Wideband Propagation Measurements and Analysis of Indoor Radio Channel at 5GHz and 18GHz Using Directive Antennas

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Abstract: - Wideband radio propagation measurements at the 4.8 to 5.2GHz and 18 to 19GHz frequency bands using directive antennas were made in the foyer of Main Lecture Theatre(MLT) Nanyang Technological University, Singapore. The area is characterized by high glass panel and zigzag shape with few indoor trees and scattering objects within. Frequency responses of the channel were collected and then transformed to the time domain for analysis by using the Inverse Fast Fourier Transform (IFFT). The collected data was classified into Line Of Sight (LOS) and Obstructed Sight (OBS) at 5GHz and 18GHz band for analysis. The characteristics of the channel were analyzed and compared in terms of path loss and RMS delay spread for these two frequency bands. The exponent values (n) were found less than the free space propagation power law exponent of 2.0 for the LOS areas, and larger than 2.5 for the OBS areas at both these two frequency bands. The RMS delay values obtained here were relative small compared with the results reported by other researchers[1][2] using omni-directional antennas. The use of directive antennas significantly decreases the RMS delay spread and hence reduces the ISI for the Wireless LAN.

*Key-Words:*Indoor Radio Propagation,Multipath,Path Loss,RMS Delay Spread,Wireless LAN, ISI Proc.pp..6171-6175

1 Introduction

For the indoor high speed wireless communication system one of the most significant factor that should be considered is multipath. Multipath causes inter-symbol interference (ISI) and seriously limits the data transmission rate of the system. Owing to the multiple reflections, diffraction and scattering effects of walls, floors and furniture many multipath components are introduced in the indoor environment. Multipath components arrive at the receiver in several directions. The use of directive antennas to confine the received signal in a smaller angular range can reduce the number of multipath components and hence decrease the delay spread. There is a relatively large selection of reports on the measurements and modelling of indoor radio channel around PCN frequencies of 1~2GHz [1] but few at the Wireless LAN frequencies of 5GHz, 17GHz [2] and 18GHz [3] over different indoor environments. However most of the measurements reported were performed with omni-directional antennas. This work provide some measurements results and analysis of indoor Wireless LAN channel at 5GHz and 18GHz bands using directive antennas.

Measurements were performed within a foyer of a building using a frequency domain measurement system incorporating a vector network analyzer. The aim of the experiments was to evaluate path-loss and the statistics of the RMS delay spread by using a pair of directive antennas in a typical WLAN environment and to compare the results for different frequencies.

2 Measurement Setup and Plan

The block diagram of the measurement system is shown in Figure 1. At the heart of the system lies a vector network analyzer(HP8722D) which was used to collect the frequency response of the indoor radio channel. Amplifiers were used to compensate the power loss introduced by the 50 meters coaxial cable. A pair of WJ 48430 Watkins Johnson Dual Polarisation Quad-ridged Horn Antennas(3dB beam width of 40^0 at 5GHz) and a pair of TECOM Dual Polarisation Horn antennas(3dB beam width of 60^0 at 18.5GHz) were employed for the 5GHz and 18GHz campaign respectively.

The network analyzer was swept from 4.8GHz to 5.2GHz in 1.0MHz steps(401 points) and from 18GHz to 19GHz in 1.25MHz(801 points). Every measurement was averaged over 8 sweeps. Before the measurements were carried out the system was carefully calibrated at the frequency bands of interest to compensate for the phase and amplitude variations caused by amplifiers, cables, measurement equipments and antennas.

