

Extraction of channel parameter on the office in LOS indoor building environment

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Abstract— This paper describes the methods for extracting the root mean square (r.m.s) delay spread at 60GHz. A validation of the ray tracing method based on both image and ray tube with our in-office room measurement in line-of-sight (LOS) environment is also presented. And, empirical cumulative distribution function (CDF) from average (r.m.s) delay spread is derived.

Keywords— Delay, spread, office, LOS, millimeter

I. INTRODUCTION

Increasing demand of real-time high speed application calls for wireless local area network (WLAN) operating in the 60GHz band as part of the 4th generation (4G) system. The 60GHz band has made great interest [1-3] because of its large bandwidth allocated for future dense wireless local communications, particularly as relates to large wireless LAN bridges, and wireless high quality video conferencing.

Channel characterizations at these millimeter wave frequencies have made using the measurement [2] and high-frequency asymptotic approaches such as ray tracing (RT) method for modelling the channels. The measurement can be expensive (especially in the millimeter wave bands) as compared to electromagnetic modelling approach. RT methods have the capability to solve electrically large problems relatively fast and, as such, they become an obvious candidate for the extraction of channel parameters.

In this paper, we compare the channel parameter such as mean r.m.s delay spread based on the RT method with in-office room collected measurements. In addition, empirical cumulative distribution function (CDF) from average (r.m.s) delay spread is derived.

II. MEASUREMENT AND RAY TRACING SIMULATION

A. Measurement

An Office room was chosen whose dimensions are depicted in Figure 1. Specifically, the room is of length 13.0m, width 8.6m, and height 2.7m. Omni antenna operating as a transmitter (Tx) was positioned at Tx Ant (0.95m, 11.65m, 1.5m). Omni antenna serving as a receiver (Rx) was placed at 10 different locations inside room for measurement. The detail position of these 10 locations is

depicted in Figure 1. And, omni antenna and its vertical pattern of omni antenna illuminates in Figure 2.

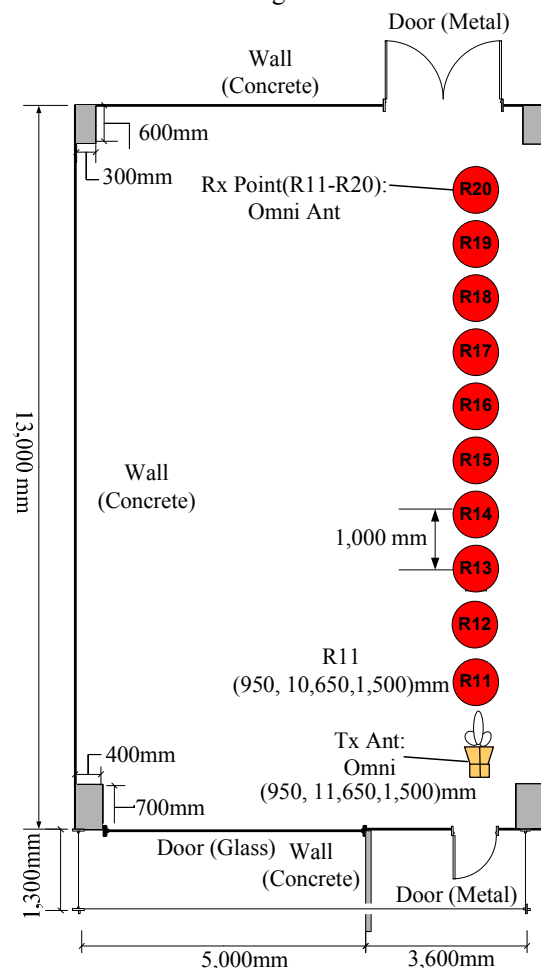
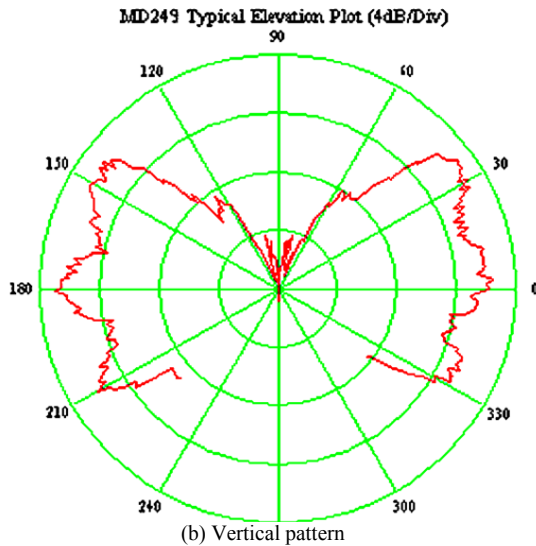


