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Site Specific Path Loss Prediction Model for Indoor Area

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Abstract: *This paper presents indoor propagation model for specific scenario in indoor environment using ray tracing technique. The indoor scenario of room with two partition and table in building as case study is considered. It includes the effect of an angle of incidence, the electrical properties of materials and an interior geometry of the building under consideration for path-loss prediction. The path loss prediction is to be done at 3 GHz, 2.2GHz, 1.8GHz and 0.9GHz frequencies. Path loss exponent at different frequencies is computed using regression analysis.*

Keywords: *Propagation model, Ray tracing method, Path loss.*

1. Introduction

Indoor radio communication systems are becoming increasingly important for extending voice and data communication services within workplace. Indoor systems can be broken down into three main classes namely cordless telephone systems, in building cellular systems and local area networks (LANs). Each of these types of communication systems must be designed with indoor channel in mind. Many researchers have worked on radio wave propagation for the indoor environment and have given a brief idea for the development of indoor propagation modeling [2]-[14]. A more detailed discussion can be found specifically, for indoor prediction models in John W. McKown 48S [2], S. Y. Seidel and et al. [3][4], A. F. Toledo [4], D. J. Cichon [5], P. A. Sharples and M. J. Mehler [6], K. Rizk [7]. Specifically, these issues [8]-[14] can be referred for indoor prediction models.

A building specific prediction tool can be much valuable when designing system for a site-specific environment. During the past few years, indoor propagation prediction techniques based on ray tracing have been used to reconstruct the many possible reflections from wall surface within building. This tool has emerged as a leading tool for indoor radio wave propagation. The ray-tracing tool [8 & 9] takes into account both transmitted and reflected rays reaching the receiver location after an arbitrary number of reflections and transmissions.

2. Ray Tracing Model

Ray-tracing model of mobile radio communication link is based on the physical reflection that an electromagnetic wave undergoes as it strikes the surfaces in the environment. The effect of such reflections can be modeled as a combination of number of directed rays that are emitted by the transmitter. These rays are normal to the surfaces and behave in a manner similar to the beam of light on reflection, i.e., the angle of incidence is equal to the angle of reflection. The type of surface determines the power and phase of the reflected signal relative to the incident wave. It also includes the free space loss due to the finite distance between the transmitter and the receiver. The electromagnetic wave received at an observation point can be calculated as the sum of all reflected waves initiated by the transmitter, plus the effect of direct line-of-sight (LOS) between the transmitter and receiver. For each reflected path, it computes the loss in excess of free space propagation loss, as a product of magnitude squared of the reflection and transmission coefficients. The reflection and transmission coefficients are necessary for computing each object and arbitrary number of surfaces whether walls, floors, ceilings or partitions, etc.

Ray-tracing tools are powerful for broadband analysis of radio wave propagation in an indoor environment. The types of ray-tracing tools that are currently in use are the bruit force ray-tracing tool and the image tool. The bruit force ray-tracing tool regards a bundle of transmitted rays that may or may not reach the receiver. It requires a number of ray-object intersection tests and extensive data arrays. For implementing this tool on computer operating platform, a considerable number of factors are required. The image tool mirrors the radio source at a particular phase. The intersection point of the mirror phase and the connecting line from the transmitter image to the receiver is the required point where the specular reflection occurs. The image tool is well suited for radio propagation analysis associated with geometries of low complexity and with a lower number of considered reflections. It is cumbersome when a large number of multiple reflections are involved.

3. RAY TRACING USING IMAGE METHOD

Reinaldo A. Valenzuela [9] has described in brief the idea of image tool for multiple reflections inside the building. According to him, the co-ordinates for the image of a point reflecting over a surface are found simply by reflecting the co-ordinate corresponding to the axis parallel to the surface normal.

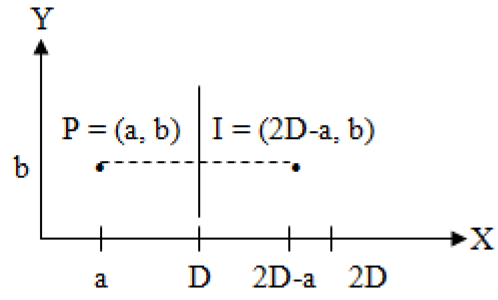
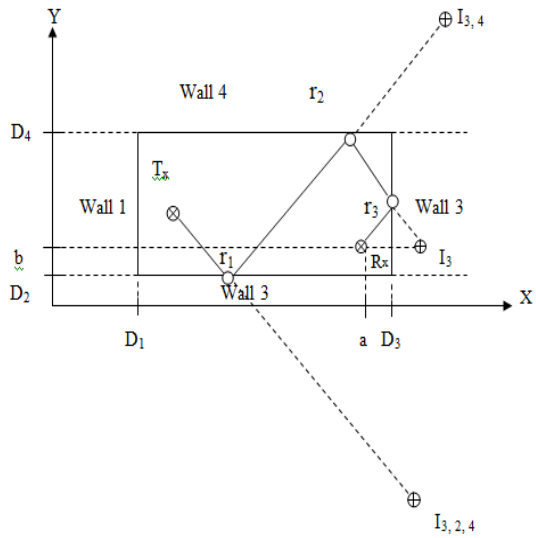


