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PROPAGATION LOSS MEASUREMENT DUE TO MISCELLANEOUS PHENOMENON AT 5.6 GHz BAND

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Abstract—In this work, the propagation loss due to diffraction and insertion losses for indoor scenario at 5.6 GHz band are measured using directive antenna and a Vector Network Analyzer (VNA). It is shown that the insertion loss of a metallic door with porthole window varies from several dB due to the propagation loss via the porthole glass up to 50 dB due to the diffraction by the porthole boards when the line between the transmitting antenna and receiving one is outside the porthole glass. It is shown that the insertion loss of a 12 cm brick wall is 4.8 dB for vertical polarization while it is 6.3 dB for horizontal polarization. Also it is shown the diffraction loss due single or double concrete columns depends on the distance between the transmitting and receiving antennas.

1. INTRODUCTION

In indoor communications and localization, propagation loss measurement due to miscellaneous phenomenon is of vital importance [1, 2]. Possible mechanisms of propagation are free space with and without multipath, transmission through walls and floors, and diffraction.

In [3–5], the propagation loss is given for different scenarios. In [6], an empirical model for indoor propagation prediction has been introduced. In [7], a prediction of propagation characteristics in indoor radio communication environments has been given. A semi empirical approach and the analytical model on how to predict the total path loss in various indoor communication links, taking into account the new analytical methods of the derivation of the fading phenomenon between floors and along corridors have been given. In [8], a geometrically based channel model for indoor radio propagation with directional antennas

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has been given. In [9], a geometry-based statistical model for radio propagation in rectangular office buildings has been presented. In [10], the human body shadowing variability in short-range indoor radio links at 3–11 GHz band has been presented. A shadowing of 30 dB at 5.5 GHz can be experienced when a person cuts the LOS between the transmitting antenna and the receiving one. In [11], the effect of metal door on indoor radio channel has been studied. It has been noticed that the door attenuation is higher than 25 dB at the 5.2 GHz band. In [12], a combination of the ray optical and FDTD methods has been used to calculate the indoor propagation loss.

The main objective of this study is to present the propagation loss due to diffraction and insertion loss for indoor scenario at the 5.6 GHz band. The measured data would be very helpful to understand propagation losses at 5.6 Band, especially, for the environments where the objects considered in the measurements are important.

2. MEASUREMENT SYSTEM

A Network Analyzer (6 GHz ZVL of Rohde & Schwarz) has been used to measure the propagation loss at the 5.6 GHz band. Calibration has been carried out with a 10 m cable. The gain of the directional patch antennas with a nominal gain of 19 dB, 11 dB and 8 dB used in the study has been measured with an error lower than 0.1 dB using the standard method (by comparison of received power between the measured antenna and a calibrated standard horn antenna). Its practical gain was only 0.2 dB from the nominal one. It is believed that the measurement error is lower than 0.5 dB. The transmitted power in all of the measurements was 10 dBm with a measurement dynamic range of almost 100 dB.

3. PROPAGATION THROUGH A METALLIC DOOR WITH PORTHOLE WINDOW

Figure 1 shows the metallic door with the porthole window. Measurements are given at 9 different points around and at the center of the porthole window with 25 cm diameter. The transmitting antenna was located 2 m from the metallic door. On the opposite side of the door, the receiving antenna was located also at 2 m from it. With the door totally open, calibration has been done (setting 0 dB reference level for free space propagation).

Figure 2 shows the propagation loss at the nine points of measurements using two directional antennas with a gain of 19 dB and horizontal polarization. It can be noticed that the minimum

