INDOOR TO OUTDOOR PROPAGATION MODEL IMPROVEMENT FOR GSM900/GSM1800/CDMA-2100

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Abstract

This paper presents a modified indoor to outdoor propagation model based on empirical techniques. The proposed model improves the accuracy of the COST 231 model [8] and valid for GSM 900, GSM 1800 and CDMA 2100. While generated model deviates from measurements by at most 8dB, theory and measurements are in good track. Generated model includes building structures as well as frequency dependence.

1. Introduction

Mobile communication has becoming more popular with the help of rapidly growing new wireless technologies. Due to the increasing the number of the speech and data users, the wireless network operators tends to increase the number of their indoor base stations and femtocells instead of macro base stations. Today, the most commonly used examples of femtocells are hotels, malls, hospitals, airport buildings, factories, etc.

On the other hand, in the city centers, increasing the number of indoor base stations leads to increase indoor to outdoor interference which must be taken into consideration when designing wireless network, especially in dense urban areas. In literature, there are studies about indoor propagation [1], outdoor to indoor propagation loss calculations [2- 5], but there are a few studies considering about indoor to outdoor propagation [6-7]. The experimental setup of Valcarce and Zhang [6] for indoor to outdoor model was locating femtocell transmitter next to the window. This scenario does not have capability to satisfy the goal, because, their transmitter is not located deeper into the building. Another study P.Kyösti's the WINNER project [7], the behavior of microcells ware investigated by using indoor to outdoor measurement data and a new formula was suggested with the help of the COST231 model [8]. However, lower frequencies such as GSM900 were left out of the model.

In this study, test microcell with one indoor omni antenna was installed in the second floor of a building and indoor to outdoor propagation loss was measured along the outer periphery of a building at GSM900, GSM1800 and CDMA 2100. A new indoor to outdoor empirical penetration formula has been derived from outdoor to indoor propagation model [4]. In the calculations, floor height gain (G_{FH}, dB/floor) has been taken into consideration.

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2. Mathematical Background and Methodology

Radio waves transmitted by indoor microcell propagate inside the building, penetrate the building external wall, and reach to the receiver, respectively. The propagation loss formula derived from COST231 [8] has been predicted in the following.

$$\Delta Loss = Loss(in) + Loss(out) \quad (1)$$

$$\Delta_{Loss} = W_e + W_{ge} + \max(\Gamma_1, \Gamma_3) + G_{FH} + 10.81\sqrt{f} - 9.51 \quad (2)$$

$$\Gamma_1 = W_i \times p \quad (3a)$$

$$\Gamma_3 = \alpha \times d \quad (3b)$$

where f is the frequency in GHz, Loss(in) is the propagation loss inside the building, Loss(out) is propagation loss outside the building, "W_e" is the loss because of perpendicular penetration at an external wall, and the value of "W_e" is 4-10 dB (concrete with normal-size window: 7dB ; wood: 4dB.) "W_{GE}" is the loss at the external wall angle dependent loss which comes from COST231 [3- 7]. The value of "W_{GE}" is 3-5 dB at 900 MHz and 5-7 dB at 1800 MHz and 7-8 dB at 2100 MHz. The term "W_i" is the loss in the internal walls, and the value of "W_i" is 4-10 dB(concrete with normal-size window: 7dB ; wood: 4dB). "ρ" is the number of penetrated walls, " $\propto$ " is the penetration coefficient that equals to 0.6 dB/m. The term "d" is the penetration distance and "G_n" is 4-7 dB/floor when the floor height is 4-5mt [3]. In order to include the affects of frequency, frequency has been added as $10.81\sqrt{f} - 9.51$ (f in GHz). The structural characteristic of the building determines W_e, α, W_i, and presented in Table 1. [3]

Table 1. The Parameter Values used in calculations

We	Wge			α	Wi	GFH
	GSM900	GSM1800	CDMA2100			
7	6	7	7	0.6	7	5

3. Test Setup and Test Environment

The transmitter (brand name is Andrew) holding a CELLMAX-O-25 omni-directional antenna operating between 806MHz-2100MHz was used as a measurement setup. Certain frequencies at GSM900, GSM1800 and CDMA 2100 were selected. Transmitting antenna was located at ceiling of the second floor having an output power of 21dBm. Nemo-Handy software loaded Nokia N95 mobile phone was used as a radio receiver as well as GPS receiver.

