

Characterization of the 60 GHz Wireless Desktop Channel

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Abstract

In this paper we measure and characterize the 55-65 GHz wireless channels for a typical desktop environment. Due to the presence of many obstructions and reflectors on the desktop the 60 GHz desktop channel differs from an intra-room propagation environment as described in the literature. The Saleh-Valenuela (S-V) model is used to model the desktop environment. Key S-V model parameters such as Cluster Decay Factor, Ray Decay Factor, Cluster Arrival Rate, and Ray Arrival Rate are extracted from the measured data.

Index

S-V model, desktop, Cluster Decay Factor, Ray Decay Factor, Cluster Arrival Rate, Ray Arrival Rate, ToA

I. Introduction

The unlicensed spectrum around 60 GHz became available in recent years in the US, Europe, Japan and Australia. This availability has unlocked significant opportunities for developing ubiquitous gigabit wireless connectivity. Significant research activity is now being undertaken to design next generation high-speed wireless communication systems in this millimetre band. An important component in the design of these systems is understanding the propagation environment to assist in choosing appropriate modulation and space time coding schemes.

An important application of millimeter wavelength wireless communication systems capable of multi gigabit per second data rates is to connect computer components and peripherals that reside on a desktop. An accurate channel model for a desktop is required. The aim of this measurement campaign is to determine the appropriate S-V model [1][5] parameters that accurately describe a 60 GHz desktop channel. We are not aware any other 60 GHz channel measurements on desktops.

In this paper experiments are developed and executed to measure the 55-65 GHz band wireless channel on typical desktop environments. The results show that the 60 GHz channel on desktops has unique characteristics and significant differences compared to intra room or outdoor propagation at 60 GHz [2]. The modified S-V model is applied to model the desktop environment. Key S-V model parameters such as Cluster Decay Factor, Ray Decay Factor, Cluster Arrival Rate, and Ray Arrival Rate are extracted from the measured data.

The paper is organized as follows. In Section II we describe the modified S-V model for the desktop propagation environment. In Section III we describe our experimental

setup. In Section IV we describe our measurements and the extracted S-V parameters are presented. In Section V conclusions are presented.

II. The Modified S-V Model

In this work a modified Saleh-Valenuela (S-V) model will be used. Based on previous work in the field [1], a log-normal distribution, rather than a Rayleigh distribution, for the multipath gain magnitude will be used. In the next section the modified Saleh-Valenuela model is presented.

2.1 Saleh-Valenuela Model

The Saleh-Valenuela multipath model is given by the discrete time impulse response:

$$h(t) = \sum_{l=0}^{L-1} \sum_{k=0}^{K_l-1} \alpha_{k,l} \delta(t - T_l - \tau_{k,l})$$

where:

L = number of clusters;

K_l = number of multipath components (number of rays) in the l^{th} cluster;

$\alpha_{k,l}$ = multipath gain coefficient of the k^{th} ray in the l^{th} cluster;

T_l = arrival time of the first ray of the l^{th} cluster;

$\tau_{k,l}$ = delay of the k^{th} ray within the l^{th} cluster relative to the first path arrival time, T_l ;

Note that by definition, we have $\tau_{0l} = 0$ and we set $T_0 = 0$. The cluster and rays form a Poisson arrival process with distributions given by

$$\begin{aligned} p(T_l | T_{l-1}) &= \Lambda \exp[-\Lambda(T_l - T_{l-1})], \quad l > 0 \\ p(\tau_{k,l} | \tau_{(k-1),l}) &= \lambda \exp[-\lambda(\tau_{k,l} - \tau_{(k-1),l})], \quad k > 0 \end{aligned}$$

where

Λ = cluster arrival rate;

λ = ray arrival rate.

Note that here it is assumed that all clusters have the same ray arrival rate, however, some wideband measurements indicate that the arrival rate is larger for clusters that arrive later in time.

