementary functions.

The SEAMCAT tool models a primary mobile station transmitter (P-MS_{Tx}) connected to a primary base station receiver (P-BS_{Rx}) which describes a primary user link and operating amongst a secondary mobile station transmitter (S-MS_{Tx}) act as interferer to the primary user spectrum or channel. A secondary user belongs to the same system as the primary. The interferers are randomly distributed around the primary base station receiver in a manner decided by the user [5]. It is common practice to use a uniform random distribution.

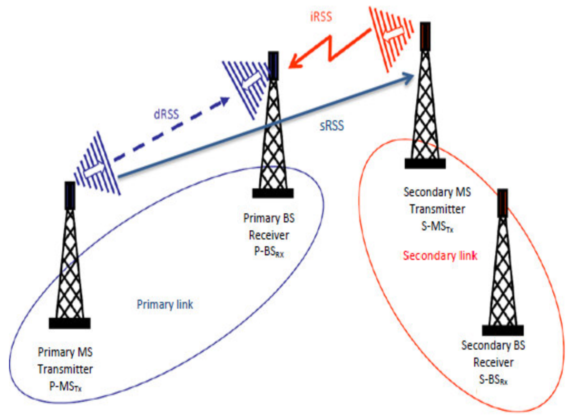

Fig.1. Primary and secondary user modelling in SEAMCAT[5]

The interference occurs when the primary receiver carrier to interference ratio (i.e. C/I) is less than the minimum allowable value. In order to calculate the primary's C/I, it is necessary to establish the primary's wanted signal strength or Desired Received Signal Strength (dRSS), corresponding to "C" and the interfering signal strength (iRSS) corresponding to the "I"

1. **dRSS**(desired Received Signal Strength): It is the signal which is transmitted by the primary mobile station transmitter ($P\text{-}MS_{Tx}$) to the primary base station receiver ($P\text{-}BS_{Rx}$). This is the signal which will experience impairment due to the interferer.

2. sRSS (sensing Received Signal Strength): It is the signal which is transmitted by the primary mobile station transmitter ($P\text{-}MS_{Tx}$) and is sensed by the secondary mobile station transmitter ($S\text{-}MS_{Tx}$). The $S\text{-}MS_{Tx}$ acts as a transceiver, meaning that when the energy is sensed though the bandwidth of the sensing device (i.e. the $S\text{-}MS_{Tx}$), it is acting as a receiving device [6][7].

3. iRSS (interfering Received Signal Strength): It is the signal which is transmitted by the secondary mobile station transmitter ($S\text{-}MS_{Tx}$) and received by the primary base station receiver ($P\text{-}BS_{Rx}$). This is the signal which will impair the dRSS. Here, the $S\text{-}MS_{Tx}$ acts as a transmitting device.

i. $iRSS_{unwanted}$: The level of unwanted emissions (i.e. consisting of the spurious emissions and out-of-band emissions of the interfering or $S\text{-}MS_{Tx}$ transmitter) falling within the primary base station receiver ($P\text{-}BS_{Rx}$) bandwidth is determined using the secondary mobile station transmitter ($S\text{-}MS_{Tx}$) or interferer's transmit mask as illustrated in Fig.2, the selectivity of the $P\text{-}BS_{Rx}$, interferer / $P\text{-}BS_{Rx}$ frequency separation, antenna gains and propagation loss.

ii.

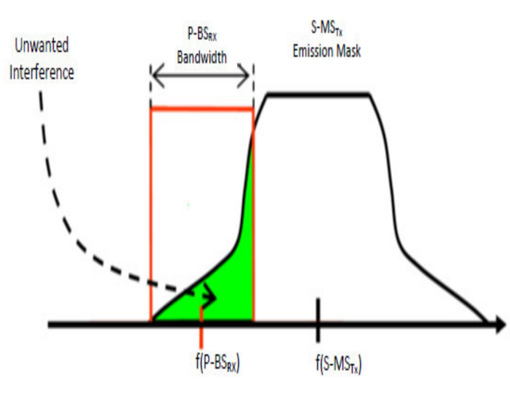

Fig.2: Interference due to unwanted emission[5]

iii. $iRSS_{blocking}$: The receiver blocking power, i.e. the power captured from the transmissions of the interferer or $S\text{-}MS_{Tx}$ due to selectivity imperfections of the primary base station receiver ($P\text{-}BS_{Rx}$) as shown in Fig.3, is determined using the interferer's transmit power, $P\text{-}BS_{Rx}$ receiver blocking performance, interferer / $P\text{-}BS_{Rx}$ frequency separation, antenna gains and propagation loss.

