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Performance Comparison between Simulation and Experimentation of a Specific Indoor Propagation System

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***Abstract*— Ensuring information quality in indoor environments are difficult but essential for applications that require higher and higher quality such as internet access, telephone, etc. In order to deploy in actual systems with the feasibility and cost savings, electromagnetic simulations must be performed carefully. The simulation of electromagnetic wave propagation in indoor environments may require the use of different wave propagation models. Some factors such as obstructions, materials, antenna installation, etc. will affect the actual results so they need to be put into simulation. This paper presented the simulation and experimentation of wave propagation in a specific building. The initial results show the feasibility to apply in practice.**

***Key words* – Broadcasting, digital television, light of site (LOS), indoor propagation.**

I. Introduction

Wireless technology is rapidly gaining popularity. The assurance of information in the indoor environment is essential for applications that require higher and higher quality, such as internet access, phone, etc. The analyzing process of wave propagation in indoor environments is complex and difficult to predict accurately due to structure, texture, construction materials of different obstruction. Modeling and simulation before deployment is indispensable. Deploying coverage inside buildings or outside always had the attention of researchers, providers and users [1]. With the aid of computer tools, we have a higher accuracy compared to theoretical models and much lower costs compared to actual survey.

The simulation of electromagnetic wave propagation in indoor environments requires the use of different wave propagation models. Many kinds of factors such as obstruction, material, antenna installation… would affect the actual results and need to be put into simulation. This paper aims to compare the coverage calculation of a three floor building between simulation and experimentation. The simulation is performed using Wireless Insite [2].

The paper is organized as follows. In Section 2, we introduce the brief background of indoor propagation. Section 3 presents our proposed implementation. Simulation and experimentation results to demonstrate the efficiency of our method and verifications are presented in Section 4. Section 5 concludes the paper with discussions on the results and remarks for future work.

II. Backgrounds of Indoor Propagation

In the literature, there are numerous experimental and theoretical researches of indoor propagation [3–7]. The most basic model of radio wave propagation is *free space* radio wave propagation. In this model, radio waves are transmitted from a point source of radio energy, traveling in all directions in a straight line, filling the entire spherical volume of space with radio energy that varies in strength with distance.

However, indoors propagation is even worse. We are not able to design a building that is free from multipath reflections, diffraction around sharp corners or scattering from wall, ceiling, or floor surfaces. Multipath occurs when there is more than one path for signal propagation [8]. The results of reflection, diffraction and scattering all give rise to additional radio propagation paths beside the line of sight (LOS) path between the radio transmitter and receiver. Average received signal power decreases logarithmically with distance. In fact, empirical models are useful to reduce computational complexity as well as increasing the accuracy of the predictions [10].

III. Case Study: A Three Floor Building

The propagation models mentioned in the previous section can be modeled and simulated using Remcom Wireless Insite which is site-specific radio propagation software for the analysis and design of wireless communication systems. It provides efficient and accurate predictions of propagation and communication channel characteristics in complex urban, indoor, rural and mixed path environments [8,9].

For indoor simulation, the Full 3D is the propagation model which places no restriction on the shape of the objects. It is also the only propagation model which consist transmission through surfaces. Thus, it is the only ray-based model which can be applied to indoor environments. When transmissions are included, all facets, except those comprising the terrain and foliage, should typically be doubled-sided.

The following list summarizes the capabilities of the Full 3D model [2] which is suitable for our work:

- Maximum reflections: 30 (assuming no transmissions)
- Maximum transmissions: 30 (assuming no reflections)

- Maximum diffractions: 4 (SBR), 3 (Eigenray)
- Environments: all
- Terrain: all
- Indoor: all, facets should usually be double-sided
- Objects: all
- Range: depends on application
- Antenna heights: all

This method can construct ray paths with up to 30 total reflections and transmissions. The computation time is roughly proportional to

$$L = \frac{(N_r + N_t + 1)!}{N_r! \times N_t!}$$

where N_r and N_t is the number of reflections and the number of transmissions.