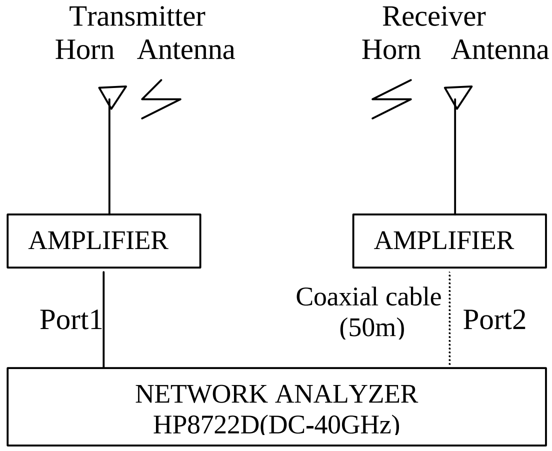

Fig.1. Block diagram of the frequency domain measurement system

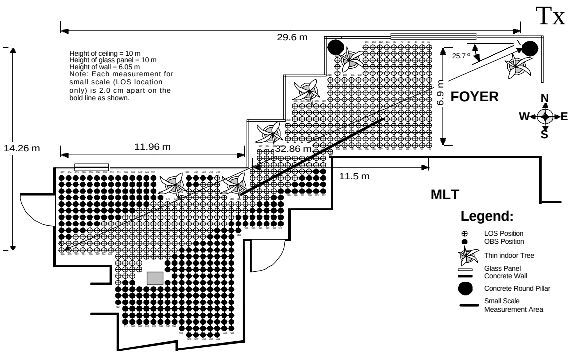

Figure 2. Measurement Floor Plan in the Foyer of MLT

All the Measurements were performed in the foyer of Main Lecture Theatre in Nanyang Technological University, Singapore. Figure 2. Illustrates the floor plan of the foyer. The foyer has a zigzag shape in the horizontal plane with the dimension of about 30m long 20m wide and 10m high. The inner wall is made of concrete material which separate the foyer from the Main Lecture Theatre. The outside wall is a 10 meter high glass panel. There are six indoor trees along the glass panel about 2 meters away from it. The ceiling is about 10m high from the fully carpeted floor. The floor is made of concrete with metal stud embedded to reinforce it. This environment is not different from an office area.

The transmitter antenna was fixed at one pillar (the upright corner ● in figure 2) at 1.65m high. The receiver antenna was mounted on a trolley at the same height. The locations of the receiver were on a grid 0.46m apart. In order to give a good coverage of all the LOS positions within the 3dB beamwidth of the transmitting antenna, the boresight of the transmitting antenna was fixed at an fixed angle of "25.7°" from the concrete wall opposite the glass panel. The classification of LOS and OBS is done by determining the optical clearance from the receiver's position to that of the transmitter. If the receiver is shadowed such that the transmitter and receiver cannot "see" each other, it is classified as a OBS position. The LOS positions are marked out as "⊕" while OBS positions are represented as "•" in the layout of the measurement plan as shown in Figure 2.

3. Result and Analysis

Frequency responses of the channel were collected and then transformed to the time domain for analysis by using the Inverse Fast Fourier Transform(IFFT). A 3-term minimum Blackman-Harris window[4] is used for the 1024-points IFFT. The time resolutions are 5ns and 2.3ns for the 5GHz and 18GHz campaign respectively. A total of 828 profiles were collected at the 5GHz band among which 492 profiles were for LOS and 336 profiles for OBS. There were 142 profiles for LOS and 54 profiles for OBS at the 18GHz band.

Figure 3 shows a typical power delay profile(LOS) while Figure 4 shows another power delay profile in an OBS area collected during the measurements. Here the relative amplitudes are calculated with reference to the values obtained in an anechoic chamber with the Transmitter and Receiver separation 1.5 m.

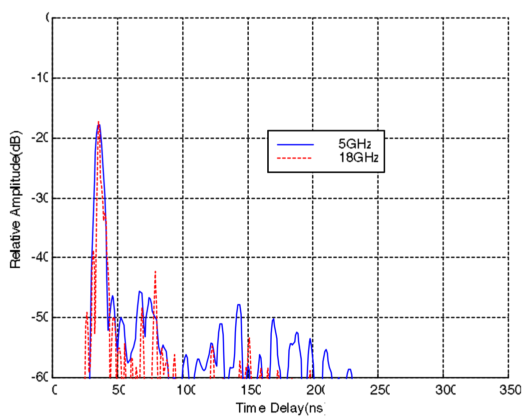

Figure 3. LOS power delay profiles at 5GHz and 18GHz bands. T-R separation 10.57 m

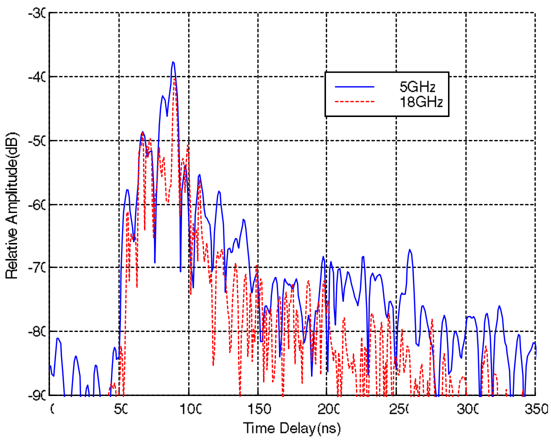

Figure 4. OBS power delay profiles at 5GHz and 18GHz bands. T-R separation 16.42 m

3.1 Large Scale Path Loss

The indoor propagation large scale path loss information is very useful for power coverage prediction in indoor wireless communication system design.

