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MATERIALS' INSERTION LOSS IN THREE FREQUENCY BANDS

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Abstract—The insertion loss of different materials is measured at 2.4, 3.3 and 5.5 GHz bands. Directive antennas with a nominal gain of 19 dB are used in the measurement campaign. The height of the antennas has been selected to have the minimum possible reflection from around surfaces. Thick concrete wall, thick concrete column and tree's insertion loss are measured. It is noticed that the insertion loss increases with the increment of the operating frequency. For tress, the insertion loss for the leafless tress is 6 to 10 dB lower than the deciduous trees.

1. INTRODUCTION

In indoor communications and localization, propagation loss measurements due to different phenomenon are very important [1, 2]. Possible mechanisms of propagation are free space with and without multipath, transmission through materials, walls, floors, and diffraction.

In [3–5], the propagation loss is given for different scenarios and mechanisms. In [6], the effect of metal door on the indoor radio channel received signal has been studied. Three frequency bands namely, (850–950) MHz, (2.4–2.5) GHz and (5.1–5.3) GHz have been used in the measurement campaign. It has been noticed that the door attenuation is higher than 40 dB at the 5.2 GHz band. In [7], the outdoor-to-indoor propagation loss measurements for broadband wireless access in rural areas are given. In [8], materials' insertion loss at 2.4, 3.3 and 5.5 GHz bands has been presented.

The main objective of this study is to present the propagation loss due to different materials at the 2.4, 3.3 and 5.5 GHz bands. These frequencies have been chosen because they present the frequencies at

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which WiFi and WiMAX work. The measured data would be very helpful to understand propagation losses at these bands.

2. MEASUREMENT SYSTEM

A Network Analyzer (6 GHz ZVL of Rohde & Schwarz) has been used to measure the propagation loss at the three (2.4, 3.3 and 5.5) GHz bands. Calibration has been carried out with low loss cables up to 20 m long depending on the studied scenario. Directional panel antennas with a nominal gain of 19 dB have been used in the measurements. The distance between the transmitting antenna and the object was 1 meter or more to assure that the object is at the far field of the antenna. The transmitted power in all of the measurements was 20 dBm with a measurement dynamic range of almost 100 dB. In each band, there is atone at each 1 MHz. Averaging has been used to remove fast fading. The height of the antennas has been selected to have the minimum possible reflection from around surfaces illuminating the surface by only the side lobes (at an angle higher than 30°). Antennas are adjusted mechanically to have a vertical or horizontal polarization. Calibration has been carried out for horizontal-horizontal polarization of transmitting and receiving antennas and vertical-vertical polarization of transmitting and receiving antennas.

3. INSERTION LOSS OF CONCRETE WALL

First of all, the insertion loss of $(4 * 2.4 * 0.63)$ m concrete wall will be given. The wall is a concrete wall covered by bricks on both sides of it as shown in Fig. 1. Measurements have been carried out at 24 different points within the wall. Then the average value and the standard deviation of the insertion loss (due to the 24 different points of measurement) are calculated at each tone within the band.

Figures 2 to 3 show the average value and the standard deviation from the average value of the insertion loss at the three frequency bands for horizontal and vertical polarization. It can be noticed that the insertion loss is the lowest at the 2.4 GHz and the highest at the 5.5 GHz band. Insertion loss of 18 dB has been measured at the 5.5 GHz band at the horizontal polarization while an insertion loss of almost 16 dB has been measured at the 5.5 GHz band at the vertical polarization. The difference between the measured values of the insertion loss at vertical and horizontal polarization is due to the fact that the covering bricks are horizontally oriented as can be seen in Fig. 1. In [9], a plasterboard wall insertion loss of 4.8 dB has been reported. Our wall has a higher thickness in comparison with the plasterboard wall. Thus,

Figure 1. Picture of the studied wall.

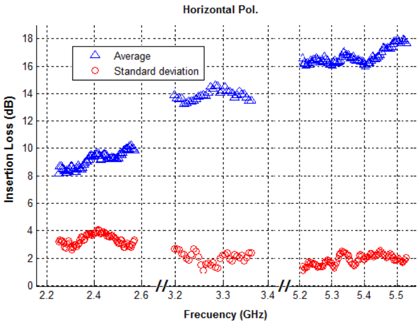

Figure 2. Wall insertion loss at horizontal polarization.