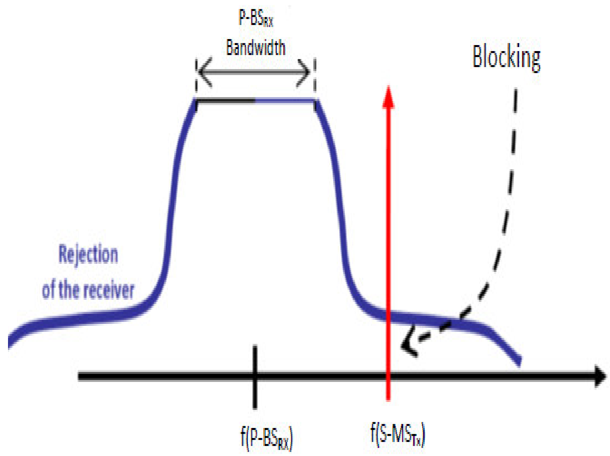

Fig.3: Blocking by victim or primary receiver[5]

The flow process to calculate the unwanted and blocking interference to the primary base station receiver ($P\text{-}BS_{Rx}$) by the secondary mobile station transmitter ($S\text{-}MS_{Tx}$) in different wireless radio environment is shown in fig.3 and formulation is given below [5].

$$iRSS_{blocking} = P_{P\text{-}MSTx} + G_{S\text{-}MSTx \to P\text{-}BSTx}(f_{S\text{-}MSTx}) + G_{P\text{-}BSTx \to S\text{-}MSTx}(f_{S\text{-}MSTx}) - L_{S\text{-}MSTx \to P\text{-}BSTx}(f_{S\text{-}MSTx}) + a_{P\text{-}BSRx} \quad (1.1)$$

$$iRSS_{unwanted} = G_{S\text{-}MSTx \to P\text{-}BSTx}(f_{P\text{-}BSRx}) + G_{P\text{-}BSTx \to S\text{-}MSTx}(f_{P\text{-}BSRx}) - L_{S\text{-}MSTx \to P\text{-}BSTx}(f_{P\text{-}BSRx}) + unwanted(f_{S\text{-}MSTx}, f_{P\text{-}BSRx}) \quad (1.2)$$

Where:
$G_{S\text{-}MSTx \to P\text{-}BSTx}$:Gain in dBi in the $S\text{-}MS_{Tx}$to $P\text{-}BS_{Rx}$ direction.

$G_{P\text{-}BSTx \to S\text{-}MSTx}$:Gain in dBi in the $P\text{-}BS_{Rx}$ to $S\text{-}MS_{Tx}$direction

$L_{S\text{-}MSTx \to P\text{-}BSTx}(f_{S\text{-}MSTx})$: Path Loss from $S\text{-}MS_{Tx}$to $P\text{-}BS_{Rx}$with frequency of the secondary mobile station transmitter $f_{S\text{-}MSTx}$.

$L_{S\text{-}MSTx \to P\text{-}BSTx}(f_{P\text{-}BSRx})$: Path Loss from $S\text{-}MS_{Tx}$to $P\text{-}BS_{Rx}$with frequency of the primary base station receiver $f_{P\text{-}BSRx}$.

SIMULATION SCENARIOS

The study has been conducted for the Global System for Mobile Communication, considering two channels with channel spacing 200 kHz to study the effect of detection threshold on interference at primary user receiver or victim receiver by single secondary user and to study the impact of using power control on interference. The propagation model used is a variation of the Okumura Extended Hata [5] [2] developed by CEPT.

The frequencies of the Primary Mobile Station Transmitter ($P\text{-}MS_{Tx}$) and Secondary Mobile Station Transmitter ($S\text{-}MS_{Tx}$) are same i.e. 935.1 MHz and 935.3 MHz because the Secondary Mobile Station Transmitter ($S\text{-}MS_{Tx}$) is a Cognitive Radio Device that will find the vacant channel in accordance with the detection threshold specified for it.

Table 1: Parameters of Primary Mobile Station Transmitter (P-MS_{Tx})

Primary Mobile Station Transmitter (P-MS_{Tx})	
$P_{P\text{-}MSTx}$(supplied)	33 dBm
$G_{P\text{-}MSTx}$(max)	0 dBi
$pattern_{P\text{-}MSTx}$	Omni-directional
$H_{P\text{-}MSTx}$	1.5 m
$f_{P\text{-}MSTx}$	935.1 MHz

Table 2: Parameters of Primary Base Station Receiver (P-BS_{Rx})

Primary Base Station Receiver (P-BS_{Rx})	
C/I	19 dB
$G_{P\text{-}BSRx}$ (max)	18 dBi
$pattern_{P\text{-}BSRx}$	Omni-directional
$H_{P\text{-}BSRx}$	30 m
$sens_{P\text{-}BSRx}$	-102 dBm
$b_{P\text{-}BSRx}$	100 kHz
$f_{P\text{-}BSRx}$	935.1.1 MHz

The distance between primary mobile station transmitter (P-MS_{Tx}) and primary base station receiver (P-BS_{Rx}) is fixed to 1 Km and the simulation radius of secondary mobile station transmitter (S-MS_{Tx}) for random distribution around P-$BS_{Rx}$is approximately 10 metres. The probability of failure is considered 5 % for different propagation environments from prospective of comparative analysis and the reception bandwidth of secondary mobile station is 200 kHz.

