Propagation Prediction Based on Measurement at 5.8GHz for Fixed Wireless Access

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Abstract. This paper reviews most commonly used ray tracing techniques and applies a ray tracing technique which incorporates site specific environmental data to predict path loss in newly constructed hostels in Universiti Teknologi Malaysia (UTM) for 5.8 GHz Industrial, Scientific and Medical (ISM) band in Malaysia. Radio propagation path loss has been measured in order to verify the predicted results. As the prediction model excluding the vegetation affects that appeared in the fresnel zone clearance in the real site environment, corrections has been done on the predicted total loss in taking account the obstruction loss. It indicates a good agreement between measurements and predicted result with a deviation range of 0.01 dB to 2.82 dB.

1 Introduction

Radio propagation is heavily site-specific and can vary significantly depending on the terrain, frequency of operation, velocity of the mobile terminal, interference sources and other dynamic factors. To achieve high radio system availability, apart from the radio equipment design, good location of radio antenna sites, good radio path planning and choice of an interference-free radio channel are most important. [1] Hence, accurate prediction of radio wave propagation in a communication channel is essential before installation of any wireless system. Site specific analysis tools have proliferated for this purpose. The used of these tools has also been boosted by the availability of detailed city or building maps in electronic format. One of the basic site-specific analysis tools is ray tracing software module that applied in this paper. This technique of prediction is then verified and enhanced with actual RF measurements in the possible installation scenario.

There are two main options that are available for the implementation of a ray tracing software module known as ray launching, and point-to point ray tracing approach. [2]-[5] Both of them have their individual pros and cons. Ray tracing computes all rays receiver point individually but require an extremely high computation times. Thus, to make this technique computationally feasible, many acceleration techniques have been proposed to be implemented in this approach. On the other hand, ray

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launching [6]-[8] is an option that the casting of rays from transmitter is in a limited set directions in space causing inaccuracy for those rays traveling long distance. A small constant angle separation between launched rays needs to be specified to produce reliable results. Though, this technique is very efficient computationally.

In conjunction with the two options available, there are authors that mixed the two techniques by splitting the three dimensional (3D) into two successive two-dimensional stages, without loss of generality compared with the full 3D techniques. [3], [9]-[11]

All the options in ray tracing software models have been widely used as simulation tools for the design and planning of wireless system in mobile and personal communication environments: outdoor macro cells, street micro cells, and indoor pico cells. All the available modeled ray tracing techniques approximate electromagnetic waves as discrete propagating rays that undergo attenuation, reflection, diffractions and diffuse scattering phenomena if available due to the presence of buildings, walls, and other obstructions. The total received electric field at a point is the summation of the electric fields of each multipath component that illuminates the receiver. These models have the advantage of taking 3D environments into account, and are thus theoretically more precise. In addition, they are adaptable to environment changes such as transmitter location, antenna position and frequency and predict wideband behavior as well as the waves' direction of arrival.

This paper is organized as follow: Firstly, a brief description of a ray tracing model that applied in this paper. This is followed by experimental setup and results. Then, predicted results are corrected to take accounts the vegetation obstructions in the fresnel clearance and presented in Section IV. Finally, discussions and comparisons of experimental results and predicted result are presented.

2 Propagation Prediction Model

The model applied in this paper is based on a 3D Vertical Plane Launch (VPL) ray tracing technique, developed in [12]. The VPL approach accounts for specular reflections from vertical surfaces and diffraction at vertical edges and approximates diffractions at a horizontal edge by restricting the diffracted rays to lie in the plane incidence. Some limitations and simplifications arise from this software to obtain a computational efficient model. This model neglects diffuse scattering from the walls, rays that travel under a structure and also reflections from the rooftop that travel upward and hence away from the buildings and receivers. It is believed that the rays do not contribute to the total received power in a microcellular environment, or that they occur very infrequently.

