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Applying Beamforming to LTE Base Station for Reducing Interference Impact and Saving Frequency

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Abstract

This paper assumes that Long Term Evolution (LTE) will be deployed in TV White Spaces (TVWSs). Beamforming is a technology that is applied to an LTE base station (BS) for reducing interference impact of LTE on DTV. A simulation method based on Monte Carlo is proposed to evaluate the interference probability in DTV receivers in the case of interference impact of LTE BS on DTV receiver. As per simulation results, the interference impact of LTE BS on DTV receiver is efficiently mitigated and the guard band remarkably reduced when LTE BS uses beamforming.

Keywords*: Long Term Evolution (LTE); TV White Spaces (TVWSs); Beamforming; DTV; Interference Probability*

1. Introduction

TV White Spaces (TVWSs) is a spectrum freed up by the FCC when the U.S. transitioned from analog television to Digital Television (DTV). Because TVWSs are located in the VHF and UHF bands, TVWSs have several important properties that make them highly desirable for wireless communications systems, such as excellent propagation, ability to penetrate buildings and foliage, non-line of sight connectivity and broadband payload capacity [1]. Therefore, TVWs can be allocated to potential wireless communication systems. This paper assumes that Long Term Evolution (LTE) will be deployed in TVWSs. However, the compatibility between LTE and DTV in DTV bands has to be taken into account. In this paper, only interference from LET base stations (BSs) to DTV is considered. Beamforming, as one of interference mitigation techniques, shall be applied to LTE BS for reducing impact of interference on DTV and saving frequency. On the basis of this assumption, the performance of DTV receiver is evaluated using Monte Carlo method.

2. Proposed Simulation Method

The interference probability is chosen as the criteria to evaluate the performance of DTV receivers (Rx). Referring to the principle of calculation of the interference probability in victim, which is referred to as the interfered system in Spectrum Engineering Advanced Monte Carlo Analysis Tool (SEAMCAT) [2], the interference probability (P_I) in DTV Rx can be calculated as

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$$P_I = 1 - P_{NI} \tag{1}$$

Where P_{NI} is the probability of non-interference (NI) in DTV receiver.

In the case of LTE interfering with DTV, the ratio of the desired received signal level (C) in DTV Rx to the received interfering signal level (I) in DTV Rx is chosen as the protection criteria. Therefore, P_{IN} is defined as

$$P_{NI} = P\left((C/I)_{trial} > (C/I)_{criteria} \,\middle|\, C_{trial} >= Sensitivity\right) \tag{2}$$

Where $(C/I)_{trial}$ is one trial C/I. $(C/I)_{criteria}$ represents the protection criteria of DTV receiver, C_{trial} is desired received signal strength in DTV at one trial and sensitivity is the sensitivity of DTV Rx.

By definition of P(A|B)=P(A∩B)/P(B), PNI becomes

$$P_{NI} = \frac{P\left((C/I)_{trial} > (C/I)_{criteria}, C_{trial} >= Sensitivity\right)}{P(C_{trial} >= Sensitivity)} \tag{3}$$

Because LTE BS uses beamforming in the scenario of LTE interfering with DTV Rx, only the interference of LTE BS into DTV Rx is analyzed. $(C/I)_{trial}$ in DTV Rx can be expressed as follows

$$\left(C/I\right)_{\substack{trial \\ LTE\ BS \to DTV\ Rx}} = \frac{Desired\ signal\ in\ DTV\ Rx}{\sum_{j=1}^{n}\sum_{i=1}^{N}\left(10^{\frac{P_{BS_i}}{10}} \times 10^{\frac{G(Beamformig)_{j,\ Between\ BS_i\ and\ DTV\_Rx}}{10}} \times 10^{-\frac{PL(d_i)}{10}} \times 10^{-\frac{Shaowing(\xi_i)}{10}}\right)} \tag{4}$$

Where considering the worst case, DTV Rx is assumed to be located at the edge of DTV transmitter coverage. Therefore, sensitivity of DTV Rx is used as the minimum desired received signal level in DTV Rx. The j represents the number of the jth MS_j in each LTE Cell and the i represents the number of the ith BS_i in each LTE cell. P_{BSi} is the transmit power of the ith LTE BS_i. PL(di) is path loss (PL) corresponding to the ith path loss from the ith BS_i to DTV Rx. The ξ_i is the distortion due to shadowing between the ith BS_i and DTV Rx.