Figure 1. Scenario on office room in building

For each measurement, a total of 400 points (i.e., S21) between 1GHz and 3GHz was used, resulting in a frequency step of 5 MHz. This frequency resolution implied a maximum excess delay of about 200ns and a temporal resolution of 0.5ns (because of the 2GHz bandwidth). We remark that a signal-to-noise ratio (SNR) of at least 25 dB was maintained throughout all measurements



(a) Omni Antenna



(b) Vertical pattern

Figure 2. Omni antenna for measurement

In Figure 3, the measurement setup consisted of a network analyzer (i.e., Agilent 8753ES) operating at 30kHz to 3GHz, a pair of low noise amplifier (LNA) with the gain of 35dB, a pair of linear power amplifier with the gain of 20dB, a pair of up-convert mixer combining a signal generating from a network analyzer with local signal, a pair of down-convert mixer combining a received signal with a local signal, and a pair of antenna (omni: Tx and Rx). Antenna has a center frequency of 60GHz, with 2GHz frequency channel bandwidth sufficient for this measurement.

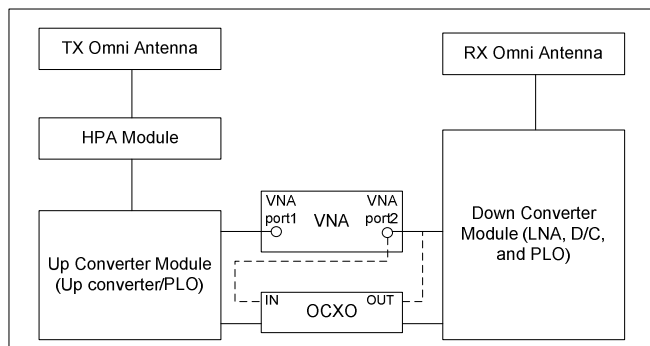


Figure 3. Measurement setup

B. Ray Tracing Simulation

Physical propagation like delay profile and delay spread could be provided from the deterministic model such as ray tracing (RT). Deterministic model are physically meaningful, and potentially accurate. RT model uses the theory of geometrical optics to treat reflection and transmission on the plane and diffraction on edges [4]. Reflections are accounted for by applying the Fresnel reflection coefficients [1], whereas for diffractions the field is multiplied by appropriate diffraction coefficients obtained from the uniform geometrical theory of diffraction [5-6].

The geographical structure of the office room for the ray tracing simulation is depicted in Figure 4. This is the same dimensions with measurement in Figure 1. For propagation analysis, we chose an omni antenna in Figure 5 as both the transmitter and receiver with 12° in azimuth and vertical pattern such as Figure 2 (b). We remark that all receiver positions through the office room had line-of-sight (LOS) path to the transmitter. Specifically, ten receiving locations, namely, R11-R20 were sampled (see Figure 1).

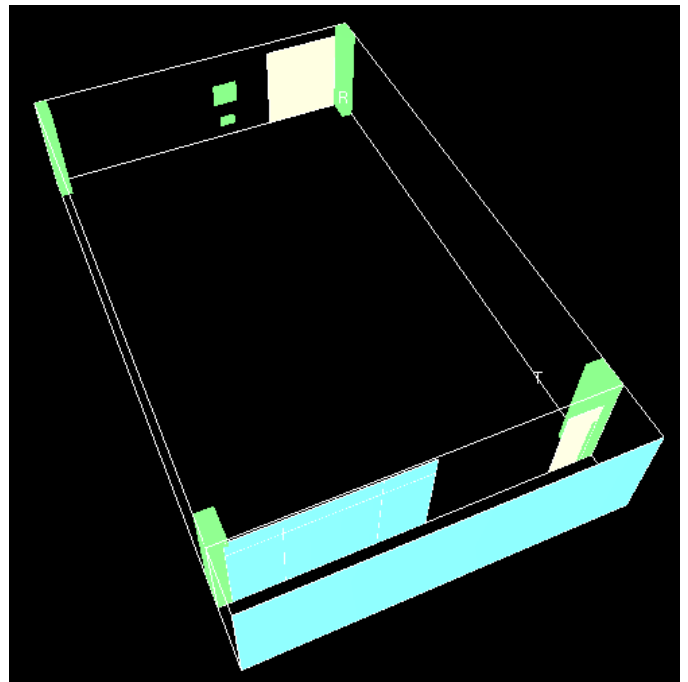


Figure 4. Geographical model of office room in building

At these locations, channel parameters were extracted as described in Section 3. For the simulations, the ray tracing tool was set to analyze the propagation response. In the simulations, the direct, reflected, transmitted and diffracted rays up to sixth order from the walls, ceiling, and floor were included for the indoor office room as shown in Figure 6. Here, our interest is the extraction of the multipath channel parameter (i.e., r.m.s delay spread). We note that the simulation times for each receiving location are approximately 60sec for the hallway, using 2.4GHz CPU machine. Detailed parameters for the ray tracing simulation are given by Table 1.

