Simulating Model of Switched Beam Antenna Systems for Compatibility Studies

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1. Introduction

The increasing demand for mobile communication services without a corresponding increase in RF spectrum allocation motivates the need for new techniques to improve spectrum utilisation [1]. Smart antennas offer a broad range of ways to improve wireless system performance. In general, smart antennas have the potential to provide enhanced range and reduced infrastructure costs in early deployments, enhanced link performance as the system is built-out and increased long term system capacity [2]. The demand for simulation model of smart antennas is increasing for evaluating the effect of interference between radio systems.

In this paper, the simple model of switched beam antennas that can be used in compatibility study is presented. The model is implemented in a sharing and compatibility study of two different radio systems that share the same geographical area and have adjacent frequency bands. We show that the results obtained using developed our tool agree well with the results obtained using the other tool using Monte-Carlo method.

2. Monte-Carlo Methodology

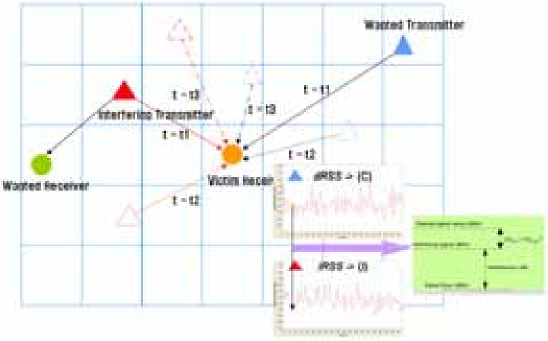


Figure 1: Example of Monte-Carlo Methodology

The statistical simulation model based on the Monte-Carlo method has been implemented in C++. Figure 1 present the example of Monte-Carlo Method and the model follows the theory presented in [3]. The Monte-Carlo method considers many independent instants in time or space. For each snapshot or simulation trial i, a scenario is built up using a number of different random variables, i.e., position of the interferers with respect to the victim, strength of the signal, which channels the victim and interferer are using, etc. The generated random variables are then being processed in order to calculate, for each trial i: the desired Received Signal Strength, $dRSS(i)$, which is the strength of the desired signal received at the Victim Receiver from the Wanted Transmitter, when there is no interference; and the interfering Received Signal Strength, $iRSS(i)$, which is the strength of a signal from the given Interfering Transmitter received at the Victim Receiver. This process is repeated M times, where M is the number of trials, chosen in such a way as to produce statistically stable results. To calculate the probability of interference, the data arrays related to the interfering mechanism, $iRSS(i)$ coming from different interferers surrounding our victim receiver are summed to build up the data array $iRSS_{\sum}(i)$ (composite Interfering Received Signal Strength), which is used in the interference probability calculation. Finally, M carrier-to-interferer ratios, $dRSS(i)/iRSS_{\sum}(i)$, are compared to a given interference criteria threshold $\left(\frac{C}{I}\right)_{th}$ to calculate the probability of interference, with the condition that the desired received signal strength is greater than the sensitivity of the Victim Receiver $(dRSS > sens)$. The probability of interference of the victim receiver is given by

$$p_I = 1 - p_{NI} \tag{1.1}$$

Where p_{NI} is the probability of non interference of the receiver. The Monte-Carlo scheme is applied individually to the numerator and to the denominator of the expression of p_{NI}. The result obtained is an estimation of p_{NI} by using the following equations [3]

$$p_{NI} = \frac{\sum_{i=1}^{M} P\left\{\frac{dRSS(i)}{iRSS_{\sum}(i)} > \left(\frac{C}{I}\right)_{th}, dRSS(i) > sens\right\}}{\sum_{i=1}^{M} P\{dRSS(i) > sens\}} \tag{1.2}$$

Where

$$P\{condition\} = \begin{cases} 1, & if\ condition\ is\ satisfied \\ 0, & else \end{cases} \tag{1.3}$$

The desired signal strength $(dRSS)$ is calculated as

$$dRSS = P_{WT} + G_{WT\to VR} - PL_{WT\to VR} + G_{VR\to WT} \tag{2}$$

Where $G_{WT\to VR}$ is the wanted transmitter antenna gain in the victim receiver direction, $G_{VR\to WT}$ is the victim receiver antenna gain in the wanted transmitter direction and $PL_{WT\to VR}$ is the path loss between the wanted transmitter and the victim receiver(propagation loss, slow fading and clutter losses taken into account).