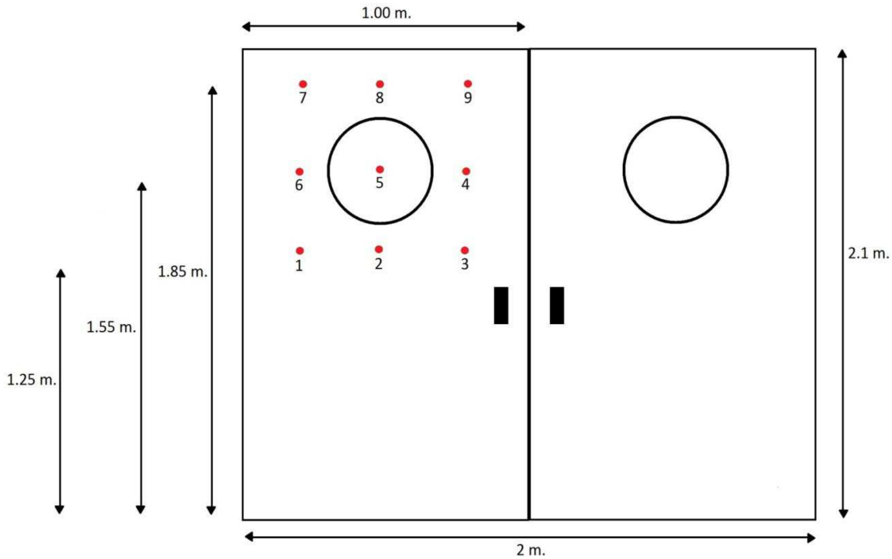


Figure 1. Metallic door with two porthole windows.

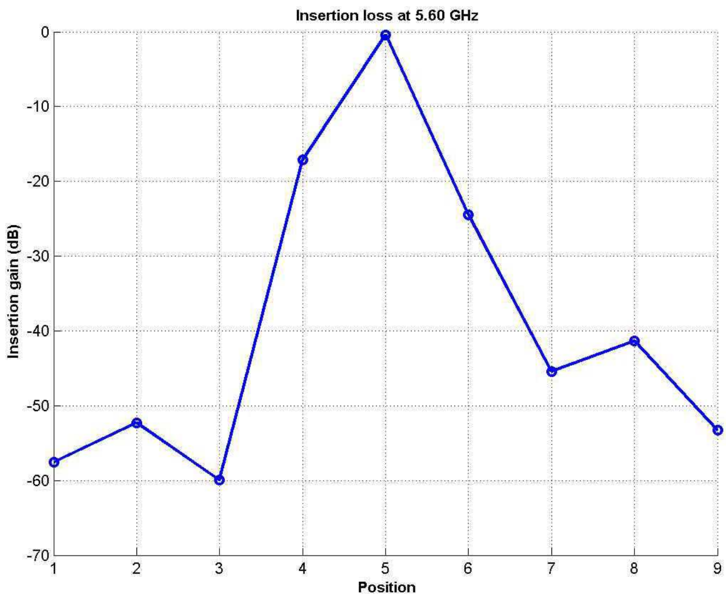


Figure 2. Insertion gain with horizontal polarization using two antennas with a gain of 19 dB.

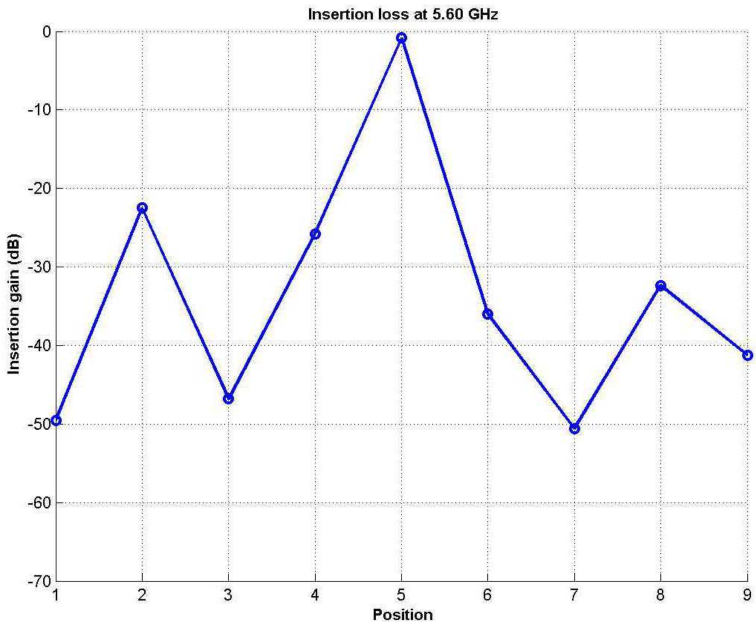


Figure 3. Insertion gain with vertical polarization using two antennas with a gain of 19 dB.

propagation loss is due to the point 5 with 0.4 dB final propagation loss due to the propagation through the very fine glass of the porthole window and the diffraction from the edge of the porthole window. The worst point is 3 with a propagation loss of 60 dB.