Figure 1. *Reflecting Surface*



⊗ … Location of transmitter and receiver
⊕ … Image points
○ … Reflection points
_ … Locations of walls

Co-ordinates of the image points:

$I_3 = (2D_3 - a, b, c)$

$I_{3,2} = (2D_3 - a, 2D_4 - b, c)$

$I_{3,2,4} = (D_3 - a, 2D_2 - (2D_4 - b), c)$

Figure 2. *A three-reflection path tracing by image method*

Fig.1 shows the point 'P', with co-ordinates (a, b, c) and a reflecting surface parallel to the Y Z plane and located at a distance 'D' along the X axis. It can be seen that the image 'I' has the co-ordinates (2D-a, b, c). This suggests the general procedure in which the co-ordinates of the image of the receiver antenna for an arbitrary path involving multiple reflections are found by successively reflecting the receiving antenna over the sequence of reflecting surfaces defining the path under consideration. This has been explained in detail in Fig. 2 which considers a rectangular room. Walls 1 & 3 parallel to the Y Z plane, and located at points D_1 and D_3 along the X axis, and walls 3 & 4 parallel to the X Z plane and located at points D_2 and D_4 along the Y axis. The transmitting antenna is located at point T_x, while the receiving antenna is located at point R with co-ordinates (a, b, c). To test the path 4-2-3, from T_x to R_x, reflecting of walls 4, 2 & 3, it is essential to find three images, i.e., I_3, $I_{3,2}$ and $I_{3,2,4}$. The first order image of the receiving antenna, i.e., I_3, the single-reflection image of the receiver over wall 3 is found by reflecting the receiver co-ordinates (a, b, c) over wall 3. Thus, I_3 has co-ordinates ($2D_3$-a, b, c). Then, the second-order image at point $I_{3,\ 2}$ is found by reflecting the first order image over the semi-infinite plane containing wall 2 giving the co-ordinates ($2D_3$-a, $2D_4$-b, c). Finally, the first wall in this path, wall 4, is also normal to the Y axis. Thus, the co-ordinates of the highest order image, at point $I_{3,2,4}$ are found by reflecting the Y co-ordinate again, giving the co-ordinates ($2D_3$-a, $2D_2$-($2D_4$- b), c). Once all the images are found, the reflection points, i.e., r_1, r_2 and r_3 at the wall surfaces are obtained. The first reflection point, r_1 is obtained at the intersection of the line $T_x - I_{3,\ 2,\ 4}$ with wall 4. The second reflection point, r_2, is found at the intersection of the line $r_1 - I_{3,\ 2}$ and wall 2. Similarly, r_3 is found at the intersection of the line $r_2 - I_3$ with wall 3. Finally, the path 3-4-2 is completed with the segment $r_3 - R_x$. Once all the reflection points are obtained, the overall path-length of the triple-reflected ray can be obtained by using simple distance formula.

A. Case Study: Scenario for Indoor Propagation Modeling

The indoor scenario of room with two partition and table in building as case study is considered. It includes the effect of an angle of incidence, the electrical properties of materials and an interior geometry of the building under consideration for path-loss prediction. The sequence of computations includes the direct path, followed by all the paths with single-reflection, double-reflection, triple-reflection, and so on, up-to the specified number of reflections.