The composite interfering signal strength is given by

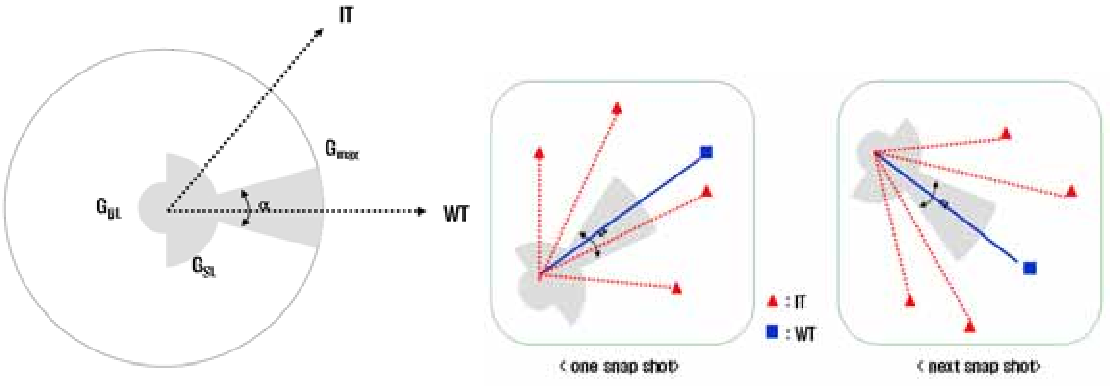
$$iRSS_{\sum} = 10\log\left(\sum_{j=1}^{N_{IT}} 10^{\frac{iRSS_j}{10}}\right) \tag{3}$$

Where the j-th interferer signal is defined as

$$iRSS_j = P_{IT} + G_{IT\to VR} - PL_{IT\to VR} + G_{VR\to IT} \tag{3-1}$$

And all the variables being defined analogously as in (2).

3. Switched Beam Antenna Model



(a) (b)

(a) Statistical Model for the Switched Beam Antenna
(b) Snap shot example using the statistical Model
Figure 2: Statistical Model for the Switched Beam Antenna

Switched beam antennas are directional antennas deployed at base station of a cell. They have only a basic switching function between separate directive antennas or predefined beams of an array. The switched beam antenna radiation pattern is time-variant and it is a function of the wanted transmitter location. The beam that covers the direction of the wanted transmitter will be switched on, while all the others are off. We introduced the statistical model to allow the user to simulate the smart antennas in Monte-Carlo statistical simulations more easily, eliminating the inconvenience of knowing the radiation pattern of all the beams [4]. Figure 2 represent the statistical model and the model replaces the active beam of the switched beam antenna and its pattern is defined by the following variables: the beamwidth α , the maximum gain $G_{\max}$, the mean gain G_{SL} modelling the mean value of the sidelobes of the active beam, and the backlobe gain G_{BL}. The user of the model has to define the value for each variable.