Figure 3 shows the propagation loss at the nine points of measurements using two directional antennas with a gain of 19 dB and vertical polarization. It can be noticed that the minimum propagation loss is due to the point 5 with 0.85 dB final propagation loss due to the propagation through the very fine glass of the porthole window and the diffraction from the edge of the porthole window. The worst points are 1 and 7 with a propagation loss of 50 dB.

Figure 4 shows the propagation loss at the nine points of measurements using two directional antennas with a gain of 11 dB and 8 dB respectively using the horizontal polarization. It can be noticed that the minimum propagation loss is due to the point 5 with 1.47 dB final propagation loss due to the propagation through the very fine glass of the porthole window and the diffraction from the edge of the porthole window. The worst point is with a propagation loss of 30 dB. The lower value of the propagation loss far away from the point 5

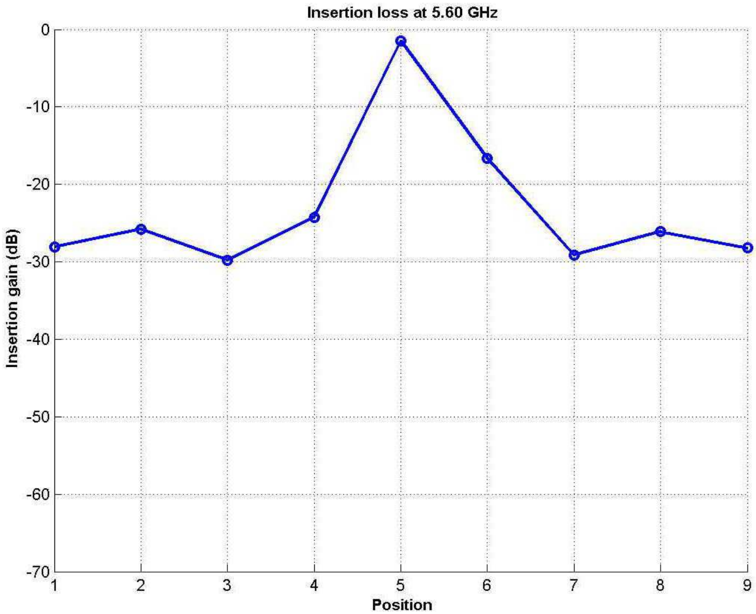


Figure 4. Insertion gain with horizontal polarization using two antennas with a gain of 11 and 8 dB respectively.

compared with the results shown in Fig. 3 is due to the diffraction from the edge of the porthole window.

Figure 5 shows the propagation loss at the nine points of measurements using two directional antennas with a gain of 11 dB and 8 dB respectively using the vertical polarization. It can be noticed that the minimum propagation loss is at the point 5 with 0.87 dB final propagation loss due to the propagation through the very fine glass of the porthole window and the diffraction from the edge of the porthole window due to the insertion loss of the fine glass of the porthole. The worst point is with a propagation loss of 37 dB. The lower value of the propagation loss far away from the point 5 compared with the results shown in Fig. 3 is due to the diffraction from the edge of the porthole window.

From the above mentioned results it can be noticed that the metallic door insertion loss is higher than 20 dB (at points 1, 3, 7 and 9) whatever is the antenna gain or the used polarization. Measurements at points that are 25 cm lower than points 1, 2 and 3 show metal door insertion loss higher than 50 dB.