Table 1. Model Parameters

Parameters [∘]	Values [∘]
Height of walls [∘]	2.7m [∘]
Relative permittivity of concrete walls [∘]	6.1473 [∘]
Relative permittivity of glass door [∘]	6.2443 [∘]
Relative permittivity of metal door [∘]	1 [∘]
Conductivity of metal door [∘]	58000000 S·m-1 [∘]
Frequency [∘]	60GHz [∘]
Polarization [∘]	Vertical [∘]
Height transmitter/receiver [∘]	1.5m/1.5m [∘]
Number of reflection diffraction order [∘]	6/2 [∘]
Transmission [∘]	activate [∘]
Diffraction [∘]	activate [∘]

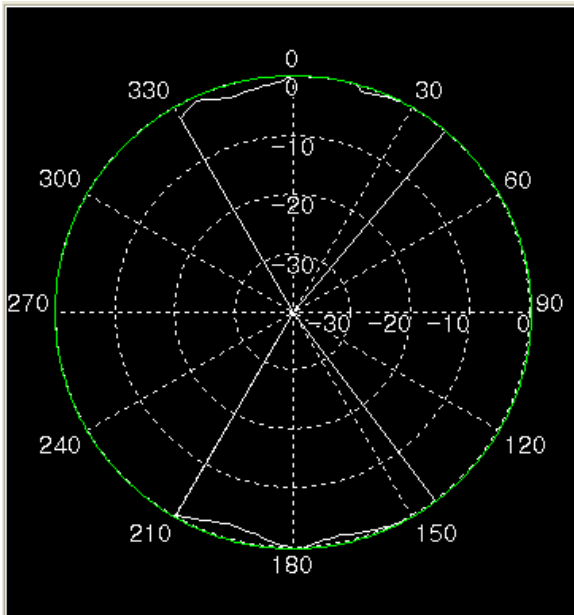


Figure 5. Omni antenna 3D pattern

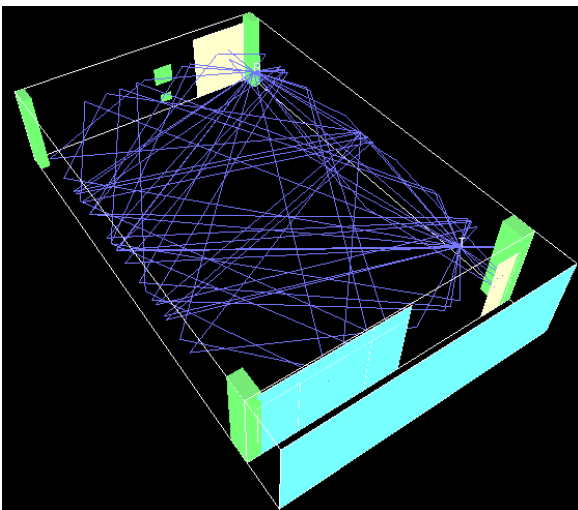


Figure 6. Example of ray tracing in T-type hallway in office building

III. RESULTS

A. Delay Spread

The measurement campaign and a ray-tracing tool delivers a prediction of the complex channel impulse response (CIR) for each receiver position, taking into account the patterns of the transmitting and the receiving antenna.

The CIR $h(\tau)$ is described by

$$h(\tau) = \sum_{i=0}^{I-1} p_i \exp(j\phi_i) \delta(\tau - \tau_i) \quad (1)$$

where, p_i , ϕ_i , τ_i are the amplitude, the phase and the delay of the i -th propagation path, respectively.

The r.m.s delay spread is a common measure to characterize the time dispersion of a multipath channel.

With $\tau_0 = 0$ it is given by

$$\tau_{rms} = \sqrt{\frac{\sum_{i=0}^{I-1} \tau_i^2 \cdot p_i^2}{\sum_{i=0}^{I-1} p_i^2}} - \tau_n^2 \quad \text{with} \quad \tau_n = \frac{\sum_{i=0}^{I-1} \tau_i \cdot p_i^2}{\sum_{i=0}^{I-1} p_i^2} \quad (2)$$

Next, we proceed to extract the multipath channel parameter (i.e., r.m.s delay spread σ) at 60GHz. Table 2 shows the r.m.s delay spread at the various receiving locations in office room for both the measurement and ray tracing method. When the receiving antenna is placed at different locations, mean r.m.s delay spread is approximately 13ns. The simulated delay spreads are in agreement with the measurement results. This also implies that the ray tracing method can be used to predict the multipath channel parameters at the mm-wave frequencies.