Equation (5) represents the jth beamforming gain from the ith LTE BS_i to DTV Rx, which is determined by the jth LTE MS_j in each LTE cell.

$$G(Beamformig)_{j,\ Between\ BS_i\ and\ DTV\_Rx} = G_{HB_i}(\theta_{HRx}) + G_{VB_i}(\phi_{VRx}) + G_{HRx}(\theta_{HB_i}) + G_{VRx}(\phi_{VB_i}) \tag{5}$$

Where the symbol $G_{HBi}(\theta_{HRx})$ represents the horizontal antenna gain of the ith LTE BS_i toward θ_{HRx}, where θ_{HRx} is direction of DTV Rx from the ith LTE BS_i in horizontal direction. The symbol $G_{VBi}(\phi_{VRx})$ represents the vertical antenna gain of the ith LTE BS_i toward ϕ_{VRx}, where ϕ_{VRx} is the vertical direction from LTE BS_i to DTV Rx. In the same way, $G_{HRx}(\theta_{HBi})$ represents the horizontal antenna gain of DTV Rx toward θ_{HBi}, where θ_{HBi} is the horizontal direction from DTV Rx to BS_i. The symbol $GVRx(\phi_{VBi})$ is the vertical antenna gain of DTV toward ϕ_{VBi}, where ϕ_{VBi} is the vertical direction from DTV Rx to BS_i [3].

3. Simulations and Results

In the scenario of LTE BS interfering with DTV Rx, the 19-cell LTE structure is assumed. Frequency reuse is not applied in this study. 24 LTE mobile stations (MSs) in

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each LTE cell are assumed to be active. In comparing the performance of DTV Rx between the case of LTE BS applying beamforming and the case of LTE BS without applying beamforming, the simulations will be implemented in two cases as follows:

Case 1: Beamforming technology is applied to LTE BS

Case 2: Beamforming technology is not applied to LTE BS

Calculation process in the case of LTE BS interfering with DTV Rx is summarized as follows:

(1) Calculate distance and angle between the ith LTE BSi in the ith LTE cell and the DTV Rx.

(2) Calculate angle between the ith LTE BSi and the jth LTE MSj in the ith LTE cell.

(3) Calculate angle difference between angle between the ith LTE BSi in the ith LTE cell and the DTV Rx and angle between the ith LTE BSi and the jth LTE MSj in the ith LTE cell.

(4) Calculate the beamforming gain for the direction of the ith LTE BSi torward DTV Rx.

(5) Calculate Path loss from the ith LTE BSi to DTV Rx.

(6) Calculate the effect of shadowing.

(7) C/I calculation for case 1 and case 2.

(8) Calculate the interference probability in DTV Rx for case 1 and case 2.

The parameters for simulation are summarized in Table 1 and Table 2, respectively.

Table 1. LTE Parameters for Simulation

Parameters	value
Frequency	DL:579MHz, UL:595MHz
Bandwidth	10 MHz
Transmit power of LTE BS	46 dBm
Antenna height of LTE BS	32 m
LTE BS emission mask	CEPT report 40 [4]
Transmit power of LTE MS	-30 dBm~ 24dBm
Antenna height of LTE MS	1.5 m
LTE cell radius	1 km
Propagation model	Macro cell propagation model, Urban [5]
The number of LTE BS: N	19
The number of LTE MS in each LTE cell: n	24
Standard deviation of shadowing σ	6.5

Table 2. DTV Parameters for Simulation [6]

Parameters	value
Frequency	587 MHz
Bandwidth	6 MHz
Sensitivity of DTV Rx	-83 dBm
Antenna height of DTV Rx	10 m

Figure 1 shows one simulation status wherein 24 MSs are randomly distributed in each LTE cell when snapshot is 1 and the separation distance between the central LTE BS (the reference LTE BS) is 500 m.