In this section, we set up the Full 3D propagation model in a three floor building by six following steps:

Step 1: create a building from the realistic architecture design. This building has three floors with specific characteristics:
- The first floor has an area of 43.8×24= 1051.2 m^2, a floor level of 0 m and a ceiling of 3.9 (m).
- The second floor has an area of 43.8×24 + 4×24= 1147.2 m^2, a floor level of 3.9 m and a ceiling of 7.8 (m).
- The second floor has an area of 1147.2 m^2, a floor level of 7.8 m and a ceiling of 11.7 (m).

We not only use the geometry design of the building, but also its material (see Table 1).

TABLE I. MATERIAL PARAMETERS

Material	Dielectric constant	Conduction	Thickness (m)
Brick	4.44	0.001	0.125
Glass	2.4	0.000	0.013
Concrete	15.0	0.015	0.300
Wood	5.0	0.000	0.030

Step 2: select the study area which is the whole building (see Fig. 2).

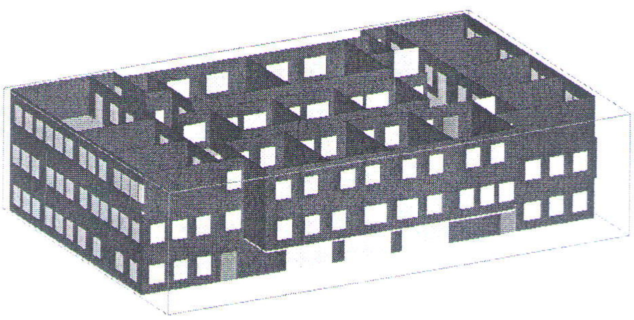


Fig. 1. Study area of the three floor building

Step 3: design the sine waveform whose center frequency is 915 MHz and the bandwidth is 200 kHz (see Fig. 2)

Step 4: design the transmitting and receiving antennas which are square loop and dipole ones, respectively (see Fig. 3). The transmitting antenna works with the power of 20 dBm.

Step 5: place the transmitter at the center of the building at the height of 5.2 m. Receivers are set up in a polygon configuration at the height of 0.75 m relative to each floor. The grid size of the mesh is 1 m (see Fig. 4-6).

Step 6: select the output parameters. In this work, the receiving power is selected for coverage calculation.