The power loss increase with T-R seperation (d) following a simple d to power n law where n is the exponent whose value depends on the propagation environments. That is the path loss can be written as

$$\overline{PL}(d)[dB] = 10\times n\times\log_{10}\left(\frac{d}{d_0}\right) - PL(d_0) \quad (1)$$

Where $\overline{PL}$ is the mean path loss; n is the power law exponent; d_0 is the reference distance(at 1.50m in the anechoic) and d is the T-R distance. When plotted on a log-log scale, the slope of the best-fit-line through the measurement is taken as the exponent n.

Figure 5 and Figure 6 illustrate the path loss scatter plot versus T-R separation for the data collected in the foyer of MLT at the 5GHz and 18GHz bands respectively. The n value is smaller than 2.0(the free space path loss) for the LOS locations and larger than 2.5 for the OBS areas at both the 5GHz and 18GHz bands. The low n value obtained for LOS can ascribe to the fact that directive horn antennas were used and most of the LOS locations are within the 3dB beam width of the transmitting antenna. Another reason is that there is no furniture and other scatters around the transmitter and receiver antennas to cause any additional losses. However, because of the lack of Line-of-Sight Paths, the path losses for the OBS areas are higher than that of free space. Similar results were also reported by Sun [3] who got a n value of 1.9 for LOS and 2.7 for OBS at the18GHz band using directive antennas in a communication laboratory. It can also be found that the n values for the data collected at 18GHz band are larger than those n values at 5GHz band for both LOS and OBS locations.

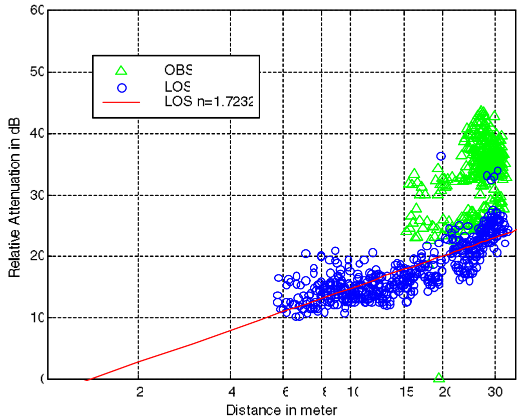

Figure 5 Path Loss against distance for the data collected at 5GHz band(LOS n=1.723; OBS n=2.66)

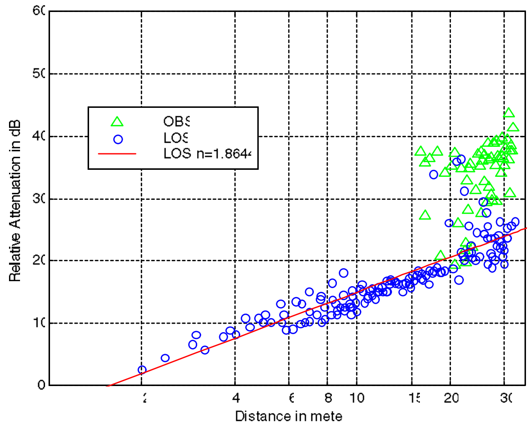

Figure 6 Path Loss against distance for the data collected at 18GHz band(LOS n=1.86; OBS n=2.752)

3.2 RMS Delay Spread

RMS delay spread is a good indication of the severity of the multipath delay and thus is a very important parameter for the wireless channel. The RMS delay spread is calculated by the following formula:

$$\tau_{rms} = \sum_{k=1}^{N}(t_k - t_m - t_A)^2 a_k^2 / \sum_{k=1}^{N} a_k^2 \quad (2)$$

where t_A is arrival time of the first path in a profile and τ_m is the mean excess delay which is calculated by the following formula:

$$\tau_m = \sum_{k=1}^{N}(t_k - t_A)a_k^2 / \sum_{k=1}^{N} a_k^2 \quad (3)$$

RMS delay spread is a very important parameter for the channel's performance since it causes the inter-symbol interference and thus limits the data transmission rate of the system.

