IEEE P802.15
Wireless Personal Area Networks

Project	IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)	
Title	Channel Measurements and Setup for SV channel model parameter determination at 60GHz	
Date Submitted	[25 June, 2005]	
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Re:	[Respond to TG3c subgroup on channel modeling call for experimental setup and measurement technique to determine SV parameters]	
Abstract	[General guidelines for measurement techniques and procedures]	
Purpose	[General guidelines for measurement techniques and procedures]	
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1. Aim

The aim of this measurement campaign is to determine the appropriate SV model with AoA modifications and a set of parameters that accurately describe the 60 GHz channel for the following indoor situations:

1. Corridor
2. Large Room/Lecture Theatre with LOS
3. Large Room/Lecture Theatre with NLOS only
4. Office with LOS
5. Office with NLOS only
6. Desktop
7. Inter Room Propagation

Path loss due to static human interference and, where possible, the effects of dynamic human interference within the environment will also be measured.

All measurements shall be conducted indoors. The 802.15.3c channel modeling sub-committee considered this necessary because it was felt that outdoor propagation models and measurements at 60 GHz are widely available in the literature.

2. Proposed Channel Model

In this work a modified Saleh-Valenuela 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 section 2.2 extension of the model to include angle of arrival (AoA) information 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

$$p\left(T_l \left| T_{l-1}\right.\right) = \Lambda \exp\left[-\Lambda\left(T_l - T_{l-1}\right)\right], \quad l > 0$$
$$p\left(\tau_{k,l} \left| \tau_{(k-1),l}\right.\right) = \lambda \exp\left[-\lambda\left(\tau_{k,l} - \tau_{(k-1),l}\right)\right], \quad k > 0$$

where

Λ = cluster arrival rate;
λ = ray arrival rate.

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

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

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

where $\Omega_0 = E\left[\beta^2\left(T_l = 0, \tau_{k,l} = 0\right)\right]$ 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, giving

$$20\log10(\beta_{k,l}) \propto \text{Normal}(\mu_{k,l}, \sigma^2)$$

or

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

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

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

Other possible variations presented in the literature include Nakagami fading distributions rather than log-normal.

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. This modification changes the channel coefficients in the following way. If the fading for both the cluster and ray amplitudes are log-normal (note that the product of two log-normal random variables results in a log-normal random variable) then,

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

with

$$20\log10(\xi_l\beta_{k,l}) \propto \text{Normal}(\mu_{k,l}, \sigma_1^2 + \sigma_2^2),$$

or

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

where n_1 and n_2 are independent, and $\mu_{k,l}$ 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.

2.2 AoA Modified Saleh-Valenuela Model

Several AoA measurement campaigns, e.g. [2], indicate that the multipath rays arrive clustered not only in time but also in angle of arrival. Therefore, similar to cluster and ray arrival times we define a cluster and ray angle of arrivals:

Ψ_l = mean angle of arrival of l^{th} cluster;

$\psi_{k,l}$ = angle of arrival of the k^{th} ray from the l^{th} cluster.

The spatial and temporal impulse response of the channel may now be written as

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

Similarly to the ToA case, we set $\Psi_0=0$. It is assumed that each cluster will have a zero mean distribution of the form

$$p(\psi_{k,l})=K\exp\left[f(\psi_{k,l})\right]$$

where K is a normalizing factor and $f(\psi_{k,l})$ is one of

Gaussian: $f(\psi_{k,l})=-\left(\frac{\psi_{k,l}}{\sqrt{2}\sigma_G}\right)^2$, where σ_G is the standard deviation,

Von-Mises: $f(\psi_{k,l})=\kappa\cos\psi_{k,l}$, where $\kappa\geq 0$ is the degree of non-isotropy,

Laplacian: $f(\psi_{k,l})=-\left(\frac{\sqrt{2}\left|\psi_{k,l}\right|}{\sigma_L}\right)$, where σ_L is the standard deviation.

Each of these can be characterised by the standard deviation σ_ψ of the distribution $p(\psi_{k,l})$ and is related to the non-isotropy parameters σ_G , κ, or σ_L .

As clustering is now assumed in both space and time, an important factor in the proposed model is that of correlation between the ToA and AoA, in particular the joint cluster distribution $p(T_l,\Psi_l)$, and ray distribution $p(\tau_{k,l},\psi_{k,l})$. Independence is expected for NLOS environments, however some correlation may exist for LOS situations.

2.3 Channel Model parameters

For the modified S-V model there are 7 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
σ_ψ	ray AoA distribution standard deviation

Along with these model parameters, the number of clusters, rays within clusters, AoA ray distributions, and ToA to AoA correlations (if any) will be determined. All of the required information will be estimated from the measured channel impulses responses. Extracting these parameters from the measured impulse responses will be conducted in similar fashion as the procedures described in [4].