The multipath gains are defined as follows:

$$\alpha_{k,l} = p_{k,l} \beta_{k,l}$$

with $p_{k,l}$ equiprobable ± 1 representing signal inversions due to reflections. In the original S-V model the amplitudes of each arrival are assumed to be Rayleigh distributed with

$$E[\beta_{k,l}^2] = \Omega_0 e^{-T_l/\Gamma} e^{-\tau_{k,l}/\gamma}$$

where $\Omega_0 = E[\beta^2(T_l=0, \tau_{k,l}=0)]$ is the average power of the first ray of the first cluster. That is, both the clusters and rays have amplitudes which decay exponentially with time, and are characterised by:

Γ = cluster decay factor;

γ = ray decay factor.

For the wideband channel we follow [1] and assume a log-normal distribution for the multipath gains given by

$$20\log_{10}(\beta_{k,l}) \propto \text{Normal}(\mu_{k,l}, \sigma^2)$$

or

$$|\beta_{k,l}| = 10^{n/20}, \quad n \propto \text{Normal}(\mu_{k,l}, \sigma^2)$$

where $\mu_{k,l}$ is given by

$$\mu_{k,l} = \frac{10\ln(\Omega_0) - 10T_l/\Gamma - 10\tau_{k,l}/\gamma}{\ln(10)} - \frac{\sigma^2 \ln(10)}{20}.$$

In [1] the clusters are assumed to fade independently of rays. For example, each multipath arrival would have a fading term associated with the cluster arrival and a fading term associated with the ray arrival. If the fading for both the cluster and ray amplitudes are log-normal, this modification changes the channel coefficients in the following way, (note that the product of two log-normal random variables results in a log-normal random variable):

$$\alpha_{k,l} = p_{k,l} \xi_l \beta_{k,l},$$

with

$$20\log_{10}(\xi_l \beta_{k,l}) \propto \text{Normal}(\mu_{k,l}, \sigma_1^2 + \sigma_2^2),$$

or

$$|\xi_l \beta_{k,l}| = 10^{(\mu_{k,l} + n_1 + n_2)/20}, \quad n_1 \propto \text{Normal}(0, \sigma_1^2), \quad n_2 \propto \text{Normal}(0, \sigma_2^2)$$

where n_1 and n_2 are independent, $\mu_{k,l}$ is now given by

$$\mu_{k,l} = \frac{10\ln(\Omega_0) - 10T_l/\Gamma - 10\tau_{k,l}/\gamma}{\ln(10)} - \frac{(\sigma_1^2 + \sigma_2^2)\ln(10)}{20}.$$

In the above equations, ξ_l reflects the fading associated with the l^{th} cluster, and $\beta_{k,l}$ corresponds to the fading associated with the k^{th} ray of the l^{th} cluster.

For the modified S-V model there are 6 key parameters that define the model:

Λ	cluster arrival rate
λ	ray arrival rate (within each cluster)
Γ	cluster decay factor
γ	ray decay factor
σ_1, σ_2	cluster and ray log-normal standard deviation

Along with these model parameters we model the number of clusters and the number of rays within clusters. All of the required information will be estimated from the measured channel impulse responses. Extracting these parameters from the measured impulse responses will be conducted in fashion similar to the procedures described in [3].

III. Measurement Setup

Spatial and temporal measurements of Time of Arrival (ToA), number of multipath components, and component amplitudes for five desktops in different size offices, cubicles and laboratories were made.

An Anritsu 37397 Vector Network Analyzer (VNA) was used to measure the channel transfer function. At the two ports of the VNA two 5 meter 60 GHz millimetre-wave cables were attached. The attenuation of each cable was approximately 25dB and 50dB in total. In order to contend with the significant cable and propagation loss two 30dB broadband power amplifiers used on the transmit and receive ports of the VNA. The outputs of the amplifiers where connected to the antennas used in the experiment. The two antennas were mounted on tracks and the directional receive antenna was attached to an electronically steerable platform that permitted the angle of the antenna to be precisely and automatically controlled. The setup is shown in Figure 1.

VNA Setup

In this setup the VNA was set to sweep between 55-65GHz with a frequency step of 6.25MHz for 1601 data points. This setup is consistent with the requirements presented in [4][6][7].