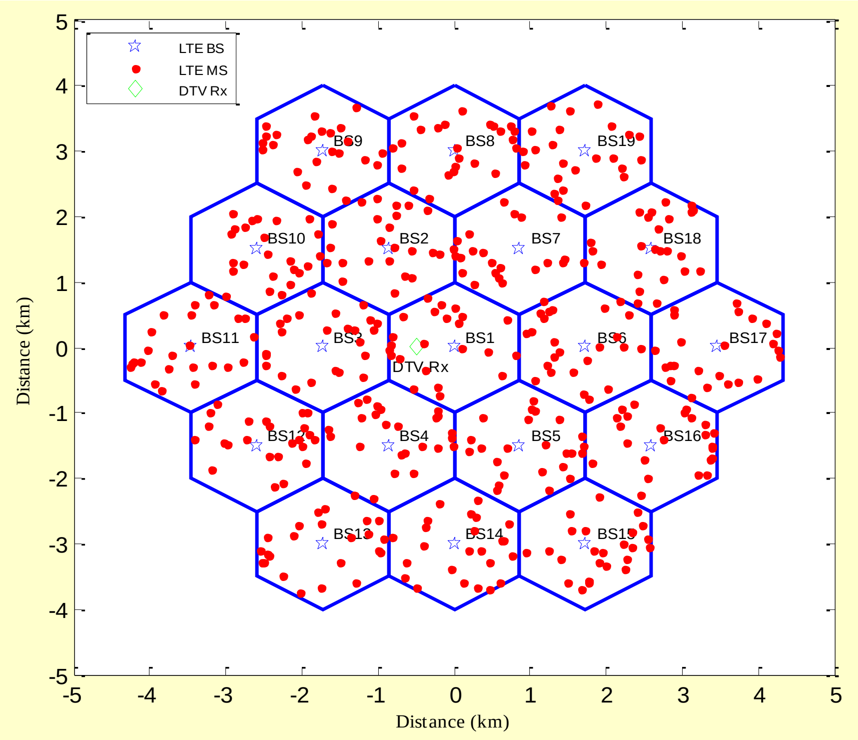

Figure 1. Simulation Status

According to the LTE BS emission mask [4], the guard band of 0 and 10 MHz are respectively selected, and the interference probability in DTV Rx and the maximum allowable transmit power of LTE BS are respectively evaluated along with the increase of separation distance between DTV Rx and the reference LTE BS.

Figure 2 shows when LTE BSs are transmitting signals at the maximum allowable transmit power of 46 dBm, and at a certain separation distance, after LTE BSs use beamforming; it is obvious that the interference probability in DTV Rx can be efficiently decreased, and the guard band can be significantly reduced when DTV Rx locates within LTE network.

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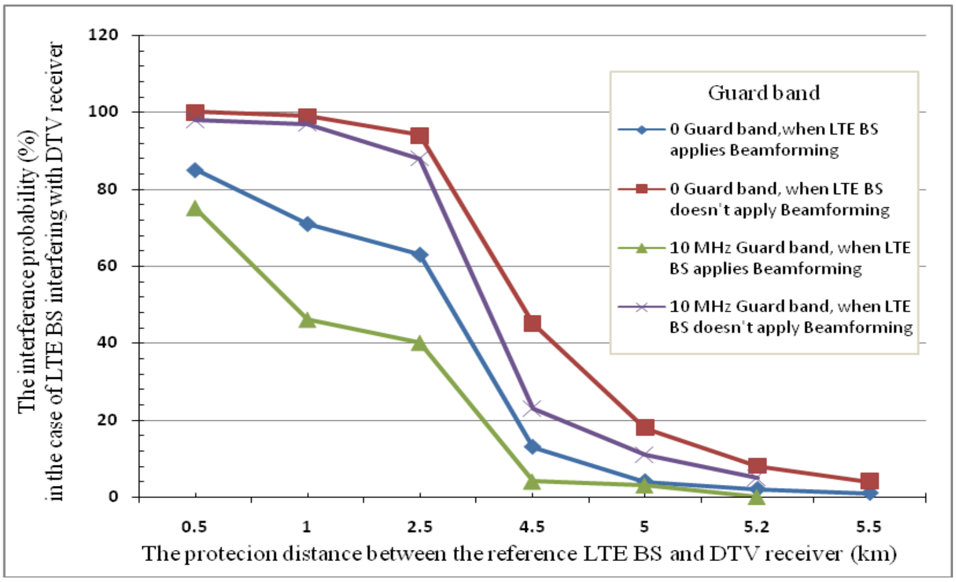

