RSSI Evaluation for Multi-story Building

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RSSI Evaluation for Multi-story Building

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***Abstract*— In this paper we investigate the reliability of ray tracing simulator in predicting the indoor radio channel response through a well specified environment. The knowledge of the indoor environment geometric and martial properties led to such site specific modeling. We assess the simulated data by comparing the predicted received power with real filed measurements. The good agreement between the predicted received power and the real field measurements suggests that a well designed site specific model can be used reliably to predict the system behavior.**

This work also proposes wall attenuation factor and floor attenuation factor based on a series of simulation scenarios.

Keywords- indoor propagation; ray tracing; multi-wall multi-floor model; path loss

I. INTRODUCTION

In wireless communications the radio channel properties strongly affect the system performance. It is common to use mathematical models to design, evaluate and describe the channel. One approach is stochastic modeling where the key feature of the propagating signal (e.g. multipath fading) is captured by probability distributions. Stochastic models are preferential when the propagation environment is unknown except for some feature description as rural, suburban, urban and dense urban. These descriptions are open to different definitions by deferent users, which leads to doubts whether the predictions models based on measurements made in one area are generally applicable elsewhere. Therefore there is an obvious need to accurately describe the propagation area to avoid any ambiguity. Stochastic models are best used when the study questions are general, e.g. how well cellular communication performs in rural areas? However, in some cases the interest is in a specific environment, e.g. WLAN in University building.

Ray tracing methods are popular for predicting site specific radio propagation characteristics [1], [2], [3], [4], [5]; although they are computationally extensive they provide more accurate results than statistical models if the environment is well specified

Thanks to the software development advances, the implementation of ray tracing technique has become a user friendly technique to model in a site specific environment. Designed by the combination of the shoot and bouncing rays (SBR) technique and the uniform theory of diffraction (UTD) [6], this technique makes 3D SBR an efficient propagation prediction tool.

The work developed in [7] demonstrates the efficiency of the 3D propagation prediction combined with the 2D method. It also presents a saving of 99% of computational time compared to the traditional 3D techniques with the use of their model.

In this paper we consider a particular environment, namely the second and the third floor of the engineering school at An-Najah National University to study the indoor propagation environment using Wireless Insite simulator, a ray tracing tool developed by Remcom [8].

II. SIMULATION MODEL

Indoor systems tend to be complex, with the radio waves encountering many obstacles which give rise to multiple diffractions and reflections. The electrical characteristics of the materials are often unclearly known and people, furniture and even walls can be moved which makes the situation more complicated.

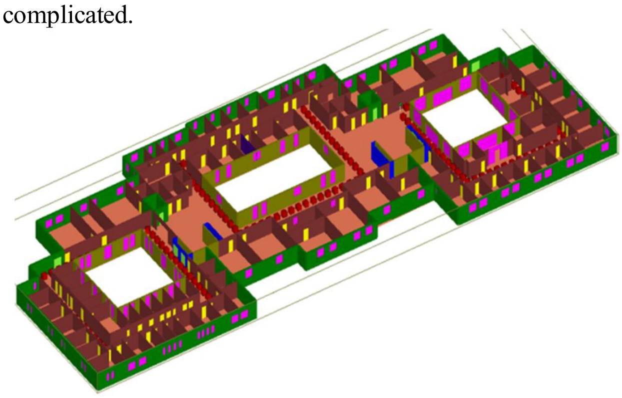

Fig. 1 3D single floor indoor environment model.

The simulation was carried out through the 3D Shoot and Bounce Ray (3D SBR) technique, using 0.2° ray spacing, 7 reflections, 2 transmissions and 0 diffractions, which allowed the evaluation of paths launched from the transmitter. Using the basic multipath propagation mechanisms (reflection, diffraction, transmission and scattering), it was possible to determine the rays reached at the receiver and therefore the path loss was calculated. Applying the image method approach the ray tracing technique captures the large structure precisely. The 2D and 3D simulations are carried out in computational scenarios for accuracy due to the high number of multipath calculated [9]. The Wireless InSite model includes the configuration of specific parameters for simulating the tested area: waveform, antenna, transmitter, receiver, model, materials and output.

The layout model is comprised of a floor and ceiling made of concrete with the ceiling 3m above the floor. A second ceiling of

3cm thickness made of soft dielectric material to represent foam tiles is included 2.5m above the floor.