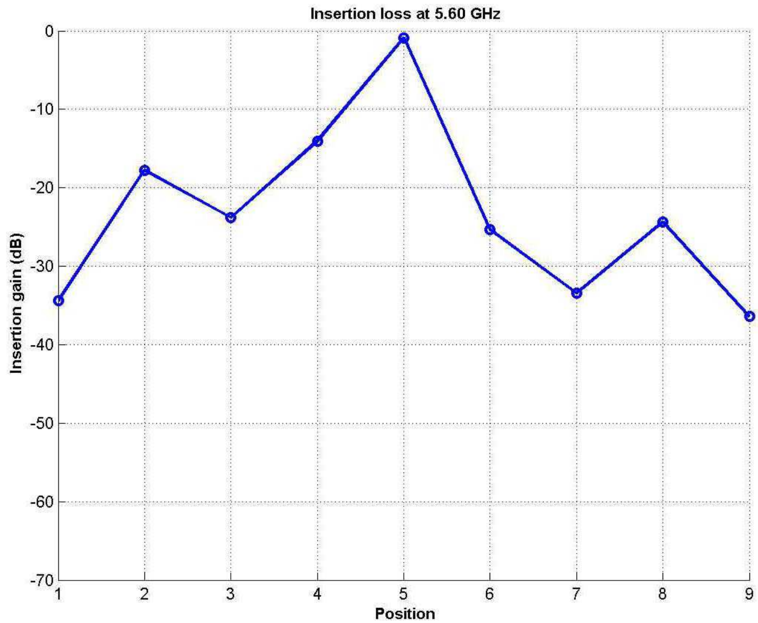


Figure 5. Insertion gain with vertical polarization using two antennas with a gain of 11 and 8 dB respectively.

4. WALL INSERTION LOSS

A brick wall with a thickness of 12 cm is used to measure the wall insertion loss (gain). Measurements are done at 25 different points at 5 different heights using two antennas with a nominal gain of 19 dB. Fig. 6 presents the wall insertion loss with horizontal polarization and a frequency band of (5.60 to 5.62) GHz. The line with circles represents the mean value of the insertion loss of the 25 points at a given frequency. The mean value of the insertion loss presented by the straight line is 6.3 dB. Fig. 7 presents the wall insertion loss with vertical polarization and a frequency band of (5.60 to 5.62) GHz. The mean value of the insertion loss presented by the straight line is 4.8 dB.

For a brick wall with a thickness of 24 cm, the penetration loss medium value was 7.9 dB for vertical polarization and 9.4 dB for horizontal polarization.

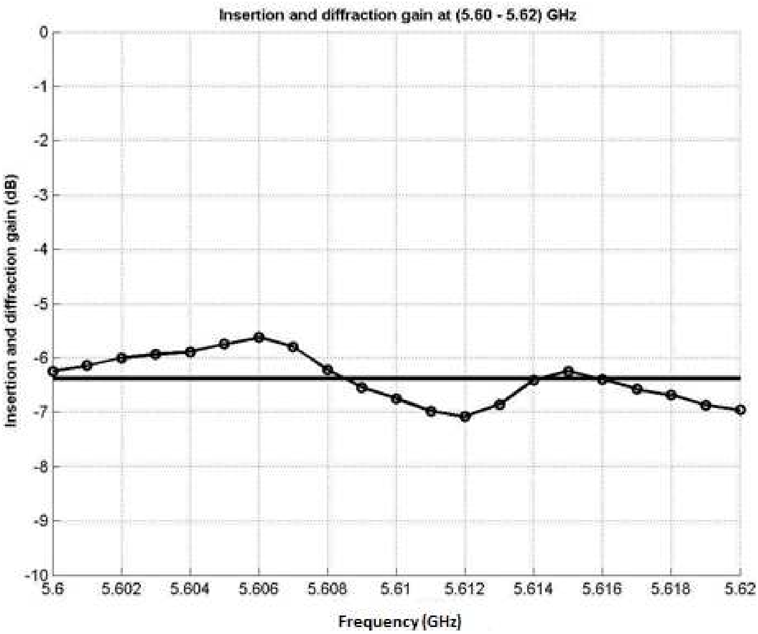


Figure 6. Wall insertion gain with horizontal polarization.