To save computer time, we restricted the number of reflections to six for each branch between vertical diffractions. The number of diffractions on horizontal wedges is not limited in any of the cases. Due to diffraction by vertical wedges is very time consuming, a limitation on the number of diffraction at vertical edge is done where any given ray path to at most two. Besides, $\varepsilon_r = 6$ is used for the reflection coefficient at walls [11] because the use of reflection coefficient for a dielectric half space with $\varepsilon_r \approx 5-7$ give the least error with measurements. Vegetation effects did not considered in this model due to the irregularity of the plantations along the paths. Nevertheless, corrections will be done in the end of the prediction to obtain an accurate prediction.

2.1 Site Survey

A visit to the related site is carried out. There are mainly seven blocks three-wings with eight to ten floors buildings in first hostel and two u-shaped with five floors buildings in another hostel. Transmit site is at Wireless Communication Centre (WCC), which is located at least 30 meters higher than the hostels' building. The terrain between WCC and the hostels is a small oil palm plantation. Hence, the site overlooked a terrain of light rolling hills with moderate tree densities. From the highest floor of WCC, we can clearly see these buildings and the oil palm plantation. Figure 1 (a) and (b) show the photos that captured from WCC to both the hostels, whereas figure 1(c) shows the photo that is captured from one of the receiver site in the hostel to WCC.

(a) (b) (c)

Fig. 1. Photographs Illustrating the Site Related

2.2 Geometry Databases

The first step of site specific propagation prediction is characterizing the geometrical and electrical attributes of the site. The obtained building plans and contour maps are digitized into databases. This prediction area covers 720 X 1280meter^2. The same building database and terrain database will be used in the simulation to predict and analyze the result on different placements of the receiver point. Figure 2 shows the visualization of the building and terrain databases for the software.

2.3 Antenna Parameters

Besides geometry databases, antenna radiation pattern and gain are also important inputs in the software. Market available planar array directional antennas are used in the wireless measurement for both the transmitting and receiving sites. Unlike omni-directional antenna that used in mobile systems, the received power can be higher as much as the antenna's gain, but only if the arriving rays lie in the angular range of main lobe. Hence, before wireless prediction and measurement being carried out, is a need to verify the antenna radiation pattern and the gain of the antenna. Measurement of radiation pattern and gain of the antenna at 5.77 GHz has been carried out in an anechoic chamber followed the procedure which printed in [13]-[15]. Two 2D patterns have been measured. They are the x-z plane (elevation plane; $\varphi = 0$), which represents the principal E-plane and the x-y plane (azimuthal plane; $\theta = \pi/2$), which represents the principal H-plane. Figure 3(a) and (b) show the principal E- and H-plane radiation pattern in polar-logarithmic form.

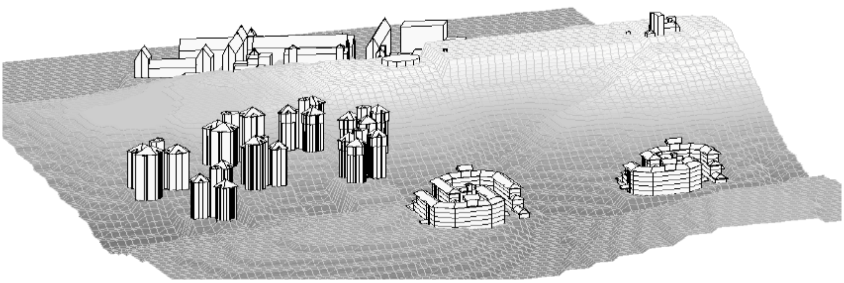
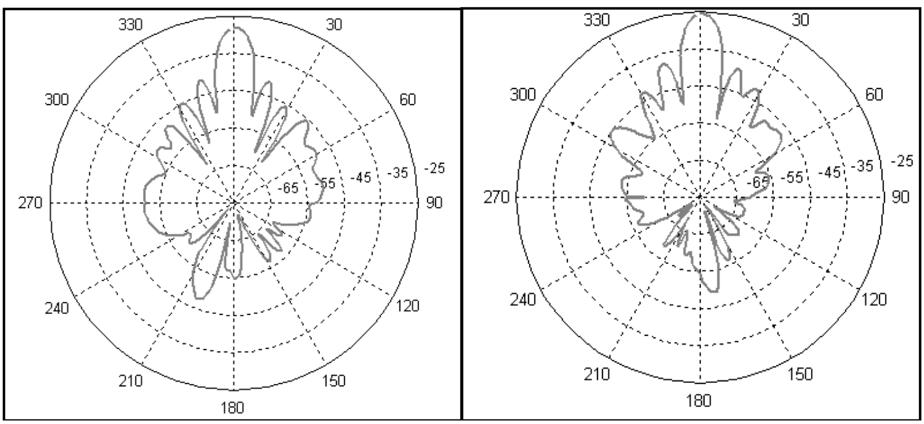


Fig. 2. Databases Visualization



(a) (b)

Fig. 3. (a) Principle E-Plane. (b) Principle H-Plane.