This model is successfully completed by detailed modelling as shown in Figure 1, establishing two types of wall materials; the first type is a concrete wall with 15 cm, 22 cm and 35 cm thickness, while the second type is a brick wall with 12.5 cm thickness. The model also contains a wooden and metal door with 3cm thickness and one-layer glass windows of 0.3cm thickness.

As the two floors are nearly the identical. Two floor model was created maintain the locations of the transmitters and recovers in both floors as shown in Figure 2.

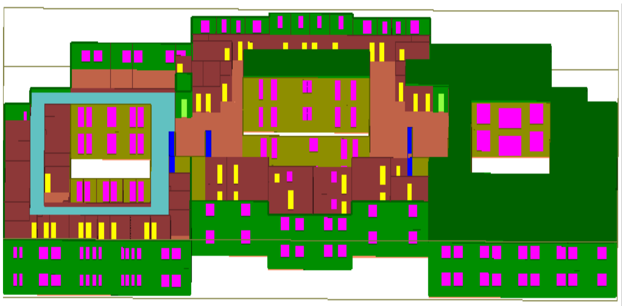

Fig. 2 3D duplicate floors indoor environment model.

III. RSSI Measurement and Simulation Results

The first measurement campaign is developed to evaluate the field distribution strength using a laptop and the MIMO 2x1 system along the corridor of the 2nd floor in the engineering building of "An-Najah National University". The physical model is obtained by dividing the total corridor space into 1.5m corresponding sections with 50 locations to cover the overall area as shown in Figure 3.

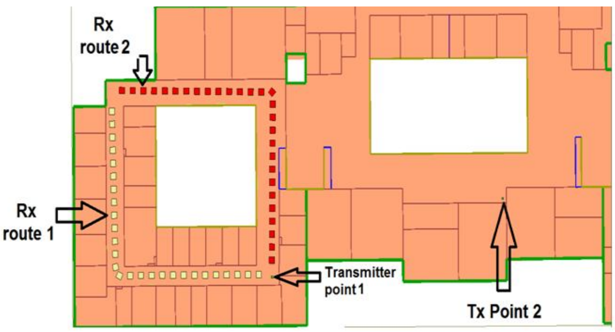

Fig.3 Transmitter point 1and 2 and Rx route 1 and 2.

The physical model was completed in a layout with the total corridor space divided into 1 meter testing points obtaining 30 locations in total. Each testing point was evaluated for 5 Received Signal Strength Indicator (RSSI) values over 2.4 GHz frequency using the 802.11n standard at 20 MHz bandwidth.

Two simulations were averaged to analyze the propagation behavior; the graphs in Figure 4 and 5 shows the comparison of the received signal strength measured per receiver location and the simulation of the 3D RSSI Scenario results for Tx pint 1 and 2. The simulated results are the average of the received signal for the maximum and minimum transmission power of the antennas. At 2.4 was from 17 to 11 dBm, confirming the similarity of the values simulated.

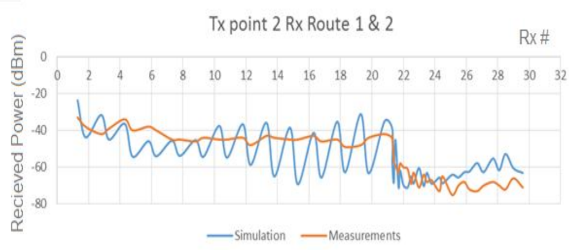

Fig.4. Simulated and measured received power against distance by route 1 and 2 for transmitting point #1.

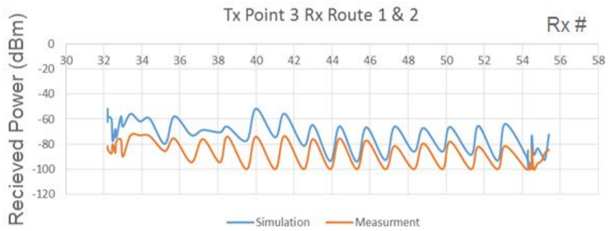

Fig. 5. Simulated and measured received power against distance by route 1 and 2 for transmitting point 2.

Figure 4 shows that the measured received power is bounded between -30 dBm to -50 dBm for the distance from 1.5m to 21m, then a sudden decrease in power occurs resulting in power drop below -60 dB because at this point (i.e. distance ≈ 21.5) the receiver has moved moved from a line of sight region to a non-line of sight region causing a power drop.