5. FIRST CASE OF DIFFRACTION

The studied scenario is a given space of the second floor of the Escuela Politecnica Superior. It consists of two narrow passages of 1.8 m width each one at one side of the building. The space between them is an open space that leads to the first floor of the school. At the exterior of each passage, concrete columns located 7 m from each other exist. The distance between each two parallel column is 2.5 m.

Figure 8 shows the diffraction geometry and some of the propagation paths where three cases can be distinguished as:

- First diffraction case: where the transmitting antenna is in front of the first column and the receiving antenna is behind the second column.
- Second diffraction case: where the transmitting antenna is in front of the first column and the receiving antenna is far away from the second column.
- Third diffraction case: where the transmitting antenna is far away from the first column and the receiving antenna is behind of the second column.

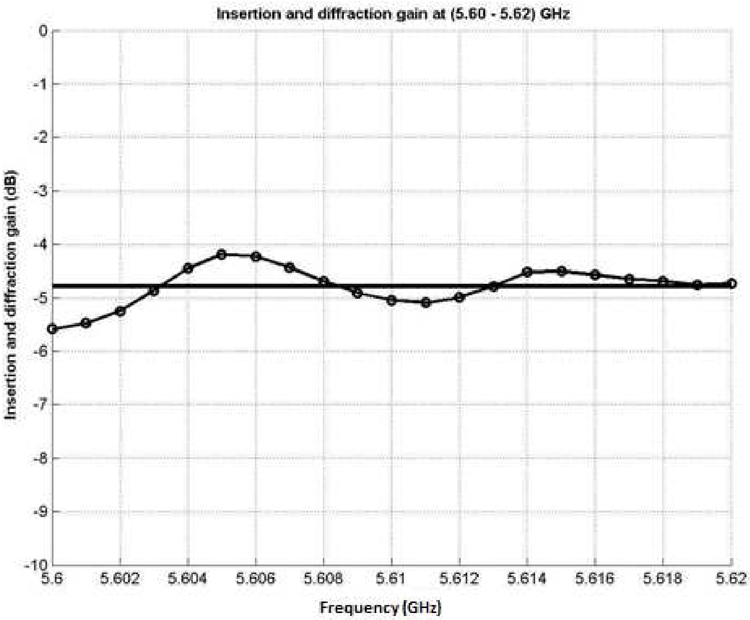
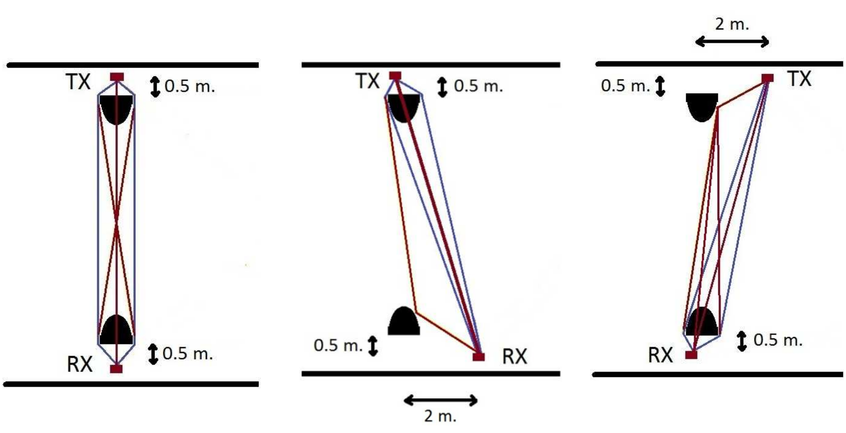


Figure 7. Wall insertion gain with vertical polarization.



(a) Case 1 (b) Case 2 (c) Case 3

Figure 8. The three studied diffraction cases.

The distance between the inner points of the columns is 2.5 m.

