# Radio Propagation Prediction for Selected Locations on Sun-U Campus: A Ray Tracing Approach using Image Method

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***Abstract*—Radio propagation prediction is a crucial step to determine the propagation characteristics of any arbitrary installation for the implementation of a mobile radio system. This is especially true for telecommunication systems that use electromagnetic waves for information transfer instead of relying on the conventional way that use electrical currents. In this paper, a ray tracing approach using image method is adopted to perform radio propagation predictions in two selected areas of Sun-U Campus, namely an empty hallway located on the second floor in the School of Computer Technology (SCT), and its adjacent academic staff rooms. The values of electrical parameter such as dielectric constant (relative permittivity) of different materials are altered assuming the walls that separate each academic staff room are made of rubber, glass, and plasterboard. How this variation affects radio wave propagation prediction is discussed while the main propagation mechanisms traveling along the empty hallway are reported.**

***Keywords-component: radio propagation, ray tracing, telecommunications***

## I. INTRODUCTION

Sunway University, Malaysia has recently made available Sun-U wireless access (Sun-U WLAN) for all staffs and students using their own devices like smartphones and notebooks all throughout the university campus. To gain wireless access, staffs and students will just have to search for and connect to "Sun-U WLAN" WiFi network and enter their regular network (PC) login credentials. This news comes in timely because with the proliferation of notebooks and smartphones in university campus, easy access to the internet will both enhance students' learning experiences and make staffs' work more productive. More importantly, in this age of information and communication technology (ICT), easy wireless access is particularly crucial for constantly bringing new excitement into learning and communication. As a matter of fact, telecommunications, wireless applications, and mobile devices, among others, are fundamentally reshaping the way information is obtained, and the ways people learn and communicate with each other.

It is a well-known fact that wireless reception in buildings has often been spotty, with poor voice quality and slow data rates. This is because radio signal, especially at the high frequency bands commonly used for the third-generation (3G) cellular and wireless LAN communications, don't penetrate building walls well [1].To understand fundamentally what affects wireless reception in buildings, a close examination of the relevant propagation mechanisms is required.

In principal, there are four basic propagation mechanisms that impact propagation in a mobile communication system, namely, reflection, transmission, diffraction, and scattering [2]. Based on the physics of these propagation mechanisms, path loss can be predicted for large-scale propagation models using ray optics with the assumption that the operation frequency is high or wavelength is small compared with the typical size of objects in the environments. For radio waves of 2.4 GHz (that of wireless LAN), ray optics is valid for objects such as hallway and the walls/partition that separate each academic staff room.

## II. RAY TRACING USING IMAGE METHOD

The ray tracing using image method provides a simple and accurate way for determining the ray trajectory between a transmitter (Tx) and a receiver (Rx) [3]. The image method utilizes the images of the transmit antenna location relative to all the surfaces of the environment. The coordinate of all the images is calculated and afterwards rays are traced towards these images. First and second order reflections can be calculated very efficiently without sending rays to all directions. The drawback of this method is that calculation time grows exponentially when the order of the calculated reflections is increased. Within the scope of this work, however, the image method is an ideal approach for determining the main propagation mechanisms. Fig. 1 presents a simple reflection surface to illustrate the basic idea of how the image method works.

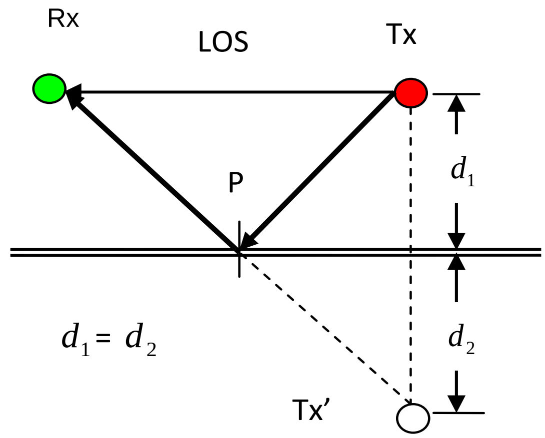


Figure 1. Ray tracing using image method.

For the scenario in Fig. 1, LOS (line-of-sight) is the path between the Tx and the Rx. To calculate the reflection from the surface, the image of Tx with respect to the surface is identified and is denoted as Tx'. Note that the distance from Tx to the surface and the distance from Tx' to the same surface are equal ( $d_1 = d_2$ ). Next, by connecting Tx' and Rx, the intersection point on the surface (P) is the reflection point where reflection occurs. For multiple reflections, multiple images with respect to the relevant surfaces will be determined in a similar way and the corresponding ray paths can then be obtained.

There are two locations of interest within the Sun-U Campus, which will be described in Section A and B.

*A. SCT Academic Staff Rooms*

Buildings have a huge selection of partitions and obstacles that form not only the internal but external structure as well [4]. For instance, in an office building environment, soft and hard partitions can be commonly seen. While the former are partitions that may be moved and do not span to the ceiling, the latter are formed as part of the building structure. On Sun-U campus in particular, the buildings walls and hard partitions are made up of various materials such as bricks, plasterboard, and glass.