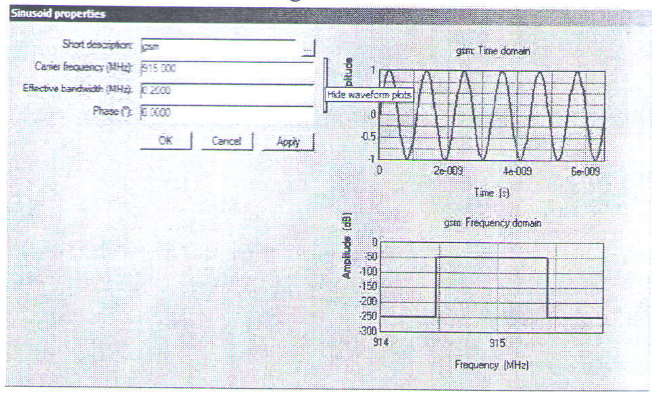


Fig. 2. Carrier wave in frequency and time domains

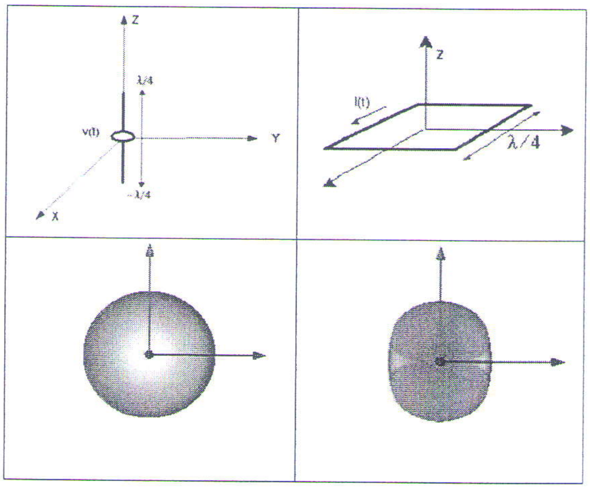


Fig. 3. Transmitted and received antennas

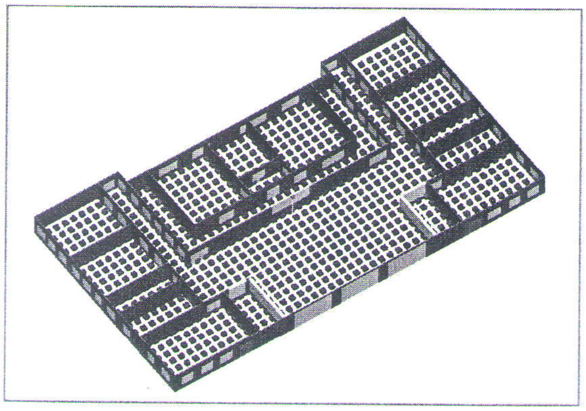


Fig. 4. Receiver placement in polygon configuration at the first floor

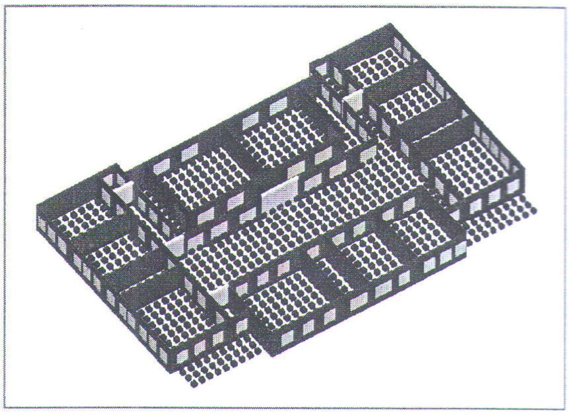


Fig. 5. Receiver placement in polygon configuration at the second floor

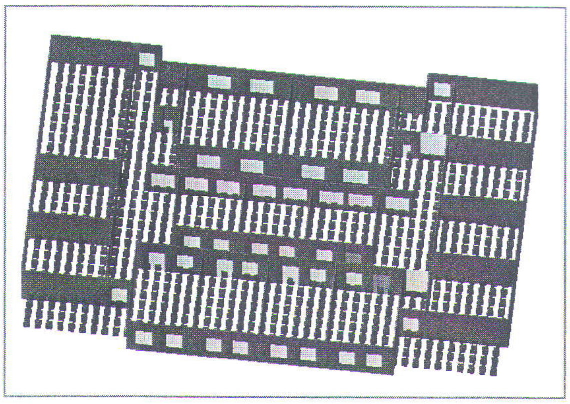


Fig. 6. Receiver placement in polygon configuration at the third floor

IV. Verification

A. *Software Package*

Wireless InSite makes these calculations by shooting rays from the transmitters, and propagating them through the defined environment. These rays interact with environmental features and make their way to receivers [10]. The effects of each interaction along a ray's path to the receiver are evaluated to determine the resulting signal level. At each receiver location, rays are combined and evaluated to determine signal characteristics such as path loss, delay, direction of arrival, and impulse response.

B. *Simulation Results*

The program would run the simulation and calculate the output parameters based on the building layout, physical parameters of the walls, ceilings, floors, windows, wooden doors with multi-path effects, etc.

When we set two thresholds that an antenna can still receive signal at -60 or -55 dBm, the levels of coverage are shown in Tables 2 and 3.