4. Simulation Scenario

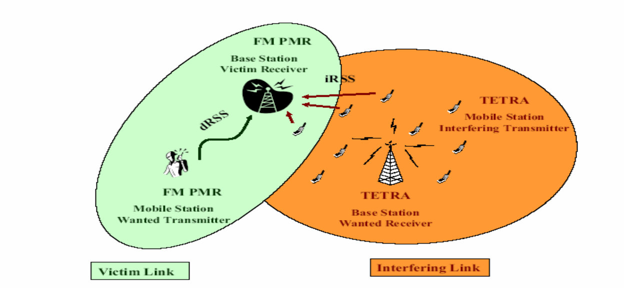


Figure 3: Simulation Scenario

The analyzed simulation scenario was taken from ERO Report 104[5] and involves a victim FM base station that operates at a frequency $f = 412.00625 MHz$, and that has an antenna with the maximum gain G_{VR} situated at the height $h_{VR} = 30m$ and covering the cell area with the radius $R_1 = 7.8km$. The wanted transmitter (WT) emits a signal of power $P_{WT} = 37dBm$ from a height $h_{WT} = 1.5m$ using an omnidirectional antenna with the gain $G_{WT} = 0dBi$ from a random position with this cell. The interfering transmitters (IT), are a population of N_{IT} TETRA mobile stations, uniformly distributed in the area around their base station, that communicate with a TETRA base station in a random frequency between 410.1875 and $411.9875 MHz$. They are all supposed to emit signals of the same power P_{IT} using omnidirectional antennas with the gain $G_{IT} = 0dBi$ at the height $h_{IT} = 1.5m$. As a worst case assumption, we may suppose that the FM base station will be based in the TETRA cell where the channel ($411.9875 MHz$) operating close to the edge of the TETRA band is used. Figure 4 represents the probability of interference as a function of interfering transmitter power. The number of events in the Monte-Carlo simulations was set to 20000 and the probability of interference is calculated for interfering transmitter power ranging from 0dBm to 160dBm. The blue line is the results obtained from our tool, and the black line the results from SEAMCAT [6]. Our results agree very well with the reference ones, which validates our C++ code. The parameters of the statistical model were as follows. Since in each of the three sectors, four switched beam antenna is used, the beamwidth was set to $\alpha = 30^\circ$. The maximum gain has

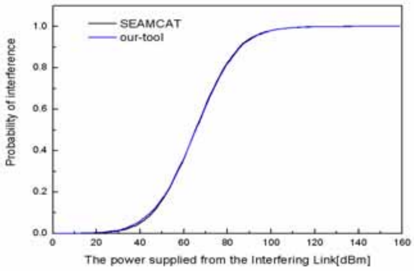


Figure 4: Results obtained using our tool

been computed as the mean value of the main lobe gains of all four measured beams within the beamwidth $\alpha : G_{\max} = -2.5dB$. The same for the mean sidelobes level: $G_{SL} = -20dB$. For the backlobe level, the value of $G_{BL} = -40dB$ has been used, as it is supposed for the switched beam antenna to be mounted on a mast. The results are shown in Figure 5. This shows probability of interference as a function of interfering transmitter power for the above explained simulation scenario with $N_{IT} = 9$ interferers. It can be seen from this figure that the probability of interference decreases significantly when switched beam antennas (with four beams) are used instead of traditional three-sector directional antennas.

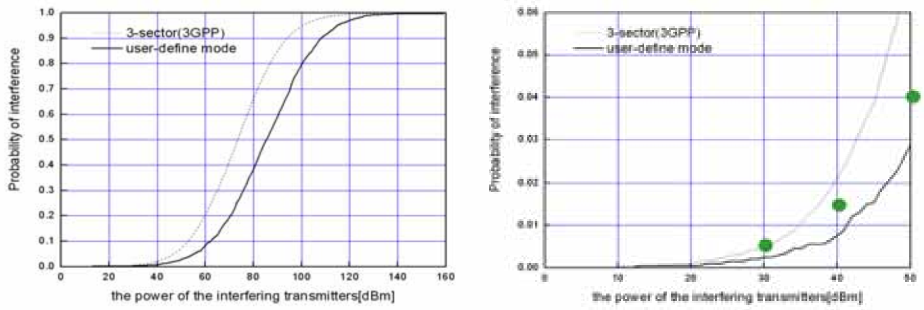


Figure 5: The probability of interference in the victim receiver as a function of the power of the interfering transmitters with statistical model

5. Conclusions

The software simulator is developed to evaluate the effect of co-channel and adjacent channel interference of the smart antenna system using Monte Carlo methodology. The simple model is implemented that allow the user to simulate the switched beam antenna more easily and the tool is verified by other tool. Also this model is applied to any simulation scenario. We can confirm the probability of interference decreases significantly when switched beam antennas are used instead of traditional three-sector directional antennas. This model can be used to analyze the compatibility possibility of the smart antenna system for frequency allocation.

Acknowledgments

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