Diffraction loss is assumed to be the difference between the power level with and without the obstacle (used as reference). The nominal

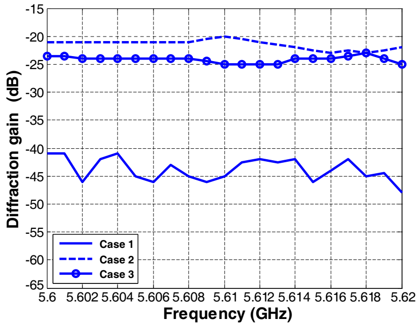


Figure 9. Diffraction gain for the horizontal polarization.

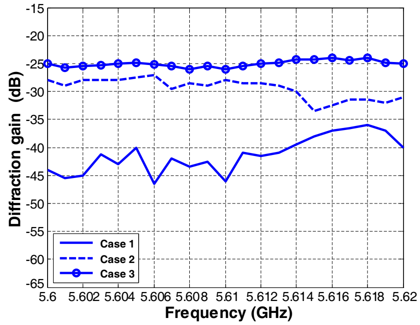


Figure 10. Diffraction gain for the vertical polarization.

Figure 11. Second diffraction scenario.

difference in this case will depend on the power of the incident wave on the edge of the obstacle. Incident wave power will depend on the radiation pattern of the antenna which has lower horizontal beam width which provokes that the incident wave power will be lower and the apparent diffraction loss will be higher.

Figure 9 shows the diffraction loss for the horizontal polarization while Fig. 10 shows the diffraction loss for the vertical polarization. From Fig. 9 it can be noticed that the minimum diffraction loss is due to the second case of diffraction while the higher diffraction loss is due to the first case of diffraction. From Fig. 10 it can be noticed that the minimum diffraction loss is due to the second case of diffraction while the higher diffraction loss is due to the first case of diffraction.

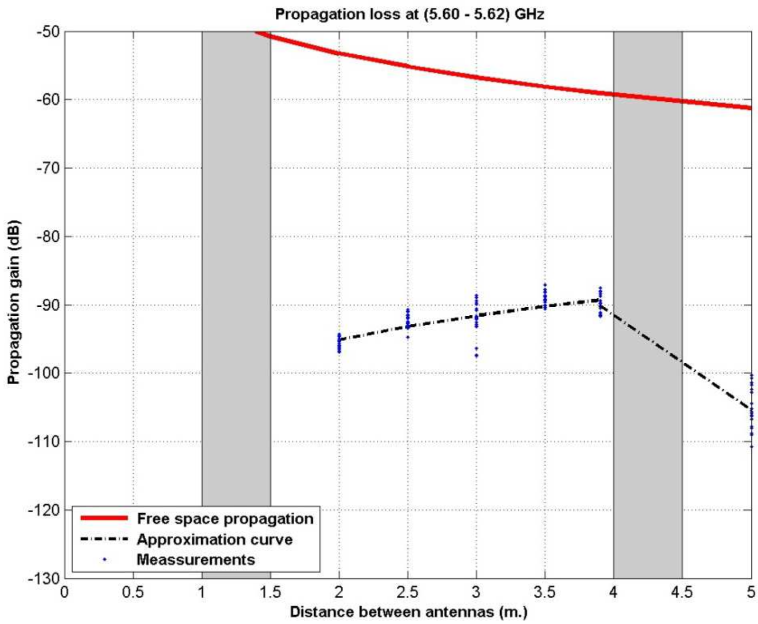


Figure 12. Propagation loss due to the second diffraction scenario with vertical polarization and antenna gain of 19 dB at both transmitting and receiving sides.

6. SECOND CASE OF DIFFRACTION

Figure 11 shows another diffraction scenario where the transmitting antenna was at 1 m distance from the concrete column and the receiving antenna at a distance of 0.5 up to 3.5 m from it.

First of all we present the propagation loss using a transmitting antenna and a receiving one with a gain of 19 dB.