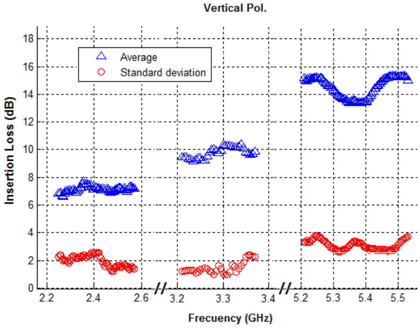

Figure 3. Wall insertion loss at vertical polarization.

Figure 4. Picture of the studied column.

the insertion loss of our wall is higher than that of the plasterboard wall.

4. INSERTION LOSS DUE TO CONCRETE COLUMN

Figure 4 shows a picture of the studied $(50 * 50 * 280)$ cm column.Measurements have been done at 10 different points at a vertical line. Here the received signal is due to the through signal and the diffracted signal.

Propagation through loss with the added diffraction loss is shown in Figs. 5 to 10. It can be noticed easily that the loss increase with the increment of the operating frequency and that the effect of the polarization is marginal. Also it can be noticed that increasing the

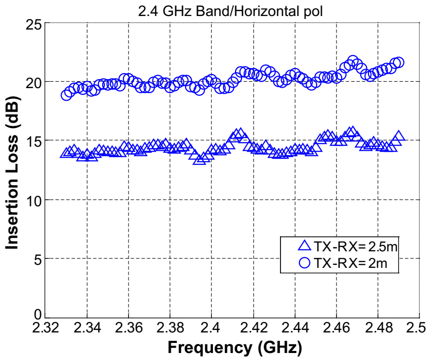

Figure 5. Column insertion loss at horizontal polarization at 2.4 GHz band.

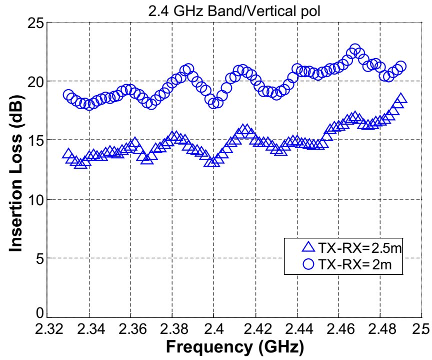

Figure 6. Column insertion loss at vertical polarization at 2.4 GHz band.

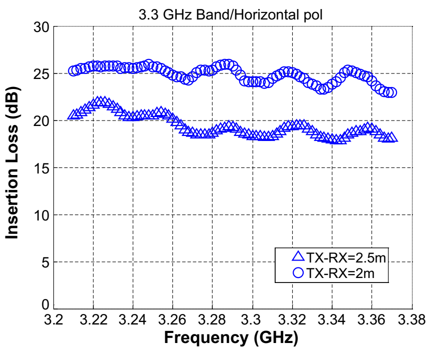

Figure 7. Column insertion loss at horizontal polarization at 3.3 GHz band.

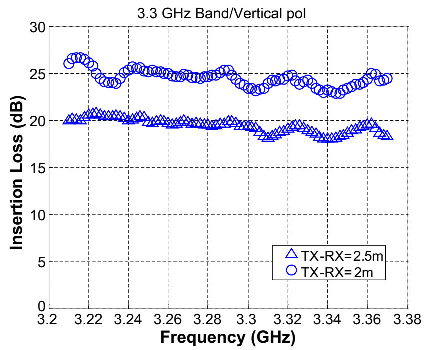

Figure 8. Column insertion loss at vertical polarization at 3.3 GHz band.

distance between the transmitting and receiving antennas reduces the insertion loss. This is due to the fact that the received signal is the sum of the penetrated signal and the diffracted signal from the column. The power of the diffracted signal will be relatively higher be when the distance between the column and the receiving signal is increased (calibration is also done at higher distance).