TABLE II. Coverage Simulation with -60 dBm Received Theshold

Floor	Number of survey antennas	Number of survey antennas whose signal larger than the threshold	Percent of coverage (%)
1	989	831	84.02
2	1161	937	80,71
3	1161	909	78,30
All the building	3311	2677	80,85

TABLE III. Coverage Simulation with -55dBm Received Theshold

Floor	Number of survey antennas	Number of survey antennas whose signal larger than the threshold	Percent of coverage (%)
1	989	645	65,22
2	1161	685	59,00
3	1161	740	63,74
All the building	3311	2070	62,52

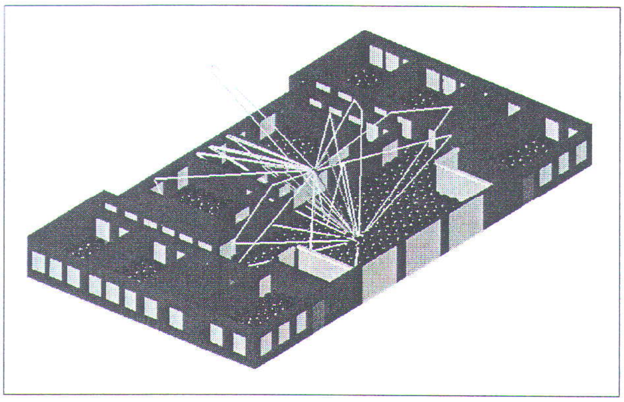


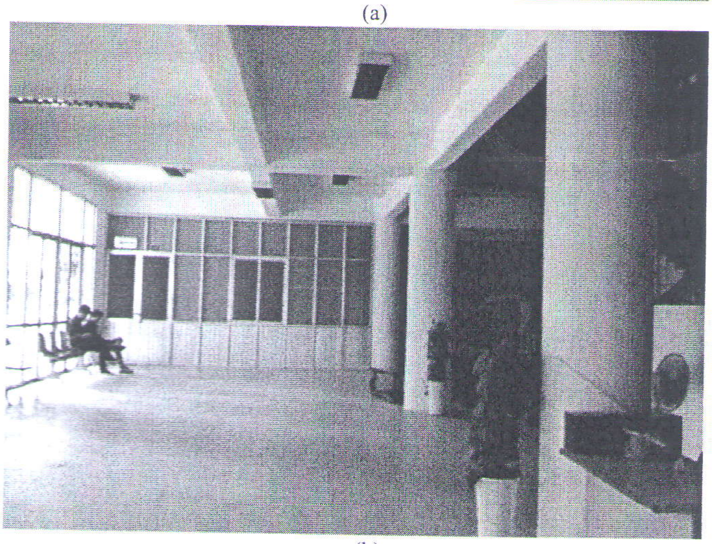
Fig. 7. Propagated rays are coming to one receiver

Figure 7 shows a lot of rays propagated from the transmitter to a receiver. The light of sight (LOS) is a red one and the other are reflected signals caused by multi path phenomenon. This phenomenon will affect the received signal such as changing the strength of the signal or time offset. In this work, we do not refer to the movement of the transmitter and receiver or movement of objects, thus, it should not occur Doppler frequency sifting.

C. *Experimental Results*

Figures 8.a and 8.b are photos taken from outside and inside of the real building.

(a)



(b)

Fig. 8. Outside (a) and inside (b) of the real building

In order to evaluate the reliability of the simulation results, the experimentation was performed with the same conditions.

Transmitted antenna is a square loop placed at the center of the building at a height of 5.2 m.