Figure 2. The Relationship between the Interference Probability in DTV Rx and the Separation Distance between the Reference LTE BS and DTV Rx

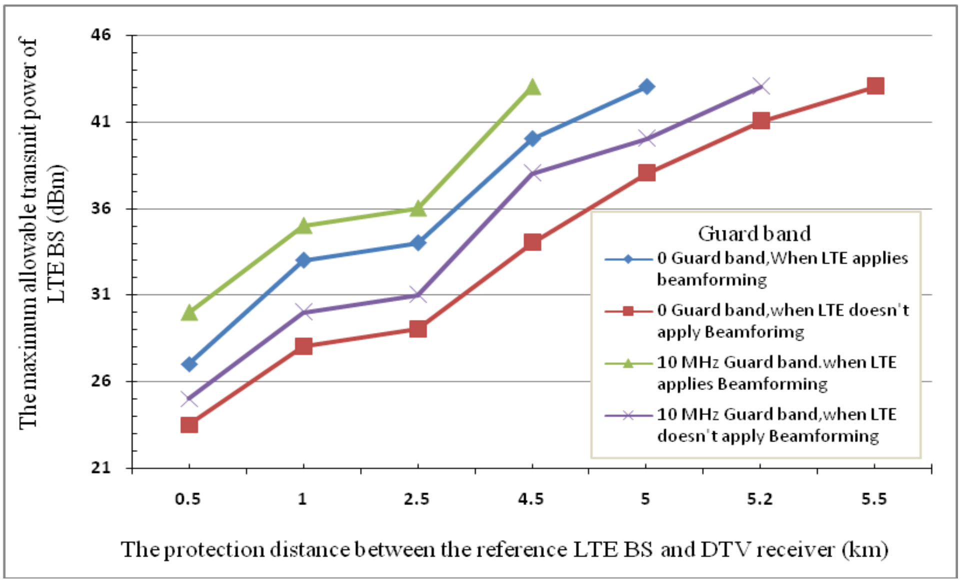

Figure 3. The Relationship between the Maximum Allowable Transmit Power of LTE BS and the Separation Distance between DTV Rx and the Reference LTE BS

Figure 3 shows that if the interference probability of 5% in DTV Rx is acceptable, the corresponding maximum allowable transmit power of LTE BS can be figured out when the different guard bands are defined and the different separation distances between DTV Rx and the reference LTE BS are required. Comparing to the maximum allowable transmit power of LTE in the case of LTE BS without applying beamforming, about 5 dB of the maximum allowable transmit power of LTE in the case of LTE BS applying beamforming can be improved to meet the interference probability of 5%.

4. Conclusions

LTE was assumed to be deployed in TVWSs. For reducing interference from LTE BS to DTV Rx and reducing the guard band for saving frequency, beamforming was assumed to be applied by LTE BS. On the basis of this assumption, a simulation method was proposed to evaluate the interference probability in DTV Rx impacted by LET BS with or without beamforming. As per simulation results, after LTE BS applies beamforming, the impact of interference from LTE BS in DTV Rx was efficiently decreased, and the guard band can be significantly reduced, namely, saving the precious frequency when DTV Rx locates within the LTE network.

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