Table 3: Parameters of Secondary Mobile Station Transmitter (S-MS_{Tx})

Secondary Mobile Station Transmitter (S-MS_{Tx})	
$P_{S\text{-}MSTx}$ (supplied)	33 dBm
$G_{S\text{-}MSTx}$ (max)	0 dBi
R_{simu}	0.01 km
d_0	0 km
$pattern_{S\text{-}MSTx}$	Omni-directional
$F_{S\text{-}MSTx}$	935.1/935.3 MHz

SIMULATION RESULTS

In these simulation results, impact of changing a detection threshold of the White Space Devices on interference at primary user is analysed. The simulation has been conducted in different propagation environments for unwanted interference Received Signal Strength ($iRSS_{unwanted}$), blocking interference Received Signal Strength ($iRSS_{blocking}$) and unwanted interference probability. The six cases are considered such as rural area with outdoor receiver, sub-urban area with outdoor receiver, urban with outdoor receiver, rural with indoor receiver, sub-urban with indoor receiver, and urban with indoor receiver.

Inter-Wireless Radio Environment with outdoor Receiver (DT)

The probability of interference for unwanted interference has been increasing and attaining maximum value at different detection threshold values for different wireless radio environments for outdoor primary and secondary user receiver. For rural area, unwanted interference arises at higher detection threshold value than sub-urban area and for sub-urban; it arises at higher detection threshold value than urban area. In fig.4 shows that for rural area the unwanted interference probability arises as detection threshold value increases above -60dBm and becomes constant and highest above -5 dBm. In sub-urban area, interference probability arises as detection threshold value increases above -60dBm and becomes constant and highest above -10 dBm. In urban area, interference probability arises as detection threshold value increases steeply above - 70dBm and becomes constant and highest above -15 dBm.

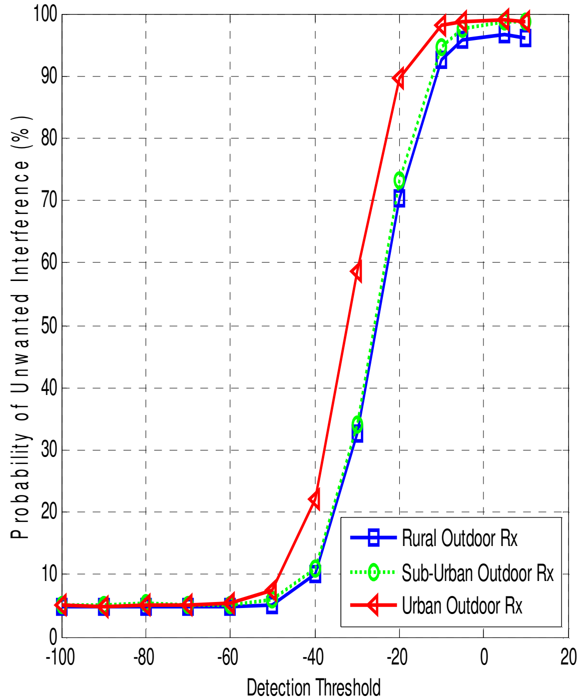

Fig.4. Probability of unwanted interference with Outdoor Receiver

Fig.5 shows, in rural area and sub urban, blocking interference probability arises as detection threshold value increases above -80dBm and becomes constant and highest above -20 dBm. In urban area, interference probability arises as detection threshold value increases steeply above -90 dBm and becomes constant and highest above --30 dBm.

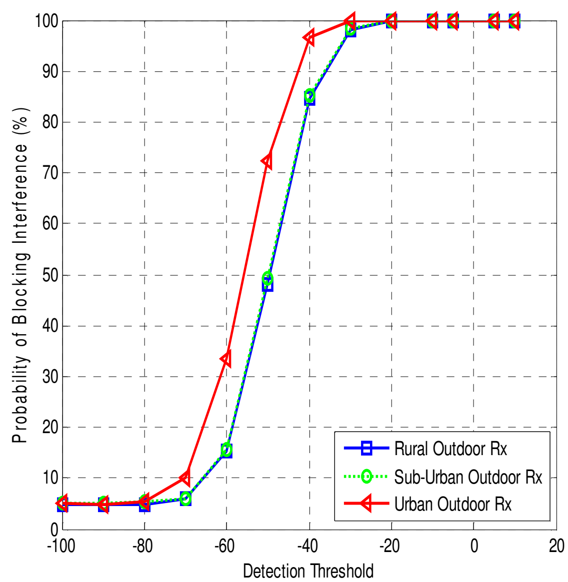

Fig.5: Probability of blocking interference with Outdoor Receiver

Inter-Wireless Radio Environment with Indoor Receiver (DT)

