Measurement of an Uneven Terrain Model for Potential Applications in Caves

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***Abstract*— Despite the fact that cave communication has an abundant history, when an accident happened, some of the major problems are seemed to be left untreated yet. A year ago, thousands of people from around the world gathered in Thailand to help rescue one Thai soccer team who was trapped inside a cave. Tragedy could be avoided or better resolved with wireless communication inside cave. In this work, we have built an uneven terrain model for potential applications in cave environment since the ground in cave is oftentimes not flat but uneven. We performed field measurement on this uneven terrain model at 2.4 GHz. Subsequently, the measured result is compared with two ray-tracing results – one original one and another one with a scattering factor incorporated. The comparison shows that the latter ray-tracing simulation matches the measured result better, with an improved standard deviation value.**

***Keywords* —wireless communication; caves; complex propagation environments; uneven terrain**

I. Introduction

There are plentiful supply of Malaysian caves that bolster bird's nest industry where collectors recklessly climb up to the ceiling of the caves using bamboo ladders. These nests are made of bird saliva and sold at a high price for their medicinal properties. Malaysian caves are also shelter to fruit bats, invertebrate and swiftlets and they have other natural attractions such as massive stalagmites and stalactites. Just like any other nature adventures, conservation of stalactites and all cave wildlife is crucial. Although major expeditions have been conducted, many caves have yet to be fully explored, luring explorers for further adventure therein. As such, it is crucial to make wireless communications available in caves. This move will benefit several activities that are caves-related such as volcanology, speleo-biology, speleo-arcehology, military reconnaissance, hydrology and cave exploration [1]. In addition, it will also enhance the safety of the operation of show caves like the tourist caves and furthermore, it may assist in the search and rescue operation in caves.

Many solutions exist which could aid in either researching more about caves or excavating them. All of these will benefit from wireless communication inside caves. A closely related work to propagation modeling in caves is the modeling of rough surfaces and rough walls [2] – [3]. In these research that were conducted at VHF and UHF bands, the researchers found that their models require the use of numerical analysis to provide solutions to the intractable mathematical formulations. They also required heavy computational resources.

We have previously investigated rough surfaces with caves in mind and predicted that in a cave environment when the ground is not smooth but rough, lower signal strength can be expected [4]. In this paper, we have further built an uneven terrain model for measurement and reported its finding. Subsequently, we compared the measured result with two ray-tracing results – one original one and another one with a scattering factor incorporated. This scattering factor is the same as what we termed attenuation factor in [4]. The measurement campaign was taken at 2.4 GHz. The 2.4 GHz frequency is commonly employed as wireless local area network (WLAN) [5]. For future development, a new real time automatic measurement scheme for swept source-based optical coherence tomography (SS-OCT) systems could be explored [6].

II. propagation Measurement Setup

The field measurement was conducted at the ground floor corridor in Block D at the University of Nottingham Malaysia. In this measurement campaign, the receiver (Rx) points are defined as the points where receiver measures the received signal strength at varying distances from the transmitter. Fig.2. illustrates the top view of the L-shaped measurement site which includes LOS and NLOS paths. A transmitter was placed stationary at the starting point of the hallway. In the meantime, the first receiver was located 1 m away from the transmitter, with consecutive receiver separated 1 m apart from one another.

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Fig.1. LOS path of measurement site (left), NLOS path of measurement site (right).

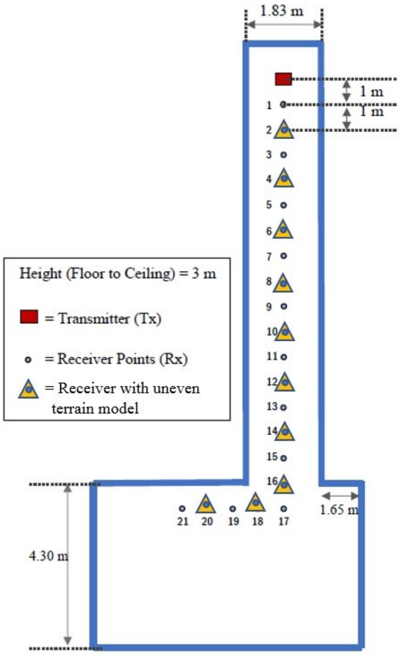

Fig.2.Top view of indoor corridor (not to scale)