3. Measurements

3.1 Measurement Environments

Measurements of ToA, AoA, number of multipath components, and component amplitudes, will be made over several spatial and temporal locations in the following indoor environments:

1. Corridor
2. Large Room/Lecture Theatre with LOS
3. Large Room/Lecture Theatre with NLOS only
4. Office with LOS
5. Office with NLOS only
6. Desktop
7. Inter Room Propagation

Path loss due to static human interference and, where possible, the effects of dynamic human interference with the environment will also be measured.

Details of the transmitter and receiver antenna physical locations along with room configurations will be provided with the results of the measurement campaign.

3.2 Measurement Techniques

3.2.1 Setup

The kernel equipment is an Anritsu 37397 Vector Network Analyzer (VNA). The transmitting and receiving antennas are connected through 60 GHz millimeter-wave cable to the two ports of the VNA. The signal will be amplified appropriately for transmission, and again at the receiver to overcome any cable loss. The calibration and measurement software is hosted on a laptop computer. The antennas are to be mounted on trails that permit precise and automatic positioning and pointing angles.

3.2.2 Calibration

The system will be calibrated using the SOLT procedure. In this calibration the “through” standard will be built by aligning the maximum of the radiation pattern of the two antennas to be used in the experiment at 1 m in an anechoic chamber. The correction coefficients will be loaded to the VNA and serve as the calibration standard. This process will ensure that impedance mismatches due to numerous effects such as antenna impedance and waveguide-to-coax transitions are not attributed as channel effects.

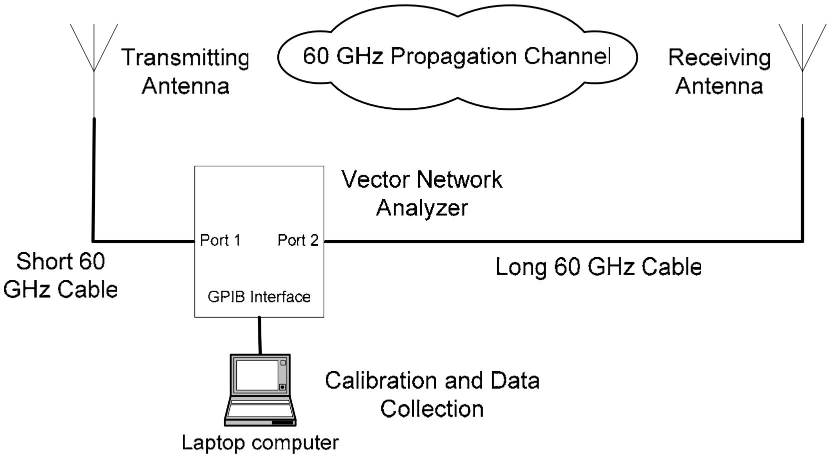

Figure 1 - Experimental setup

3.2.3 Antenna Configuration

A set of omni directional and 21dBi directional horn antennas will be employed. Measurements will be performed for:

- omni directional antennas on both the transmitter and receiver;
- 21dBi directional horn antenna on the transmitter and receiver;
- mixed combination of omni directional and 21dBi directional horn antenna.

The antennas will be mounted on trails that permit the precise and automatic positioning required at 60 GHz (a 5mm wavelength). For AoA measurements the directional antenna will be further mounted on an electronically steerable platform for precise angular sweeping over 0 to 360 degrees. For each angle the time impulse (e.g. frequency sweep) response will be measured.

3.2.4 VNA setup

In this setup the swept frequency will be 57-64GHz with a frequency step of 100MHz. This setup is consistent with the requirements presented in [4]. Further particulars of the VNA and associated settings will be provided with the measurement results.

3.3 Measurement Procedures

The characteristics of a fading channel can be described in terms of its large scale and small scale fading. Both large and small scale fading require different measurement procedures which can be found in Molisch *et. al.* [3] and Balakrishnan *et. al.* [4], and recently summarized in [5]. Measurement procedures will be similar here, with the exception of the AoA measurements, which will be conducted using a highly directional antenna, rather than (synthetic) antenna arrays proposed in [3].

References

[1] Jeff Foerster, "Path Loss Proposed Text and S-V Model Information", June 2002, IEEE P802.15-02/xxxr0-SG3a

[2] H. Xu, V. Kukshya, and T.S. Rappaport, "Spatial and temporal characterization of 60 GHz indoor channels," in IEEE Vehicular Technology Conference, 2000, pp. 6–13.

[3] A. F. Molisch, U. G. Schuster and C. C. Chong, "Measurement procedure and methods on channel parameter extraction," IEEE 15-04-283-00-4a, May 2004.

[4] Balakrishnan et al, "Characterization of Ultra Wideband Channels: Small-Scale Parameters for Indoor & Outdoor office environments", IEEE 802.15-04-0342-00-004a

[5] Su-Khiong Yong, Chia-Chin Chong and Seong-Soo Lee, "General guidelines for measurement techniques and procedures," IEEE P802.15-05-0357-00-003c/r0, June 2005.