Calibration

The system was calibrated using the short open load and thru (SOLT) procedure in an anechoic chamber. In this calibration the “through” standard was built by aligning the maximum of the radiation pattern of the two antennas to be used in the experiment at 0.5 m in an anechoic chamber. The correction coefficients were loaded into the VNA. This process was performed to ensure that impedance mismatches due to numerous effects such as antenna impedance and waveguide-to-coax transitions are not attributed as channel effects [6][7].

Antenna Configuration

An omni-directional antenna is employed at the transmitting side and a 21dBi directional pyramidal horn antenna at the receiving side. The antennae voltage standing wave ratios were better than 1.5:1 over the entire frequency of interest. The antennae were mounted on rails that permit the precise and automatic positioning required at 60 GHz (5mm wavelength). For AoA measurements a directional antenna was mounted on an electronically steerable platform for precise angular measurements from 0 to 360 degrees in 4 degree steps. For each angle the time impulse response was be measured.

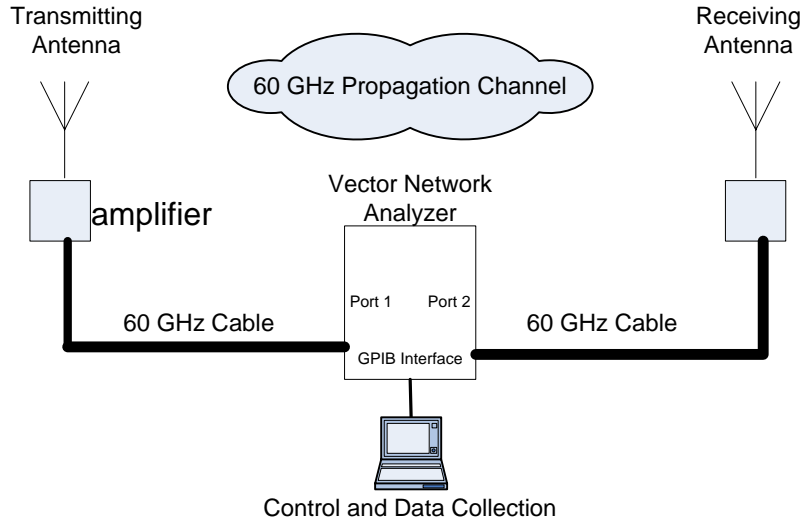


Figure 1 Experimental Setup

IV. Measurements Results and Extracted SV parameters

Measurements were made on five desktops at different times and relative location on the desktop. In Figure 2 a picture of an example desktop is shown. In Figure 3 the measured angle of arrival profile is shown. It is important to note that the signal is clustered in discrete angles of arrival in azimuth. In Figure 4 the power delay profile is illustrated for the dominant angles of arrival, namely zero (0) and three hundred and eight degrees (308) in azimuth. Note the delay and relative reduction of power of the signal relative of 308 degrees relative to the line of sight signal at 0 degrees. In Figure 5 the assumption that the distribution of the multipath gains are log-normal is tested. The measurement results show an excellent correspondence.

From the measurements captured from the experimental setup described in section III The following SV parameters were extracted:

Parameter	Description	Extracted Value
Λ (1/nsec)	cluster arrival rate	0.30
λ (1/nsec)	ray arrival rate (within each cluster)	8.73
Γ (nsec)	cluster decay factor	1.47
γ (nsec)	ray decay factor	1.00
σ_1 (dB), σ_2 (dB)	cluster and ray log-normal standard deviation	2.1, 2.1



Figure 2
Picture of A typical desktop with significant amount of clutter.