It is worth pointing out that one distinct feature about Sun-U campus is that quite a significant number of the buildings walls are glass walls. This is true especially for those at/near the foyer like the info center, security center, Manchester Business School's office, Sunway TES, Lancaster University's office, and LeCordon Bleu Institute of Culinary Arts. The LeCordon Bleu Institute of Culinary Arts for instance, is a modern, newly-completed 2-storey full glass building to house the reception office of the Sunway LeCordon Bleu Institute of Culinary Arts. This paper will examine, via ray tracing simulations, the effects of building walls (that are made up of various materials) on radio propagation path gains across multiple partitions in the SCT academic staff rooms. Fig. 3 and Fig. 4 show two pictures of the environments concerned.

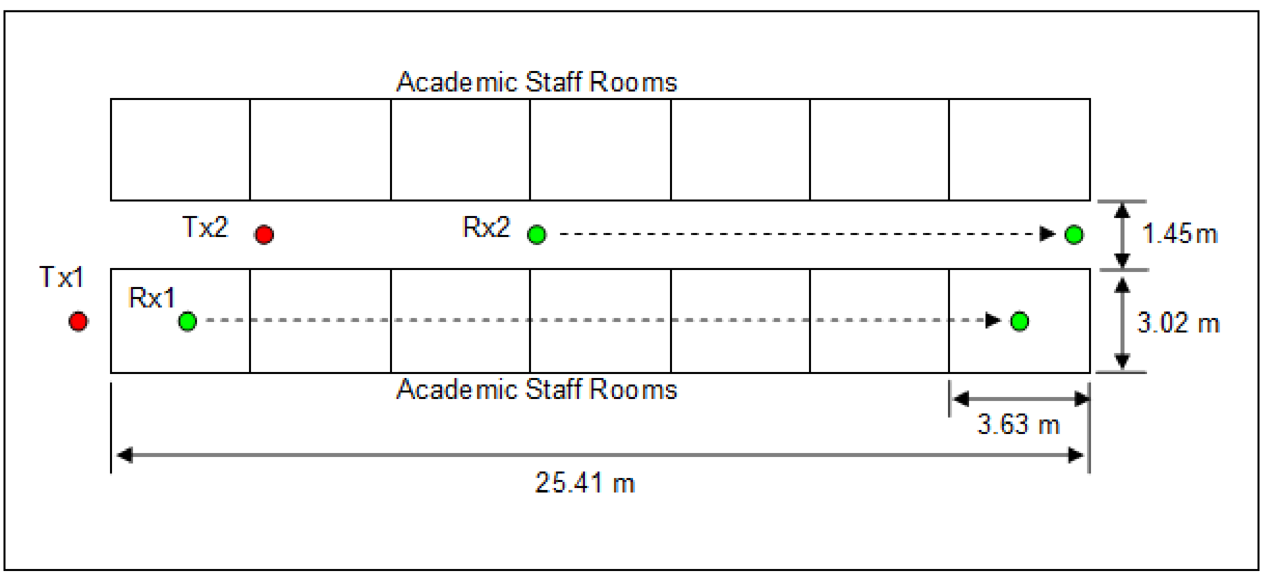


Figure 2. Layout of the SCT academic staff rooms (not to scale).

Figure 3. Picture of the SCT academic staff rooms.

Figure 4. Picture of the foyer on Sun-U campus.

### *B. Hallway Adjacent to the Academic Staff Rooms*

The other objective of this paper is to investigate, again via ray tracing simulation using image method, the main propagation mechanisms traveling along an empty hallway adjacent to the SCT academic staff rooms. This is a different propagation scenario whereby no obstacles are assumed present along the hallway for simulation purpose. Neither was there any movement of people or stuff is assumed for simulation purpose. The goal of this work is to understand how signal travels from one point (in this case the transmitter) to another point, which is the receiver that is located on the other end of the hallway.

## IV. RESULTS AND DISCUSSIONS

There are two parts in this section – part A and B. Part A reports the impact the various materials can make on radio signal attenuation across multiple walls/partitions while part B discusses the basic propagation mechanisms traveling along the empty hallway.

### *A. SCT Academic Staff Rooms*

The received signal strength from a specific transmitter will vary with location within the building as a result of the signal passing through walls. The exact nature of this variation depends primarily on the shape and construction of the building as well as the geometry of the radio link. To depict the variation resulting from signal passing through walls made up of various materials, Fig. 5 is plotted for the case when Tx 1 is put on one end of the SCT academic building while Rx 1 is moved across the SCT academic staff rooms (see Fig. 2) in a straight line manner. In this figure, five scenarios are discussed, namely line-of-sight (LOS) rays that assumed no obstruction/walls standing in the ways between Tx 1 and Rx 1, rubber wall with relative dielectric constant, $\varepsilon_r$ = 2.5, glass wall ($\varepsilon_r$ = 5), plasterboard wall ($\varepsilon_r$ = 6), and finally, concrete wall ($\varepsilon_r$ = 9).