Figure 12 shows the propagation loss against the distance from the transmitting antenna for vertical polarization. It can be seen that the diffraction loss reduces with the increment of the distance between the receiving antenna and the concrete column up to 3.8 m distance. At a distance of 5 m, the propagation loss increases due to the diffraction loss of the second column. At 2 m distance, the difference between the free space loss and the real propagation loss is almost 42 dB while for a distance of 3.8 m, the difference between the free space loss and the real propagation loss is almost 30 dB. At 5 m distance, the difference between the free space loss and the real propagation loss is almost 44 dB.

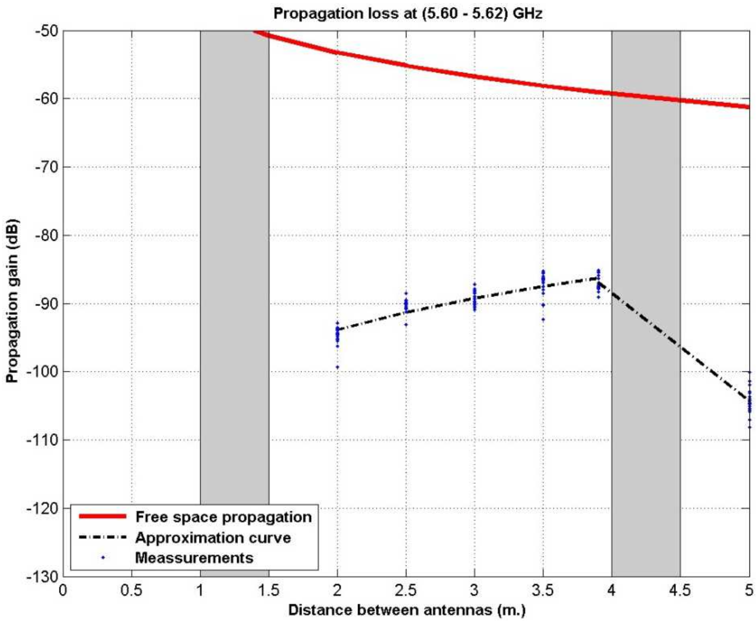


Figure 13. Propagation loss due to the second diffraction scenario with horizontal polarization and antenna gain of 19 dB at both transmitting and receiving sides.

Figure 13 shows the propagation loss against the distance from the transmitting antenna for horizontal polarization. Here also it can be seen that the diffraction loss reduces with the increment of the distance between the receiving antenna and the concrete column up to 3.8 m distance. At a distance of 5 m, the propagation loss increases due to the diffraction loss of the second column. At 2 m distance, the difference between the free space loss and the real propagation loss is almost 41 dB while for a distance of 3.8 m, the difference between the free space loss and the real propagation loss is almost 28 dB. At 5 m distance, the difference between the free space loss and the real propagation loss is almost 44 dB. Here it can be noticed that the diffraction loss (difference between the real propagation loss and the free space loss) is little bit lower than the case of vertical polarization. This difference is may be due to the different beam width at both polarizations.

Secondly, we present the propagation loss using a transmitting antenna with a gain of 11 dB and a receiving one with a gain of 8 dB.

Figure 14 shows the propagation loss against the distance from the transmitting antenna for vertical polarization. At a distance of 5 m, the propagation loss increases due to the diffraction loss of the second