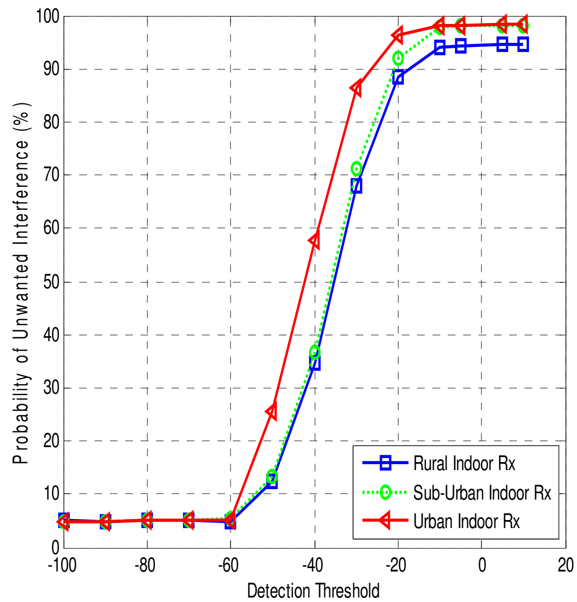

Fig.6: Probability of unwanted interference with Indoor Receiver

Fig.6 shows, in rural area, the unwanted interference probability arises as detection threshold value increases above – 60dBm and becomes constant and highest above - 10dBm. In sub-urban area, interference probability arises as detection threshold value increases steeply above -70dBm and becomes constant and highest above -20dBm. In urban area, interference probability arises as detection threshold value increases above -90dBm and becomes constant and highest above -25 dBm.

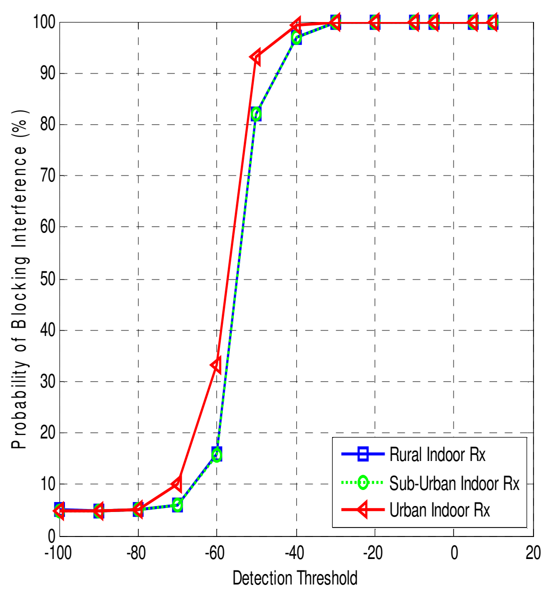

Fig.7: Probability of blocking interference with Indoor Receiver

Fig.7 shows, in rural area and sub-urban, blocking interference probability arises as detection threshold value increases above – 80 dBm and becomes constant and highest above - 30dBm. In urban area, interference probability arises as detection threshold value increases above -90 dBm and becomes constant and highest above -40 dBm. Lower the value of detection threshold lower will be the efficiency of cognitive radio.

Table 4: Value of Interference Probability (for Blocking Interference) w.r.t. Detection threshold value

Detection Threshold (dBm)	Interference Probability (%)
-50	72.46
-60	33.49
-70	10.08
-80	5.33
-90	4.94

Table 5: Value of Interference Probability (for Unwanted Interference) w.r.t. Detection threshold value

Detection Threshold (dBm)	Interference Probability (%)
-50	7.43
-60	5.31
-70	5.22
-80	5.15
-90	4.84

Table 4 and 5 shows that with the decrease in detection threshold value, the probability of blocking and unwanted interference decreases.

CONCLUSION

The interference experienced by the primary link base station receiver is also different with changing the values of detection threshold in different wireless radio environments. At highest detection threshold, the interference experienced by the base station receiver has achieved its highest value for each radio environment and the interference occurs by secondary mobile station receiver using both adjacent and co-channel in equal proportion of randomly generated events. As the detection threshold increases, then the presence of primary user is detected more precisely and the interference is reduced as the secondary user is allowed to transmit over the frequency channels used by the primary user.

In order to satisfy the picocell network, the detection threshold for rural, sub-urban and urban propagation environment should be -65 dBM, -70 dBM and -90dBM

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