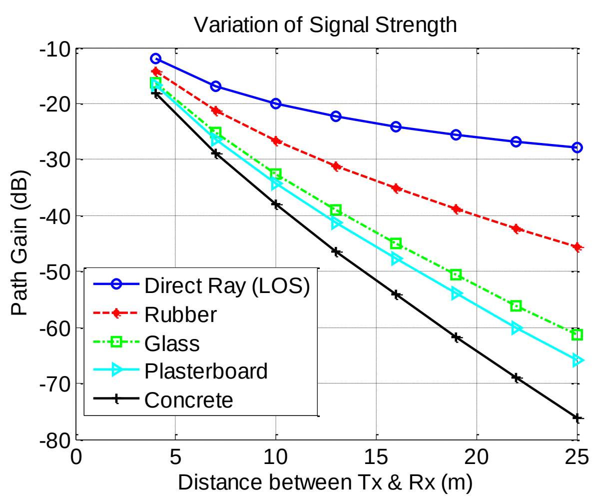


Figure 5. Signal attenuation across the SCT academic staff rooms.

It can be observed from Fig. 5 that the signal attenuation for the LOS case is the smallest, with signal dropping from -12.4 dB to -27.96 dB, or a total attenuation of 15.56 dB. However, in the absence of the LOS ray, when there are walls standing in the way between Tx 1 and Rx 1, the signal attenuation becomes greater as the value of the relative dielectric constant of the material of the wall increases. This can be seen in Fig. 5 that shows that signal attenuation for rubber wall, glass wall, plaster board wall, and concrete wall are 31.42 dB, 45.18 dB, 49.05 dB, and 58.06 dB respectively. The difference of the total signal attenuation between the LOS case and the concrete wall is 42.50 dB.

### *B. Hallway Adjacent to the Academic Staff Rooms*

In this section, a different scenario from the signal attenuation across SCT academic staff rooms is presented. In this section, both the Tx and Rx are moved to sit along an empty hallway adjacent to the SCT academic staff rooms. In particular, Tx 2 and Rx 2 are put at the center of the empty hallway, with Rx 2 being moved away gradually from the Tx in a straight line manner, as illustrated in Fig. 2 earlier. The results of the signal attenuation along this empty hallway along the receiver route are illustrated in Fig. 6.

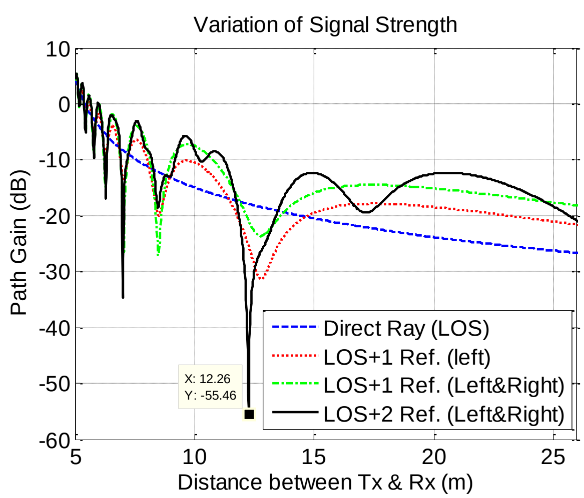


Figure 6. Signal attenuation along the empty hallway.

From Fig. 6, which shows the signal attenuation along the empty hallway depicted in Fig. 3, it can be noticed that when multiple reflections are included in the simulations, fading occurs due to multipath propagation. In this scenario, first and second orders of reflections from both the left and right walls are considered in the simulation using ray tracing of image method. The two surrounding walls act as reflectors for the empty hallway where the transmitter and the line segment (between Tx 2 and Rx 2 in Fig. 2) are located. Since the walls surround both the Tx 2 and Rx 2, it creates multiple paths for which a transmitted signal can traverse. As a result, the receiver sees the superposition of multiple copies of the transmitted signal, each traversing a different path. Each of these signals (direct ray, left-wall-reflected rays, and right-wall-reflected rays) experiences differences in attenuation, delay and phase shift while traveling from the transmitter to the receiver. Hence, at the receiver, constructive and destructive interference occur that amplifies and attenuates the signal power respectively. Strong destructive interference (deep fade) occurs at location 12.26 m along the receiver path which may result in temporary failure of communication. As for the simulation results that involves only the direct ray, signal attenuates gradually from 4.32 dB to -26.67 dB as it moves away bit by bit from the transmitter (or a total of 30.99 dB in signal attenuation).

## V. CONCLUSION

In this paper, a ray tracing using image method has been adopted to run simulations for radio propagation predictions at two selected locations on Sun-U Campus at 2.4 GHz. From this work, it was shown that multiple reflections from the surrounding walls along an empty hallway produce many paths by which the signal can propagate from the transmitter to the receiver. For simulations across the SCT academic staff rooms, the received signal shows a systematic decrease with distance, but with a varying amount of total signal attenuation that in turn depend on the materials of the wall/partition. In particular, the signal attenuation rises as the value of the relative dielectric constant of the material of the wall increases. From the findings of this work, one can conclude that radio waves propagation within a building is strongly influenced not only by the layout of the buildings but by the construction materials as well.

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