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Outdoor Propagation Link Budget Effect on Wireless Real Time Video Transmission

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***Abstract*— Real Time Video Wireless Transmission (RTVWT) combines telecommunications and imaging in order to provide remote video transmission. By removing distance barriers, it improves access to different services that would often not be regularly available in distant rural communities. It also saves lives in critical scenarios like healthcare, oil field inspection, monitoring oil and gas pipelines, and security. Wireless networks constantly suffer from different factors like bad weather conditions, fading and multipath interference, which lead to weak signals entailing packet losses or delays and rendering unacceptable video quality. This paper represents a performance study of link budget analysis (LBA) for short-range operation of remote sensing and its effects on video quality, in which both experimental and theoretical levels have been considered. The analysis presented is based on measurements conducted in a complex environment, such as an open field by the Computer Center building of the University of Birmingham during the snowy weather with surrounding vegetation. The link budget is calculated by initially measuring the input received power of a transmitted continuous wave (CW) signal at 2.45 GHz frequency at different distances from the transmitter, and then calculating the path loss for each scenario while taking the fading effect into account. Measured path loss was compared to the Two Ray (Ground Reflection) and Free Space Path Loss models in order to describe the received power for the specified remote sensing system. Outage analysis is made at the final stage.**

Keywords—Link Budget Analysis; Real Time Video Streaming; remote sensing; Outdoor Propagation Measurement; receives power; Free Space model.

I. Introduction

The literature of the twentieth century reveals remote control research mainly targeting military equipment such as radio controlled machines and weapons of World War I and World War II. It continued to arouse interest, thus nonmilitary uses were found and automatic garage door openers together with the TV remote controls were invented. Up till now, it is still advantageous in military field as military tests are currently being conducted to use radio control aircraft for video surveillance and air strikes which could save soldiers' lives [1]. There is also a massive growing interest in unmanned vehicles such as planes, boats, or cars for recreation, entertainment and industrial applications such as remote monitoring of structural damage or field surveillance.

In order to provide confident data transmission for remote sensing and communication links, rigorous estimation of power budget is necessary. It is important to know that link budget is the estimation of the signal energy loss, or outage caused by propagation losses due to fading, shadowing and noise taking place in the devices etc., Link Budget Analysis (LBA) provides an overall view of the whole system [4]. The aim of this paper is to study the LBA for a specified remote video sensing system, operating at 2.45 GHz on both experimental and theoretical levels.

The organization of the paper is as follows. Section II, revises the signal propagation models and in Section III, the experimental system and its set up used for the trials in open field is described. Then, Section IV describes the measurement scenarios followed by the conclusion in Section V.

II. Propagation Path Loss Models (Background)

The models of the path loss are determined by the analysis in order to allow visualize propagation and to describe the attenuation and behavior of how the signal propagates in various locations. Comparing the specifications of the available path loss models to those specifications and factors describing the work here, it was decided that the most suitable models for corresponding propagations are Free Space Path Loss Model (FSPL), Two-Ray or Ground Reflection Path Loss Model, and Log-Distance Path Loss Model.

A. Log Distance Path Loss Model

Log-distance model is an empirical model combining theoretical models together with measurements. The average Path Loss (LP) of a distance *d* is:

$$L_p(dB) \propto \left(\frac{d}{d_0}\right)^n \quad (1)$$

$$L_p(dB) = L_p(dB) + 10n\log_{10}\left(\frac{d}{d_0}\right) \quad (2)$$

The path loss changes by using a path loss exponent, ***n***, which shows how fast path loss increases with the distance, *d*, i.e. increasing the value of ***n*** increases the signal loss. Reference distance (d_0) can be taken as any distance point within the T-R separation range, and usually is chosen to the closest to the transmitter. The slope on a logarithmic scale that determines the attenuation of path loss as a function of distance is **10 n** and can be examined in (Eq. 2). The value of ***n*** depends on many specific factors that influence the propagation. Construction material, location of antenna, etc. Change the value of ***n***, therefore causing the changes in signal strength [reference]. The value of ***n*** varies in the range of 1.2 to 8. For example, in free space, ***n*** is equal to 2 however, in the presence of obstructions, ***n*** will have a naturally a larger value. Table 1 presents the different values on *n* corresponding to the various studied environments [6, 7].

Table 1. Path Loss Exponent Subject to Environment.

Environment	***Path Loss Exponent***
Free Space	2
Urban Area	2.7-3.5
In Building (line-of-sight)	1.6-1.8
Obstructed in Building	2-3

The Log-Distance Path Loss model was used with the purpose of finding the value of path loss exponent ***n***.