Figure 7 and 8 illustrate the cumulative distribution of the RMS delay spread for the 5GHz and 18GHz band respectively. The mean and standard deviation values of RMS delay are listed in Table 2.

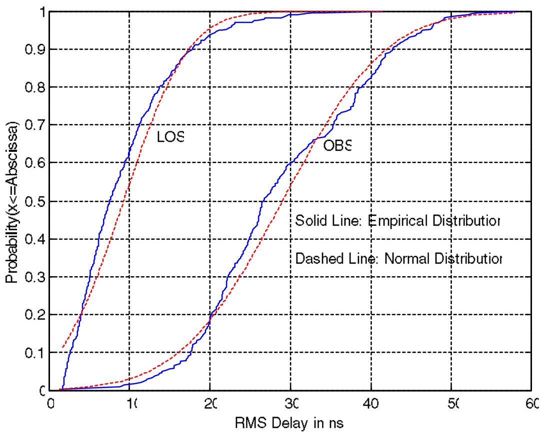

Figure 7. Cumulative distribution of RMS delay spread for the data collected at 5GHz band

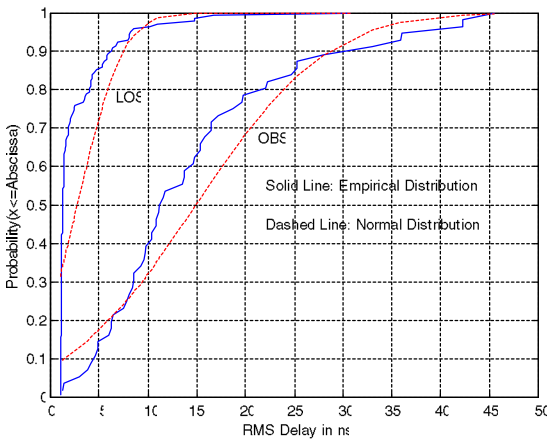

Figure 8. Cumulative distribution of RMS delay spread for the data collected at 18GHz band

Table 1. Mean & Standard Deviation values of RMS Delay Spread for the Data collected

Data Group	Mean Value	Standard Deviation
5GHz LOS	9.25 ns	6.34 ns
5GHz OBS	29.04 ns	10.11 ns
18GHz LOS	3.56 ns	3.98 ns
18GHz OBS	16.63 ns	10.72 ns

Analyzing the RMS delay spread for the data collected at the two frequency bands produces the following results:

(1) The mean of RMS delay spread for the LOS locations are very small, with the average value 9.25ns at 5GHz band and 3.56ns at 18GHz band as listed in Table 1. Here the mean RMS delay spread for LOS locations at 18GHz band is very similar to the value of 4.18ns obtained by Sun[3] in a communication laboratory using directive antennas at the same frequency band. The explanation for this result is that directive antennas were used, thus the number of multipath components was quite small compared to the measurements using omni-directional antennas [1][2].

(2) Owing to the absence of direct path, the values of RMS delay spread for OBS locations were larger than for LOS locations as illustrated in figure 7 and 8.

(3) A lower mean RMS delay spread was obtained at 18GHz band compared that at 5GHz band although a pair of 40^0 beamwidth antennas were used at 5GHz band and a pair of 60^0 were used at the 18GHz band. This may be because the free space loss is greater at 18GHz, giving rise to weaker multipath signals compared with the direct signal.

(4) The cumulative distribution of RMS delay spread fits a normal distribution as shown in Figure 7 and 8.

4 Conclusion

This paper presents the propagation measurements at 4.8GHz to 5.25GHz and 18GHz to 19GHz band by using directive horn antennas. Measurements were performed in the foyer of Main Lecture Theatre(MLT) Nanyang Technological University.

It was found that exponent values (n) were less than the free space propagation power law exponent, (n=2.0), for the LOS areas whilst larger than 2.5 for the OBS areas at all these two frequency bands. The exponent values at 18GHz band were found larger than at 5GHz band in both LOS and OBS areas. It was also observed that the mean values of RMS delay spread decreased from 9.25ns to 3.56ns for LOS locations and from 29.04ns to 16.63ns for OBS locations when the frequency increased from the 5GHz band to the 18GHz band. The RMS delay values obtained here were relative small compared with the results reported by other researchers [1][2] using omni-directional antennas. This indicates that the use of directive antennas can significantly decrease the RMS delay spread thus reducing considerably the ISI for the Wireless LAN.

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