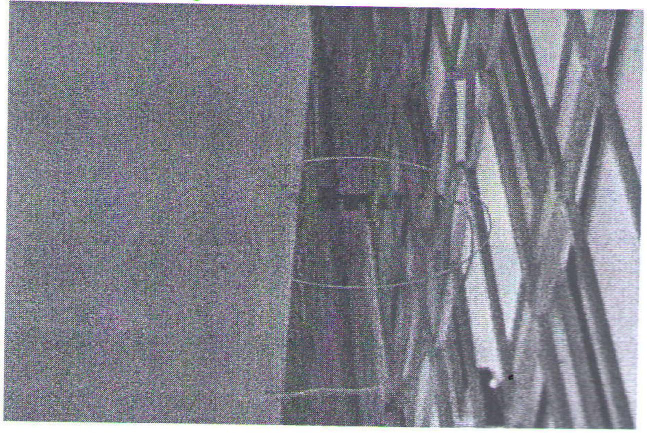


Fig. 9. Transmitted antenna

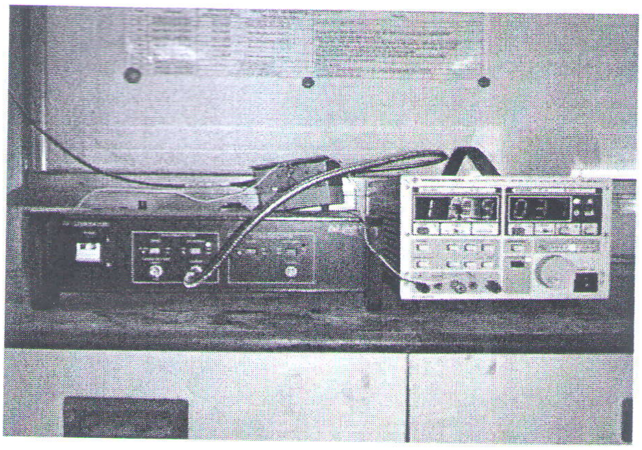


Fig. 10. Power and RF generator

The received antenna is a half-wave dipole placed at a height of 0.8 m. We need only one movable receiver to perform a polygon configuration of receiving as shown in Figs. 4-6. The receiver is connected to a spectrum analyzer to measure the power of the received signal.

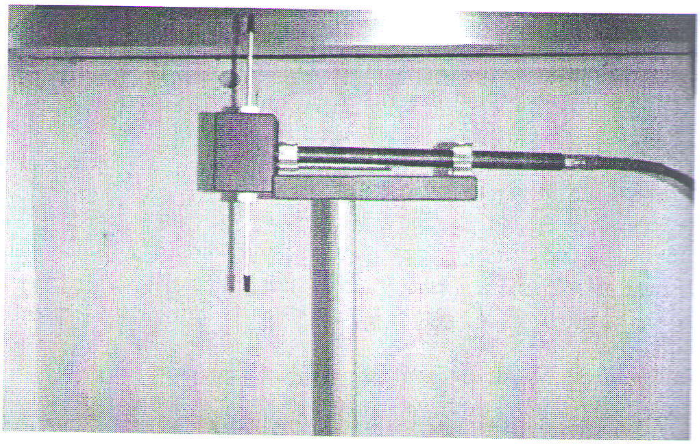


Fig. 11. Received antenna

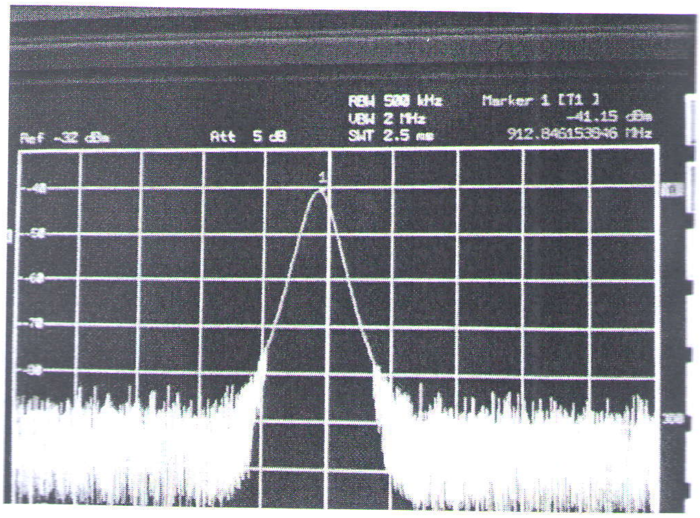


Fig. 12. Received signal in the spectrum analyzer

In this experimentation, the transmitter is fixed and the receiver can move. In the whole building, antenna is placed in a grid with size of 1 m (see Fig. 13). The power of received signal at each point is measured by a spectrum analyzer. Finally, we synthesize the results to an evaluation of the coverage area.