B. Free space Path Loss Model

The Free Space model has been selected to allow the demonstration of the loss resulting in line of sight (LOS) propagation. The principal purpose of the (FSPL) is to help visualize the open air path loss which disregards surrounding obstacles, propagation phenomena and antenna gain [7]. The formula describing path loss is a positive quantity, represented usually in dB:

$$L_{P(FSPL)} = 32.45 + 20\,log_{10}(d) + 20\,log_{10}(f) \quad (3)$$

Where:

d - Distance in km

f – Frequency in MHz

C. Two Ray (Ground Reflection) Path Loss Model

This propagation model is used for the same reason as (FSPL) with the difference that it considers the existing reflecting surface. This makes the 2-Ray model more accurate as it is better to consider both direct and reflected waves instead of just the direct one. This model has been used to reflect propagations case in test field areas, where the signal at the receiver end can be described as the sum of (LOS) and reflected waves [7].

$$P_r = \frac{P_t G_t G_r h_r^2 h_t^2}{d^4}$$

Figure 1 illustrates the general (LOS) communication path for 2-Ray Model with the transmitter of height $\mathbf{h_t}$ placed at a height $\mathbf{h_r}$ and a distance **d** from receiver.

III. EXPERIMENTAL SET UP

This section briefly describes the experimental system that is used for measurements and record of the received power of the continuous-wave signal. Figure 1 and Figure 2 display the model of the transmitting and the receiving systems. The signal of 2.7 dBm is generated using the CCTV camera placed on the top of the unmanned controlled vehicle which has a height $\mathbf{h_t}$ of 34 cm. Together with the camera, the GPS sensor is also attached to the top of the toy car. It allows tracking the system's specific trajectory. The transmitted signal is received by the omni-directional antenna, monitored with the spectrum analyzer, and recorded with the MATLAB software on a computer. Table 2 displays the measurements set up.

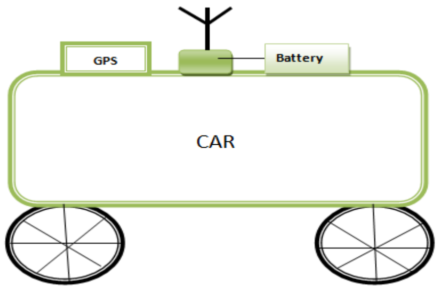

Figure 1: Transmitting System.

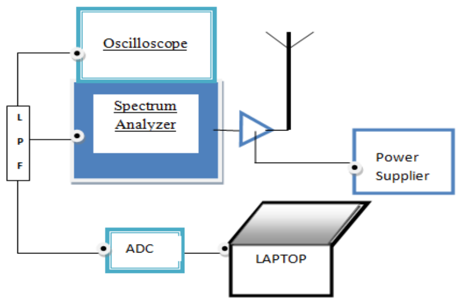

Figure 2: Receiving System.

Table 2. Measurements' Setups.

MEASUREMENT SET UP	
Carrier Frequency (GHz)	2.45
Bandwidth (MHz)	2
Transmit Power (dBm)	2.7
TX Antenna Height (m)	0.34
RX Antenna Height	0.45

I. MEASUREMENT SCENARIOS

The experimentations presented here is to measure the propagation of a continuous-wave signal at 2.45 GHz, at a location within the open field. The receiving system is placed on a metal trolley and it is fixed at one location, while the transmitting system is moving in a specific direction to a various location, starting from 5m up to 35 m along the pathway. At each location, every 5 meters apart a minimum of five measurements (each lasting 30 seconds) is taken. Nominal locations are fixed and unchanged for each scenario. By observing the details of how signal propagates from transmitter to the receiver at the different locations, the appropriate path loss model may be found for each scenario.

The environmental location for the measurement trials chosen was the open field near the Computer Center building at the University of Birmingham showed in Figure 3. In this setting, natural occurrences such as leafage and foliage have to be considered and accounted for as they have significant influence on the propagation of radio waves. In addition, the weather conditions also have an important impact.

The measurements on the field were divided into 3 scenarios, where **Tx** moved away from **Rx** for every 5 meters at 0º, 45º, and 90º as shown in Figure 4. The path loss difference among these three scenarios is examined in Section III, where the height of the receiving antenna is 45 cm.

Figure 3: The Computer Center Building at the University of Birmingham.

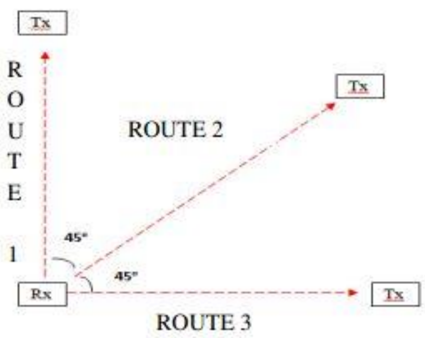

Figure 4: The 3 Scenarios with corresponding angles of 0º, 45º, and 90º.

II. Statistical Analysis

The path loss is calculated by taking into account the fading of the signal. Fading is a deviation of the signal attenuation due to the multipath propagation or due to shadowing. As a result of this fading, the propagation is considered to be a random process; therefore the propagation is analyzed by stochastic methods [6]. The statistic of slow and fast fading is characterized by probability distributions such as Rician distribution that assumes a communication link having an unobstructed path from the transmitter to the receiver as well as many reflected waves. The statistic method requires the mean and standard deviation values of the received power strength. Familiarity of the correct statistical distribution that describes the signal fluctuations ensures in a simpler characterization of the communication link and the system performance.