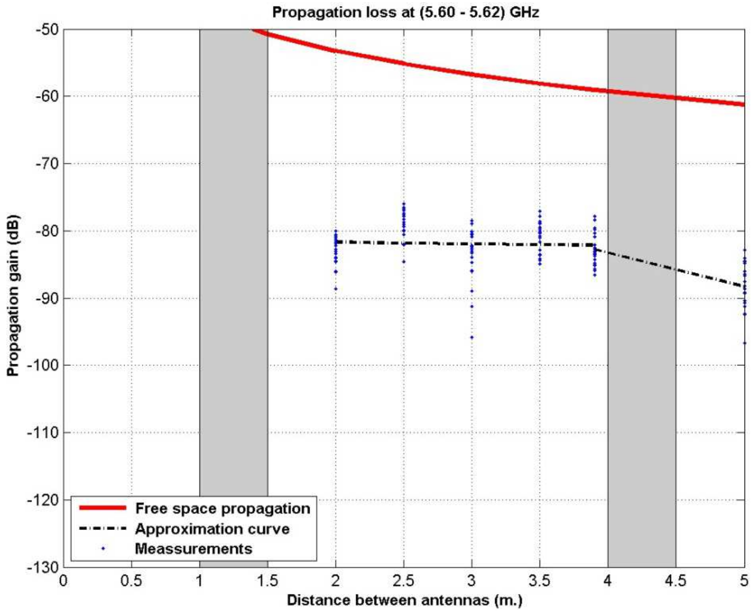


Figure 14. Propagation loss due to the second diffraction scenario with vertical polarization using a transmitting antenna with a gain of 11 dB and a receiving one with a gain of 8 dB.

column. At 2 m distance, the difference between the free space loss and the real propagation loss is almost 29 dB while for a distance of 3.8 m, the difference between the free space loss and the real propagation loss is almost 23 dB. At 5 m distance, the difference between the free space loss and the real propagation loss is almost 27 dB.

Figure 15 shows the propagation loss against the distance from the transmitting antenna for horizontal polarization. At a distance of 5 m, the propagation loss increases due to the diffraction loss of the second column. At 2 m distance, the difference between the free space loss and the real propagation loss is almost 32 dB while for a distance of 3.8 m, the difference between the free space loss and the real propagation loss is almost 19 dB. At 5 m distance, the difference between the free space loss and the real propagation loss is almost 27 dB.

Comparing the results of Figs. 12 and 13 with the results of Figs. 14 and 15 it can be noticed that the difference between the free space loss and the real loss is higher in Figs. 12 and 13 compared with the results of Figs. 14 and 15. This is due to the fact that the antennas with a gain of 11 dB and 8 dB have higher 3 dB beam width. The real diffracted field is higher and therefore the received signal is also higher.

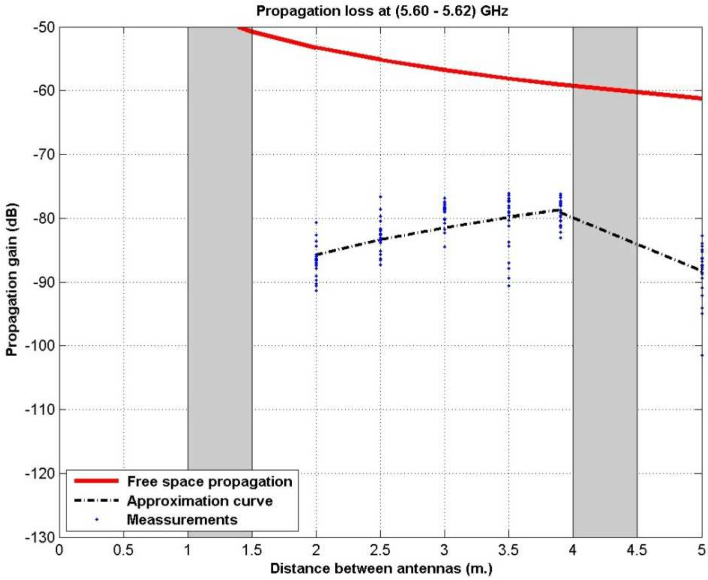


Figure 15. Propagation loss due to the second diffraction scenario with horizontal polarization using a transmitting antenna with a gain of 11 dB and a receiving one with a gain of 8 dB.

7. CONCLUSIONS

In this work, the propagation loss due to diffraction and insertion losses for indoor scenario at 5.6 GHz band have been measured using directive antenna and a Vector Network Analyzer (VNA). It has been shown that the insertion loss of a metallic door with porthole window varies from several dB due to the propagation loss via the porthole glass up to 50 dB due to the diffraction by the porthole boards when the line between the transmitting antenna and receiving one is outside the porthole glass. It has been shown that the insertion loss of a 12 cm brick wall is 4.8 dB for vertical polarization while it is 6.3 dB for horizontal polarization. Also it has been shown that the diffraction loss due to single or double concrete columns depends on the distance between the transmitting and receiving antennas.

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