Table2. Transmitter Details

Frequency Range	900-1800-2100 Mhz
Power	+21dBm
Transmitter antenna height	2,5 mt
Receiver antenna height	1.5 mt

Measurements have been conducted in the building of Industrial and Medical Based Microwave Research Center located in Akdeniz University campus. Transmitter and receiver locations are shown in Fig. 1.

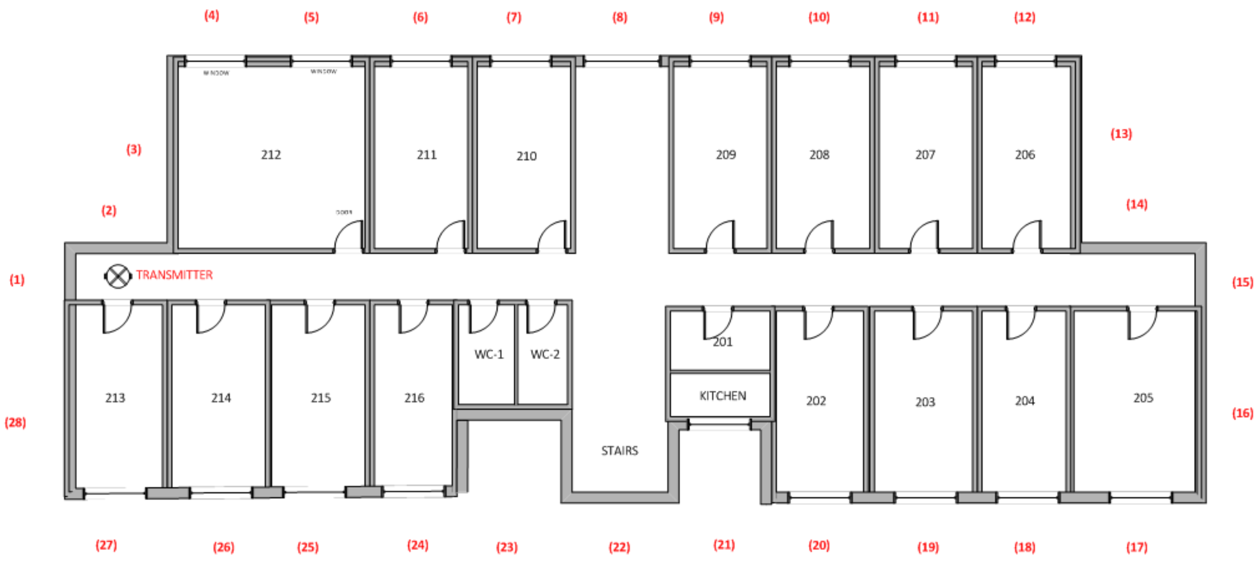
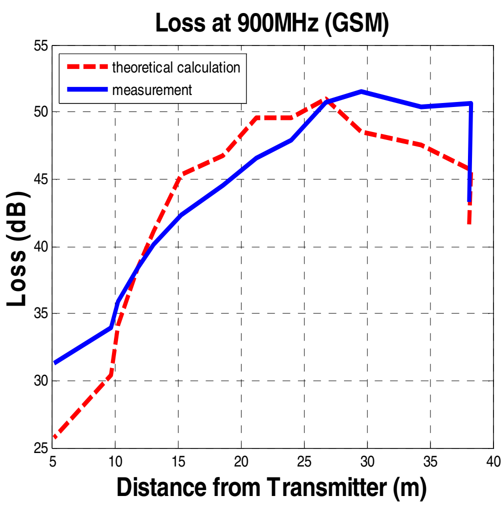