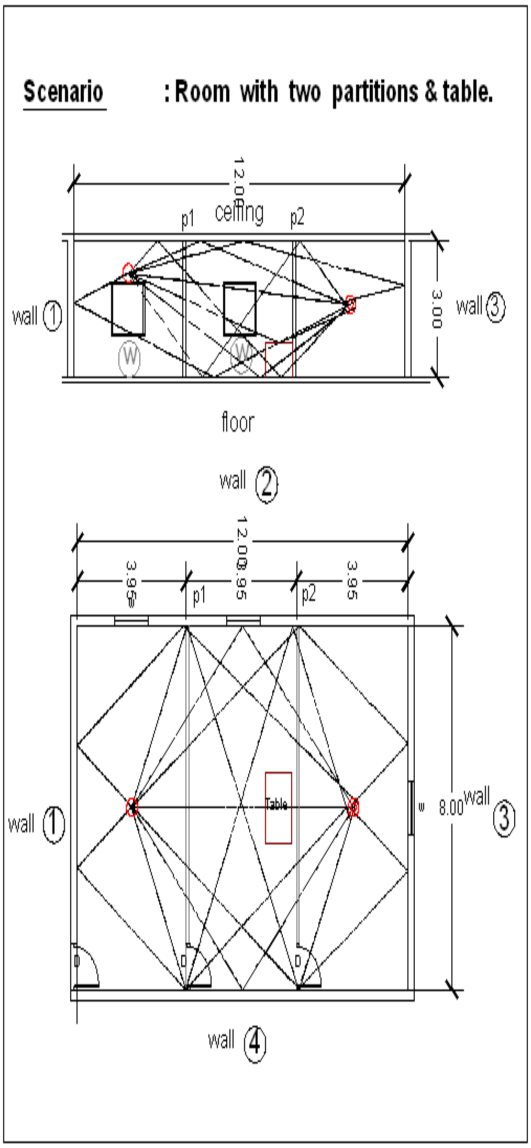


Figure 3. *STUDY CASE -Indoor Scenario of Room with Two Partition and Table*

4. SIMULATION RESULT

The path loss prediction is to be done at four different frequencies. Figure 4 shows distance Vs Path loss at 3 GHz, 2.2GHz, 1.8 GHz and 0.9GHz frequencies four different frequency for indoor scenario in figure (3). Path loss exponent at different frequencies is also computed using regression analysis. Figure 5: Distance vs. Received Signal Strength (RSS) Regression Curve at 900 MHz, 1.8 GHz, 2.2 GHz And 3.0 GHz

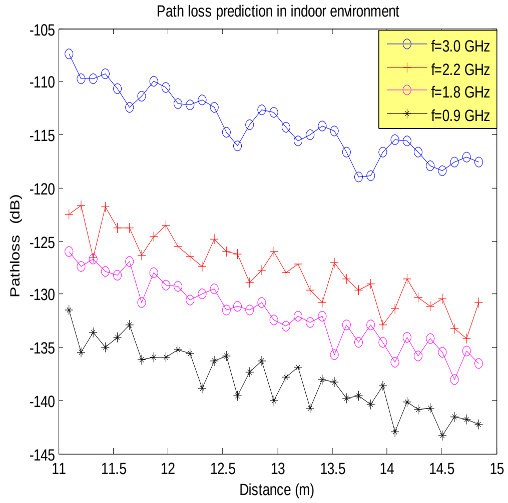


Figure 4. *Distance Vs Path loss at different frequency for indoor scenario in figure (3).*

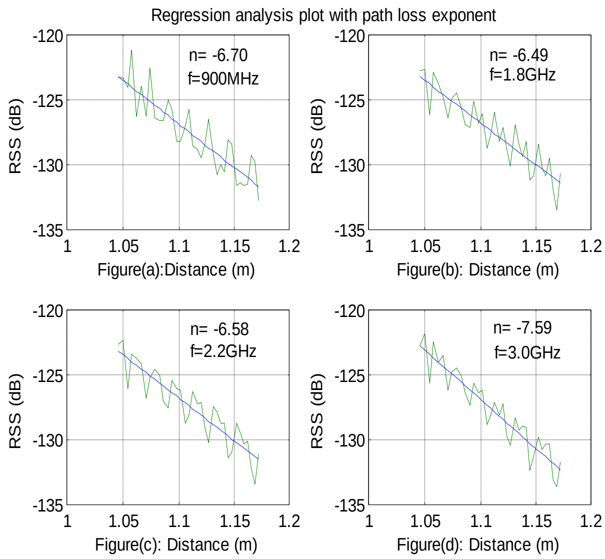


Figure 5. *Distance vs. Received Signal Strength (RSS) Regression Curve at 900 MHz, 1.8 GHz, 2.2 GHz And 3.0 GHz*

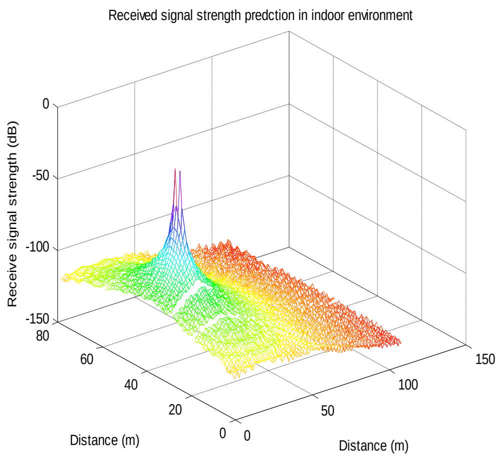


Figure 6. *Distance vs. Received Signal Strength at F= 1.8 GHz.*

5. CONCLUSION

Ray tracing using image method is used to predict the path loss for indoor area. The sequence of computations begins with the direct path, followed by all the paths with single-reflection, double-reflection, triple-reflection, and so on, up-to the specified number of reflections. For every path, the distant-dependant loss is simply the free-space propagation loss and is proportional to the total path-length squared. The total path-loss is computed as the product of the propagation loss times the reflection losses and the transmission losses. Path loss exponent depends on frequency and it varies from 6.7 to 7.59 which much higher than free space path loss exponent.

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