III. Numerical Results and Analysis

The results of the measurement trials together with the analysis are presented using MATLAB software. The numerical analysis presents the comparison of the path loss models with the measurement results shown in Table 3. The scatter plot in Figure 5 shows the signal strength (in dBm) as a function of distance.

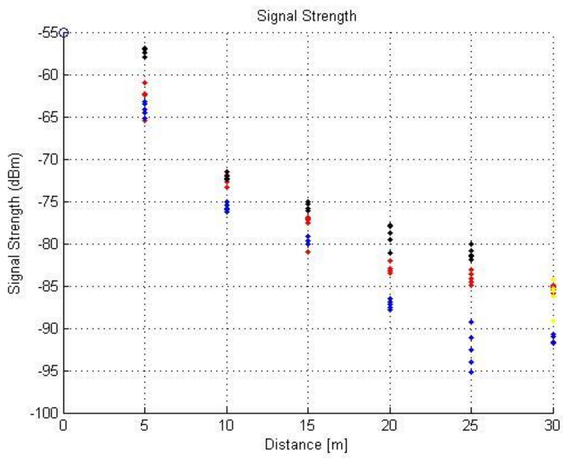

Figure 5: Signal strength (in dBm) as a function of distance.

The scatter plot in Figure 6 illustrates the measurement path loss (in dB 2) as a function of the T-R separation. At each nominal location there are 5 measurement values of each environment were used to plot the scatter where the average LP of each scenario was determined and illustrated as well. The mean (μ) of path loss at each distance point gets higher; therefore, it is obvious that the measured average path loss increases logarithmically with the distance between transmitter and the receiver. Figure 7 shows the comparison between the theoretical FSPL, 2-Ray model and measured data.

Table 3. Comparison of the path loss models with the measurement results.

Numerical Results			
distance	***0***	***45***	***90***
5 m	62.708	57.262	64.14
10 m	72.48	71.94	75.74
15 m	77.94	75.484	79.6
20 m	82.92	79.04	87.19
25 m	84.04	81.14	92.402
30 m	85.302	86.1	91.35
35 m	86.472	88.25	94.4

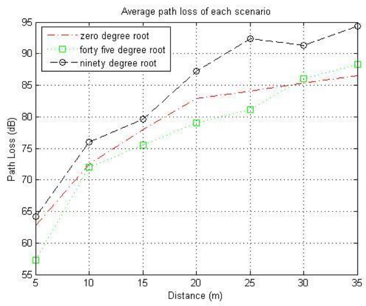

Figure 6: Measurement path loss function of the T-R separation.

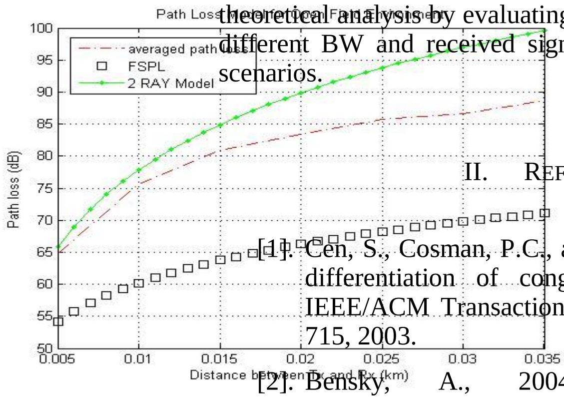

Figure 7: Theoretical FSPL and 2-Ray model vs. measured data.

The signal outage probability is fairly simple to compute if one knows the probability distribution of the fading (e.g. Rician) and outage occurs if the signal drops below the threshold, which is the certain minimum of the signal amplitude [7]. The signal threshold should have been found with the help of CCTV imaging. As it was mentioned in section 3.4.1, the lens of the transmitter, which is the CCTV camera, was closed with the tape, in order to avoid frequency modulation. So since we didn't have an image monitoring, the threshold has been found with the help of signal amplitude observation. Fig. illustrates the signal strength of the experimental data, where we can see the strength drops sharply at distance of 25 meters, so we can assume the margin of deep the signal fade can be is -92 dBm. According to the graph, only 3 measured signals out of total 115 were below threshold of -92 dBm. The percentage has been calculated of the signal outage and see approximately how much time the signal was off.

$$\frac{3}{160} \times 100 = 2.609\%$$

I. Conclusion

The experimental study focus on the effect of propagation link budget on wireless real time video transmission and its analysis for a short-range application of a remote sensing that operated at 2.45GHz for outdoor environments. The testbed (hardware and software) used in order to achieve the objectives has been described, as well as the methods of analysis of the experimentally received data using the theory for estimation and modelling the link budget for the corresponding remote system. Our analysis of radio propagation for a remote sensing indicates that the path loss LP of LOS environments increases logarithmically with the distance and the exponent n in a log-distance model has been estimated for different scenarios. Similarly, it has been found a suitable path loss model and it was found that in general the Two Ray Path Loss Model gives reasonable results for all the corresponding environments.

Future Work have conducted real experiments on video transmissions on a wireless links and analyzed the results using theoretical analysis by evaluating two-path loss models include different BW and received signal levels in LOS and NLOS scenarios.

II. References

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