Two-antenna method of absolute-gain measurement has been carried out to obtain the gain of the antenna. This measurement was carried out with both the antennas were polarization matched and the separation between the antennas prevail far-field conditions. From the measurement, the computed gain of the antenna is 23dBi.

3 Experimental Setup

This measurement campaign was carried out in nine blocks of two hostels' buildings that include 35 local area path loss measurements, with transmitter antenna was placed at the rooftop level of Wireless Communication Centre, UTM. After determining the locations for the transmitter and receiver, the antennas are mounted onto a pole with a proper polarization. The antennas and the mounting brackets used are able to withstand strong winds to avoid any movement that could introduce misalignment. The outdoor unit is then mounted to the mounting bracket, connected to the antenna via a short RF cable and connected to indoor terminal via an IF cable. At every site, the antenna is aligned in both the azimuth and elevation planes until maximum received signal level is obtained. As all operator communications with the measurement system is achieved over the Ethernet port using hypertext transfer protocol (HTTP), it eases the access and control the terminal remotely from any geographical location.

The 35 radio paths propagated from the transmitter passing through an oil palm plantation before reaching the receivers. The distances for these links were ranges from 360 to 605 meter with the transmitter was higher than the oil palm plantation and the receivers. To assure that propagation channel were stationary in time, the measured data was averaged over 30 instantaneously sampled values in 15 minutes.

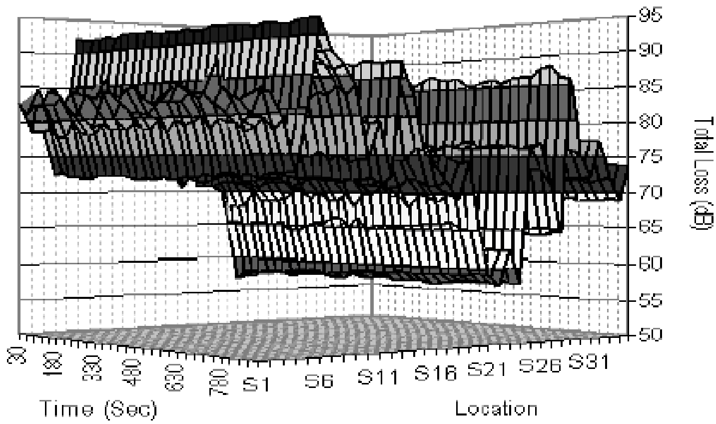


Fig. 4. Measured Loss

4 Prediction and Measurement Comparison

The discussed ray tracing wave propagation prediction software tool is used to compute the path loss value with respect to the slow fading process at the given receiver locations. Visualizations were done on every receiver location in order to understand the different ray components contained in every channel.

The 35 set experimental data obtained from field measurement is shown in Figure 4. The instantaneously sampled values are found having small fluctuation within 3.4 dB maximum ranges and with standard deviation less than 1.1 dB. Mean of the 30 sampled values is computed for comparison with prediction then.