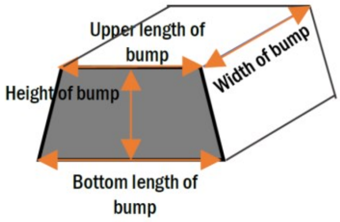

Fig.3. The model parameters

TABLE I

TX AND RX HEIGHT

Frequency (GHz)	Height of Tx (m)	Height of Rx (m)
2.4	1.59	1.59

TABLE II

UNEVEN TERRAIN MODEL SPECIFICATIONS

The position of bump	Upper Length (m)	Bottom Length (m)	Height (m)	Width (m)	Size of bump
2nd	0.53	1.05	0.53	0.61	Medium
4th	0.4	0.88	0.33	0.61	Small
6th	0.6	1.15	0.53	0.61	Medium
8th	0.48	0.78	0.8	0.61	Big
10th	0.45	0.83	0.37	0.61	Small
12th	0.67	1	0.48	0.61	Medium
14th	0.5	0.74	0.8	0.61	Big
16th	0.55	0.94	0.75	0.61	Small
18th	0.4	1.07	0.8	0.61	Big
20th	0.55	1.1	0.51	0.61	Medium

A total of 10 bumps were made for the measurement campaign. These bumps were made in 3 different sizes - small, medium and large. They are made up of thick cardboard boxes, papers or newspaper, polystyrene, PVA glue, tissue papers, paint and some tapes. Table I lists the heights of transmitter and receiver while Table II details the specifications of all bumps. This uneven terrain model was made to imitate a real irregular terrain environment and it resembles in kind the irregular ground inside caves.

We utilised the same data acquisition system in [7] to collect measurement data with slight modifications. A U-clamp is used to mount the antenna with tripod stand. The antennas are fixed to an upright position for VV-Pol. Fig. 3 shows a sample of the bump.

III. RESULT AND DISCUSSION

In Fig.4, the measured and simulated result is presented. We observe that the signal strength drops as the receiver moves further from the transmitter. There was a drastic drop of signal at a location between 18 and 22m after LOS signal turning the corner. It is because NLOS path of signal can only travel through reflection, diffraction and refraction of radio waves. When the scattering factor is applied on ray-tracing algorithm, we can observe a better agreement between the simulated and the measured results, with an improved standard deviation from 6.84 dB (without scattering factor) to 4.48 dB (with scattering factor). This finding is also consistent with what we have previously reported in [4], that when an attenuation factor is applied for a random rough surface, it can generally lower the path gain.

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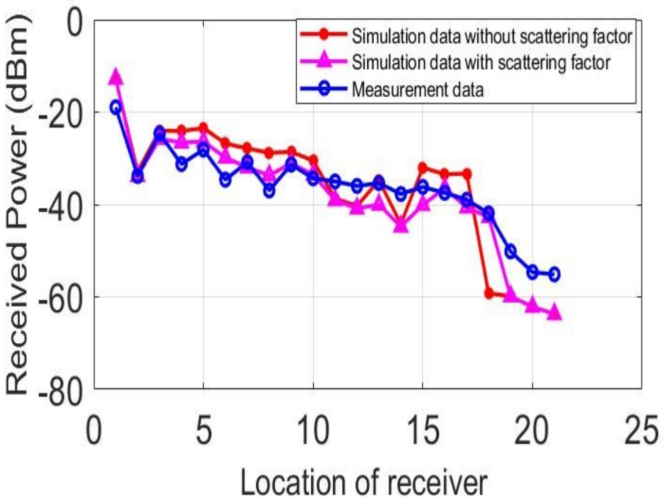

Fig.4. The simulated and measured results for VV-Pol at 2.4 GHz

IV. Conclusion

In this paper, we have built an uneven terrain model and have it measured and compared with ray-tracing simulation results at 2.4 GHz. Our comparison shows that when a scattering factor is incorporated to the ray-tracing algorithm, a better fit to the measurement result can be obtained with a reduced standard deviation. This research outcomes lay a good foundation for future works to be conducted in actual caves environment since there is still little known of the stalagmites and stalactites and their combined effects of accumulated water in a cave passage.

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