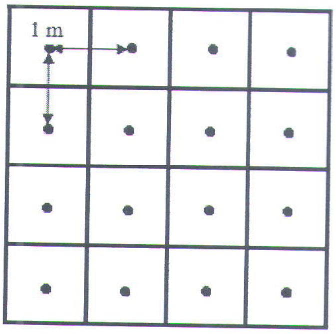


Fig. 13. Configuration of the received antennas

D. Comparisons between simulation and experimentation

It is difficult to compare between simulation and experimentation for the whole building because in experiment we could not measure at every points of the polygon configuration. Thus, the comparison between simulation and experimentation should be performed in some specific areas. Fig. 14 is the receiving powers at the center line of the hall with note that the distance between two continuous points is 1 m. The different between simulation and experimentation is around 8%.

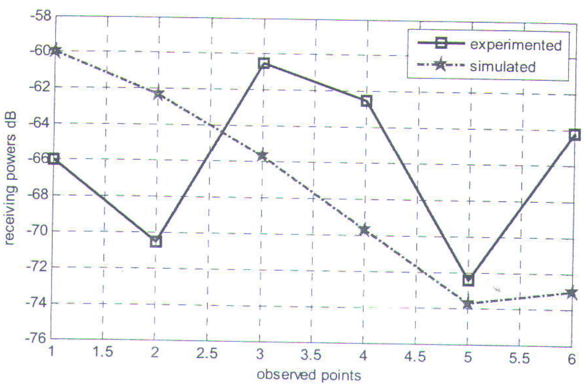


Fig. 14. Simulated (dotted curve) and experimented (solid curve) receiving powers (in dB) at seven points of the central line of the room number 311

The simulated and experimented measurements are not perfect match and it is possible caused by the following factors:

- Some obstructions have not included in the simulation such as stairs, railings, pillars, furniture in the room, the sources of interference from the GSM network. For example, in Fig. 15, there are two big pillars in front of two points 5 and 13 and lead to the strongly degrade in measured signals.
- Material properties in simulation and experimentation are not exactly the same.
- Measurement error cannot be ignored.

Another way to analyze the matching between simulation and experimentation can be shown in Tables 4 and 5. To increase the efficiency of this work, we need to improve the accuracy of the simulation model.

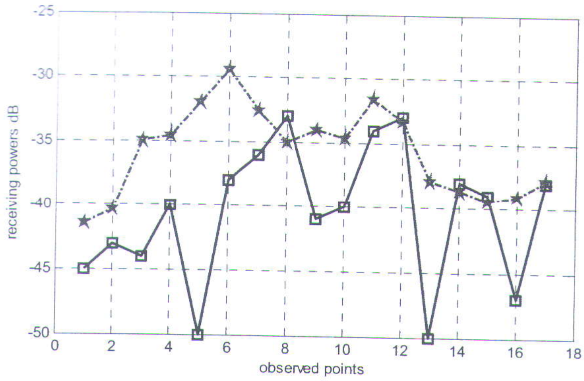


Fig. 15. Simulated (dotted curve) and experimented (solid curve) receiving powers (in dB) at 17 points in the center of the hall.

TABLE IV. SURVEY AT THE MAIL LOBBY

Received threshold (dBm)	**Number of survey antennas**	**Number of survey antennas whose signal larger than the threshold**		**Percent of coverage (%)**	
		Simulation	Experimentation	Simulation	Experimentation
-55	119	119	118	100	99,16
-45	119	117	90	98,32	75,63

TABLE V. SURVEY AT ROOM 311

Received threshold (dBm)	**Number of survey antennas**	**Number of survey antennas whose signal larger than the threshold**		**Percent of coverage (%)**	
		Simulation	Experimentation	Simulation	Experimentation
-60	35	10	3	28,6	8,6
-70	35	29	27	82,6	77,14

V. CONCLUSION

This paper has been successful in calculation of coverage area of wireless propagation using both simulation and experimentation for a specific three floor building. The information of the building (area, height, number of rooms, material properties), antenna, and transceiver parameters are based on actual data. From these obtained results, we can confirm to use this proposed scheme for practical applications.

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