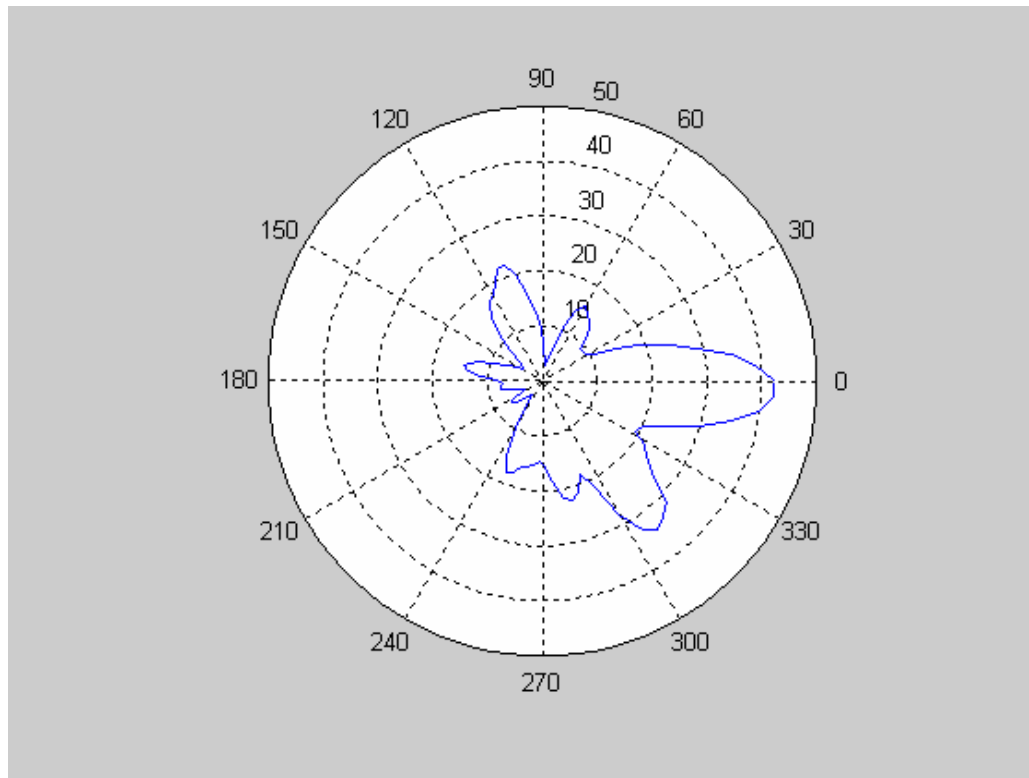


Figure 3
Angle of Arrival Profile for the desktop pictured in Figure 2. Note that signal is received in multiple angles in azimuth.