Table 2. R.M.S delay spread of office room

Rx location (m) [∘]	r.m.s delay spread, σ (ns) [∘]	
	measurement [∘]	simulation [∘]
R11 [∘] (0.95,10.65,1.5) [∘]	2.86 [∘]	2.38 [∘]
R12 [∘] (0.95, 9.65,1.5) [∘]	6.9 [∘]	6.0 [∘]
R13 [∘] (0.95, 5.65,1.5) [∘]	14.1 [∘]	15.1 [∘]
R16 [∘] (0.95, 2.65,1.5) [∘]	17.3 [∘]	16.5 [∘]
mean r.m.s delay spread (ns) [∘]	12.3 [∘]	13.1 [∘]

Figure 7 illustrates empirical cumulative distribution function (CDF) magnitude of simulated r.m.s delay spread and measured in office room in building.

Empirical CDF is defined by

$$\hat{F}_m(x) = \frac{1}{m} \sum_{k=1}^m I(X_k \leq x) \quad (3)$$

where, Let $X_1, \dots, X_m$ be i.i.d real random variables with the CDF $F(x)$. $I(A)$ is the indicator of event A . For fixed x ,

$I(X_k \leq x)$ is a bernoulli random variable with parameter $p = F(x)$.

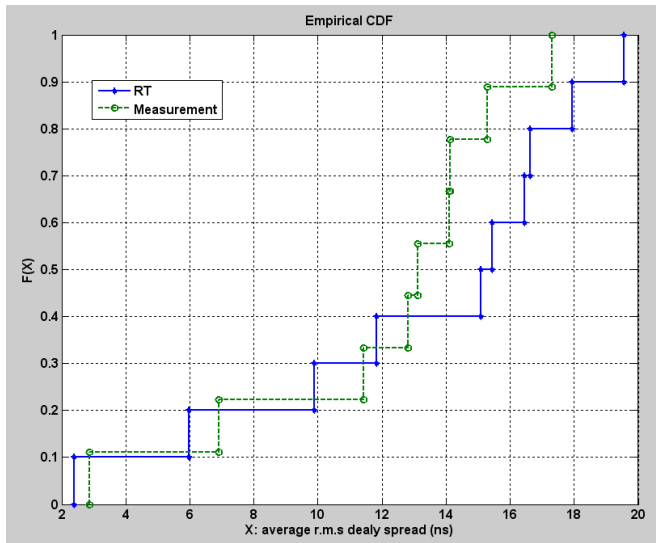


Figure 7. Empirical CDF in office room in building

IV. CONCLUSIONS

Based on the 3D ray-tracing method and measurement campaign, we extracted statistical parameters (i.e., r.m.s delay spread) for indoor site-specific environments of indoor office room. The simulated delay spreads are in agreement with the measurement results. Finally, it has been demonstrated that the ray tracing methods can be used for channel parameter extractions, particularly at 60GHz band.

ACKNOWLEDGMENT

This work was supported by the IT R&D program of MKE/IITA [2008-F-013-2, Development of Spectrum Engineering and Millimeterwave Utilizing Technology]

REFERENCES

- [1] P.Smolders, "Exploiting the 60GHz band for local wireless multimedia access: prospects and future directions," IEEE Communications Magazine, vol.40, no.1, pp.140-147, 2002
- [2] H.Xu, V.Kukshya, and T.S.Rappaport, "Spatial and temporal characteristics of 60-GHz indoor channels," IEEE Journal on Selected Areas in Communications, vol.20, no.3, pp.620-630, 2002
- [3] S.Collonge, G.Zaharia, and G.El Zein, "Influence of the human acitivity on wide-band characteristics of the 60GHz indoor radio channel," IEEE Transactions on Wireless Communications, vol.3, no.6, pp.2396- 2406, 2004
- [4] C. Balanis, Advanced Engineering Electromagnetics, John Wiley & Sons, New York, NY, USA,
- [5] R.g. Kouyoumjian and P.H.Pathak, "A uniform geometrical theory of diffraction for an edge in a perfectly conducting surface," Proceedings of the IEEE, vol.62, no.11, pp.1448-1461, 1974
- [6] R.J.Leubbers, "Finite conductivity uniform GTD versus knife edge diffraction in prediction of propagation path loss," IEEE Transactions on Antenna and Propagation, vol.32, no.1, pp.70-76, 1984