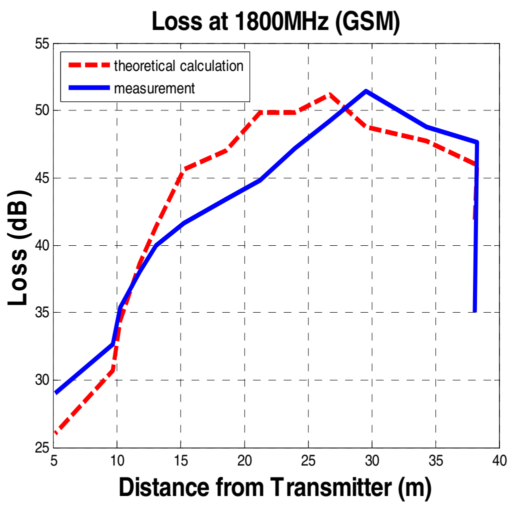
Figure1. Measurement Environment

4. Results

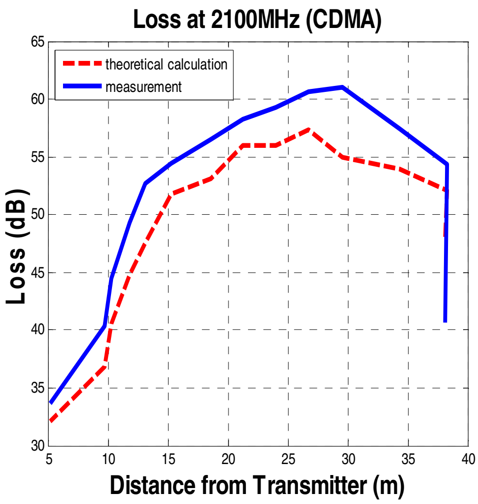
Results represent that theory and measurements are good in track of each other. Model predicts 900MHz radio propagation in the range of about 3dB deviation, 1800MHz in 4dB deviation and at most 8dB deviation at CDMA-2100, respectively. Sudden decrease of signal level around far point corner can also be predicted very well as in real measurements. The success of the proposed model is shown in Fig 2d. Fine tuning will most probably decrease this deviation, and much better model will be obtained.



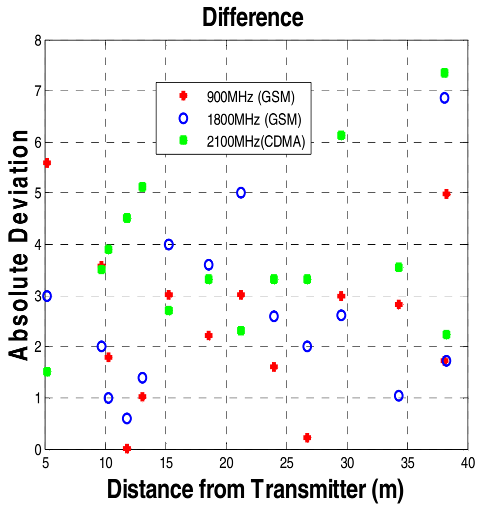
(a) 900 MHz(GSM)



(b) 1800 MHz(GSM)



(c) 2100 MHz (CDMA)



(d) Deviation from Model

Figure2. a)Generated model and measurements at 900MHz, b)Generated model and measurements at 1800MHz, c)Generated model and measurements at CDMA2100, and d) Deviation from Model.

5. Conclusion

Increasing mobile video and data requirements result in establishing indoor antennas especially in hospitals, malls and university buildings. These new type of indoor base stations called femtocells or microcells, start to interfere outdoor signals, and operators need more affective indoor to outdoor propagation models. This study presents a new model taking care of building structures as well as frequency effects.

6. Acknowledgement

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