5. INSERTION LOSS DUE TO TREES

Figure 11 shows the dimensions of the studied tree. Measurements have been done at the center of the canopy zone. Figs. 12 to 14 show the

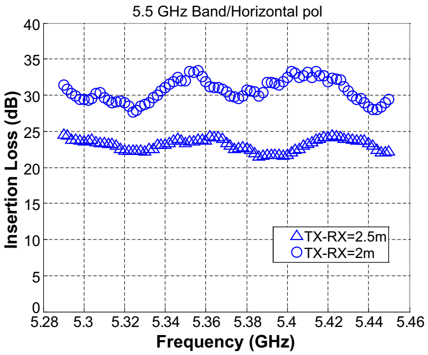

Figure 9. Column insertion loss at horizontal polarization at 5.3 GHz band.

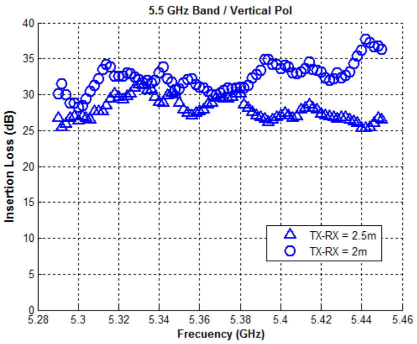

Figure 10. Column insertion loss at vertical polarization at 5.3 GHz band.

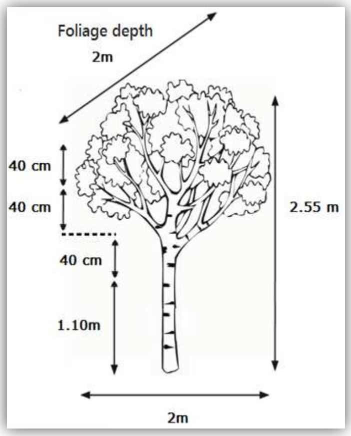

Figure 11. Dimensions of the studied tree.

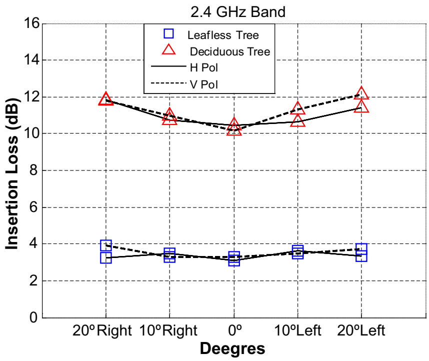

Figure 12. Tree's insertion loss at 2.4 GHz.

measured insertion loss at different horizontal receiving angles. It can be seen easily that the insertion loss increase with the increment of the operating frequency and that the leafless trees have lower insertion loss. Also it can be seen that the effect of the polarization is marginal. An insertion loss difference of 10 dB can be noticed between the leafless tree and the same tree with leaf. In [8], results dealing with only deciduous trees have been presented.

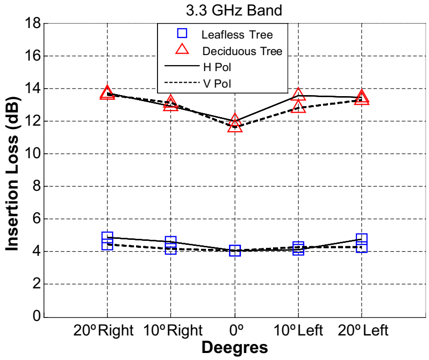

Figure 13. Tree's insertion loss at 3.3 GHz.

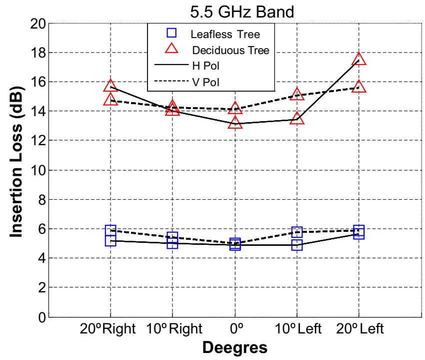

Figure 14. Tree's insertion loss at 5.5 GHz.

6. CONCLUSIONS

The insertion loss of different materials has been measured at 2.4, 3.3 and 5.5 GHz bands. Thick concrete wall, thick concrete column and tree‘s insertion loss has been measured at vertical and horizontal polarization. It has been noticed that the insertion loss increases with the increment of the operating frequency. Also it has been noticed that, for tress, the insertion loss for the leafless tress is 6 to 10 dB lower than the deciduous trees.

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