Measured and simulated results were analyzed statistically concluding the standard deviation between them is 12.60435 dB.

IV. Multi-Wall and Multi-Floor Model (MFW)

First path loss model for large scale indoor radio channel attenuation was based on simple models where the path loss exponent accounts for the entire loss phenomenon. One slope where the free space loss is modified as in equation (1) [10],

$$Path\ loss = L_o - 10n * log_{10}(d) \quad (1)$$

Where, L_o path loss in a distance of one mater (dB), d is the transmitter receiver separation distance (m) and n is the power decay index.

In [10] it was found in case within buildings, the path loss in equation (1) should be replaced by the mean, L, of a lognormal distribution with variance v which needs to be characterized for different buildings. Hence equation (1) becomes for in-building propagation.

$$path\ loss = L(v) + 10n * \log(d) \qquad (2)$$

Floors are likely to offer a significant blockage to radio signals as they are made of reinforced concrete. So it would be expected if the losses from each floor is taken in account the coverage prediction will be improved. To do so it is necessary to first identify the attenuation through each floor. This can be done by adding attenuation factor to each data point depending on the number of penetrated floors. The propagation model to do so is [10][11],

$$path\ loss = L° + 10n * \log(d) + K * F \qquad (3)$$

Where, K is number of floor and F is the attenuation per floor

To evaluate the value of F a test setup has been created in which the transmitter is located in the second floor and the receivers in third floor. The evaluation has been done using different receiver routs with different transmitter receiver separation distances as shown in Figure 6.

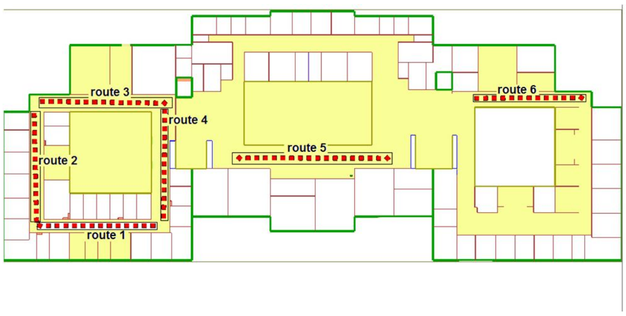

Fig. 7 Different Rx routs

The path loss was evaluated over different routes and different transmitter receiver separation distance and the mean square error was calculated to estimate the value of the floor attenuation factor, it was found that the mean square error is 8.197 dB when $L_o = 44$ dB and $F = 42$ dB.

Following on from the floor factor analysis, it was considered that the coverage prediction can be further improved if the losses due to the walls penetration can be included in the model as well, [10]

$$path\ loss = L° + 10n * \log(d) + K * F + p * w \qquad (4)$$

Where w is the attenuation per wall and p number of penetrated walls

The path loss was evaluated over different routes and different transmitter receiver separation distance and the mean square error was calculated to estimate the value of the floor attenuation factor, it was found that the concrete wall with 12.5 cm thickness was 12 dB, and the brick wall cause 8 dB attenuation.

V. CONCLUSION

The propagation of radio in buildings is strongly influenced by the size, furniture and the materials used. In propagation studies a quality description of the environment is usually employed using the terms as rural, suburban, urban, dense urban and indoor. These quality descriptions are open to different definitions by different users, which leads to doubts as to whether the prediction models based on measurements made in one area are generally applicable elsewhere. Therefore, there is an obvious need to accurately describe the propagation area to avoid any ambiguity.

In this study, a three dimensional shoot and bounce simulator has been used to evaluate the received signal power strength, for a 1000m2 two floor building model, using a (2,1) antenna system to understand the resulting multipath environment. The model may be characterized in terms of direction of arrival (DOA), time of arrival (TOA), multipath phase angles and delay spread. From these results, it can be seen that the received signal strength of MIMO system can be at maximum for line of sight or near line of sight; and the shortest receiver's distance from the transmitter in a multipath environment is as for other MIMO systems.

This work also proposed values for both floor and wall attenuations based on the site specific modeling, it was found that the floor attenuation factor is 42 dB and the wall factor for the brick wall was 8 dB and for a concrete wall with 12.5 cm thickness was 12 dB.

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