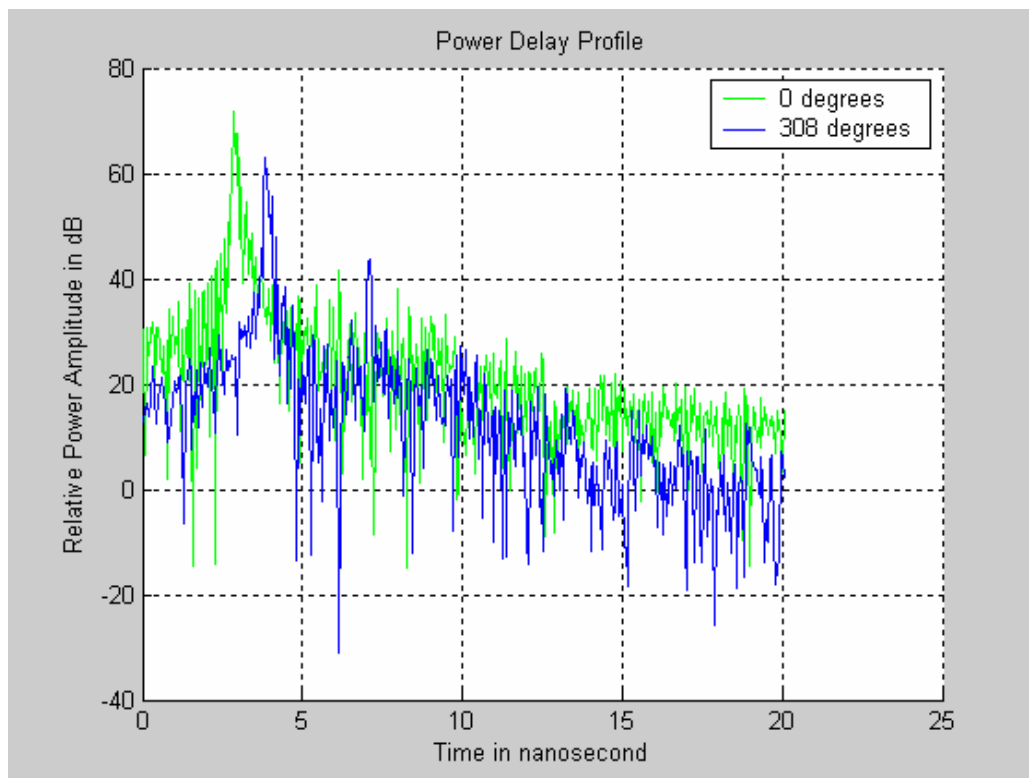


Figure 4
Power delay profile measured at desk pictured in Figure 2. Note the delay and relative reduction of power of the signal received at 308 degrees in azimuth.

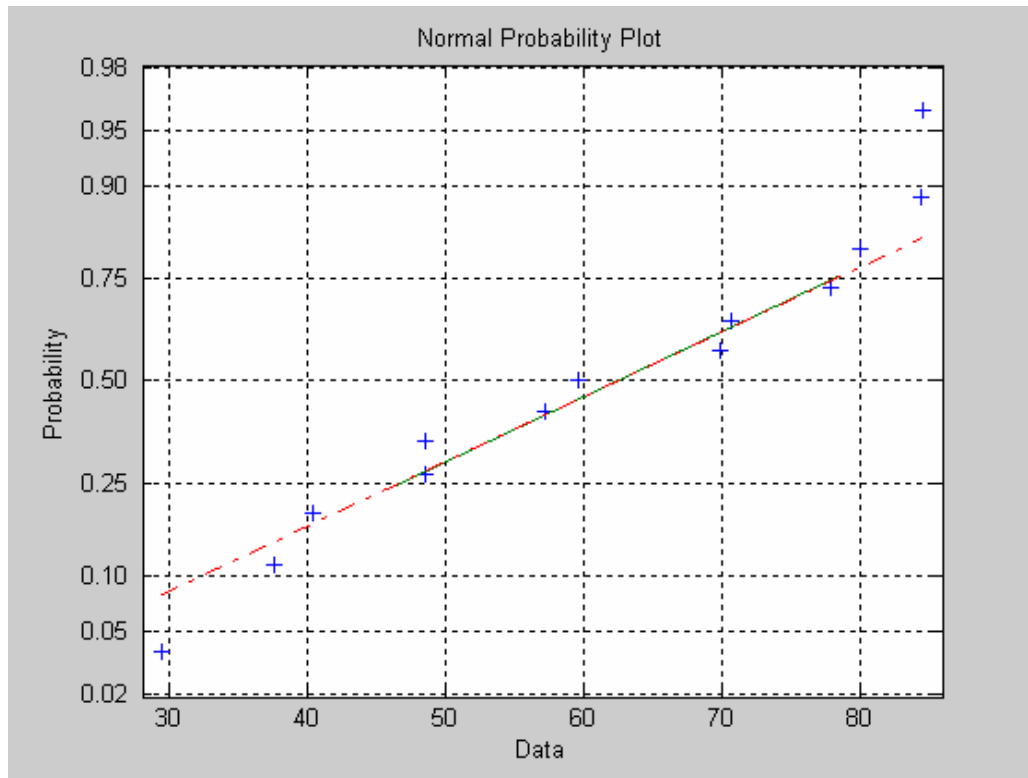


Figure 5
Normal probability plot of the log of the power amplitude of rays received within a cluster.

V. Conclusions

In this paper we measured and characterized the desktop 55-65 GHz wireless channel. Due to the presence of many obstructions and reflectors the 60 GHz desktop channel was found to be significantly different from the intra-room propagation environment that is describe in the literature. It was shown that the distribution of the multipath gains are log-normally distributed. Key S-V model parameters such as Cluster Decay Factor, Ray Decay Factor, Cluster Arrival Rate, and Ray Arrival Rate were extracted for the measured data.

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