From the 35 local area path loss predictions, there are 11 locations matched closely with measurement loss, with error range from 0.09 dB to 2.78 dB. These locations are classified with links that have 100% fresnel zone clearance with LOS or NLOS conditions. The predictions loss for another 24 locations has range from 3.61 to 33.03 dB less than measurement data. The severe difference is due to the irregular vegetation effects in fresnel zone which is hard to model and is not considered in VPL ray tracing prediction. All of these 24 locations are in LOS conditions. Hence to consider the obstruction loss of vegetation in fresnel zone, the deviation within free space loss and measurement loss will be used. The free space loss model is used to predict received signal strength when the transmitter and receiver have a clear, unobstructed LOS path between them. [16] The equation of the free space loss with *R* distance at frequency 5.775 GHz is

$$PL_{dB} = 107.671 + 20\log_{10} R_{km} \quad (1)$$

Figure 5 shows comparisons between predicted path loss and mean measured path loss, and also the computed free space loss. After VPL predicted path loss added with the computed vegetation obstruction loss, the difference between the modified predicted data and measured data is displayed in Figure 6 From this figure, is found that the modified predicted loss have a very good agreement with the measured loss. Both the computed mean and standard deviation for the error are 0.95 dB only.

5 Conclusion

The VPL ray tracing is based on an efficient 3D ray construction algorithm, taking into account a sufficient number of reflections and diffractions. Radio propagation path loss has been measured in order to verify the predicted results. As the prediction lack of important vegetation lines that appeared between the transmitter and receiver, the difference between experimental data and free space loss had been used to represent the vegetation obstruction loss in fresnel zone clearance and to correct the predicted data. The corrections were done only to those predicted ray in LOS condition with vegetation obstructions in fresnel zone and had severe difference with experimental data. Out of the 35 locations, 24 predicted were corrected. And finally, the 24 corrected data and 11 uncorrected predicted data showed good agreement with the measurement data, which the mean error and standard deviation lower than 1 dB. These small errors might be contributed by the experimental configurations such as terrain and building data inaccuracies such as wall orientation error, wrong earth levels and missing information likes construction material characteristics.

Overall, for links with LOS conditions, the obtained predicted path loss and power delay profiles that without consideration of vegetation effect can be corrected or modified accordingly in such a way described above before employed as a tool for aiding in the planning and design of wireless system, due to their accuracy and efficiency. Other LOS, OLOS or NLOS links that without vegetation obstruction in frenel zone clearance, this VPL ray tracing tool is able to provide a good prediction. For future work, the analysis of radio propagation with this method finally provides a complete set of output magnitudes that can be used to analyze BER for digital modulations and to characterize the channel where strategies like diversity, equalization, or adaptive antennas are used.

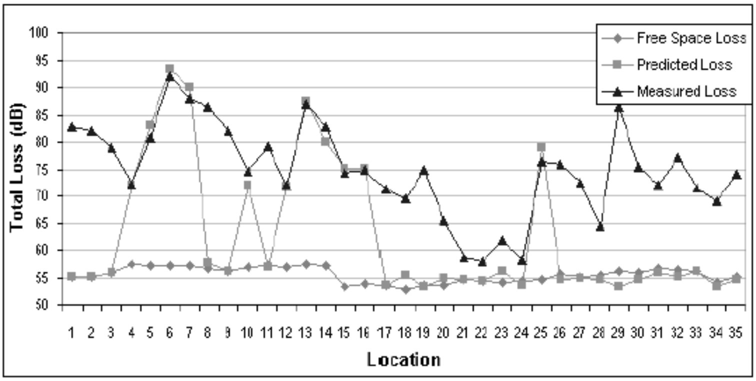


Fig. 5. Comparisons between Free Space Loss, Predicted Loss, and Measured Loss

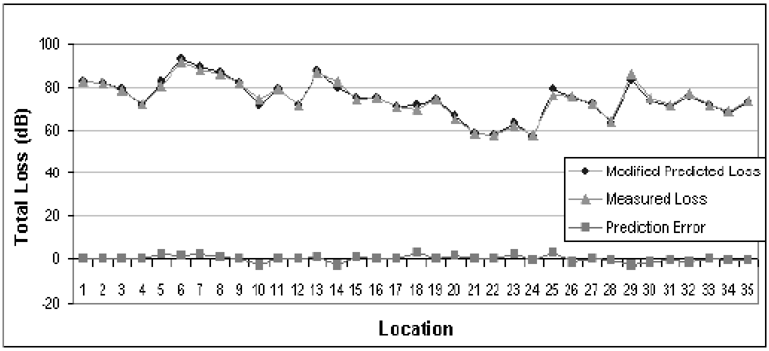


Fig. 6. Comparisons Between Modified Predicted Loss and Measured Loss

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