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Indoor UWB Communication System Model

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Abstracts

In this paper we have realized UWB (Ultra –wide band) communication system by modelling UWB signal as Gaussian and its derivatives and convolving them with the IEEE 802.15.3a channel models for LOS and different NLOS conditions, namely CM1, CM2, CM3 and CM4, using modified Saleh-Valenzuela (S-V) model.

Keywords: S-V Model,IEEE 802.15.3a.

Introduction

IEEE 802.15.3a was an attempt to provide a higher speed UWB PHY enhancement amendment to IEEE 802.15.3 for applications which involve imaging and multimedia.

Three main indoor channel models were considered the tap-delay line Rayleigh fading model, the Saleh-Valenzuela (S-V) model, and the □Δ-k model, as well as several novel modifications to these approaches that better matched the measurement characteristics. Each channel model was parameterized in order to best fit the important channel characteristics. Although many good models were contributed to the group, the model finally adopted was based on a modified S-V model that seemed to best fit the channel measurements. In particular, the channel measurements showed multipath arrivals in clusters rather than in a continuum, as is customary for narrowband channels. This is a result of the very fine resolution

UWB waveforms provide. The S-V model was modified for the IEEE model by prescribing a lognormal amplitude distribution.

The modified Saleh-Valenzuela (S-V) model was adopted as a reference UWB channel model by the IEEE 802.15.3a. The modelling of UWB channels is based on the measurement of indoor propagation environment, as the main commercial applications will be indoor communications.

Modified saleh-valenzuela channel model

The modelling of UWB propagation channel is fully based on the proposed IEEE802.15.3a standard model. The impulse response of modified Saleh-Valenzuela model may be represented as:

$h_i(t) = X_i \sum_{l=0}^{L} \sum_{k=0}^{K} \alpha_{l,k}^{i} \delta(t - T_l^i - \tau_{k,l}^i)$ (1) where , $\alpha_{k,l}^i$ represents the multipath gain coefficients, T_l^i represents the delay of the l_{th} cluster, $\tau_{k,l}^i$ represents the delay of the k_{th} multipath component relative to the l_{th}cluster arrival time T_l^i, X_i represents the log-normal shadowing, and i refers to the i_{th} realization, which is calculated by

$$20 \log_{10} \mathrm{X_i} \propto \mathrm{Normal}(0, \sigma_x^2) \quad (2)$$

The definition assumes that within a cluster, the first ray arrives at with no delay ($\tau_{0,l}$=0). The distribution of cluster arrival time and the ray arrival time can be calculated by

$$P(T_l/T_{l-1}) = \mathbf{\Lambda} \exp[-\mathbf{\Lambda}\,(T_l - T_{l-1})]\,, l > 0 \quad (3)$$

$$\mathrm{P}(\tau_{k,l}/\tau_{(k-l),l}) = \boldsymbol{\lambda} \exp[-\boldsymbol{\lambda}(\tau_{k-1} - \tau_{(k-1),l})], k > 0 \quad (4)$$

$\mathbf{\Lambda}$=cluster arrival time, $\boldsymbol{\lambda}$=ray arrival time.

Channel coefficients

The channel coefficients are defined as follows

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- multipath gain coefficients

$\alpha_{k,l}=p_{k,l}\xi_l\beta_{k,l}$ (5)

20 $\log_{10}(\xi_l\beta_{k,l})$ α Normal($\mu_{k,l}$,$\sigma_1^2+\sigma_2^2$) , Or $|\xi_l\beta_{k,l}| = 10^{(\mu_{k,l}+n_1+n_2)/20}$, Where ξ_l is fading of cluster.

- Reflection co- efficient,

$$\mu_{k,l} = \frac{10\ln(\Omega_0)-10(T_l/\Gamma)-10(\tau_{k,l}/\gamma)}{\ln 10} - \frac{(\sigma_1^2+\sigma_2^2)\ln 10}{20} \qquad (6)$$

and n_1 α Normal(0,σ_1^2) and n_2 α Normal(0,σ_2^2),

- Gain of Rays, exponentially decay with respect to delay profile

$$\overline{\beta_{k,l}^2} = \overline{\beta^2(0,0)}\exp(-T_l/\Gamma)\ \exp(-\tau_{k,l}/\lambda) \qquad (7)$$

UWB propagation channels

According to the model parameters in the Table1, the four IEEE 802.15.3a channels using the S-V model are,

CM1- this model is based on LOS (0-4 m) channel measurements;

CM2 -this model is based on NLOS (0-4 m) channel measurements;

CM3 -this model is based on NLOS (4-10 m) channel measurements;

CM4- this model was generated to fit a 25 nsec RMS (Root Mean Square) delay spread to represent an extreme NLOS multipath channel.

The channel characteristics of these different channel models namely CM1, CM2, CM3 and CM4 are shown in figs. 2-5.

UWB Signal modelling

The most common pulse shapes for Impulse-UWB work are the Gaussian pulse and its derivatives, since they are easy to describe and work with. The Gaussian pulse is described by

$$P(t) = \frac{A}{\sqrt{2\Pi\sigma^2}}\, e^{\left(\frac{-t^2}{2\sigma^2}\right)} \qquad (8)$$

where σ^2 is the variance parameter. The pulse width is given by the expression, T_p=2Πσ.

Another pulse model is the first derivative of the Gaussian pulse. This is used as a model since a UWB antenna may have the effect on the signal to be equivalent to differentiating the pulse with respect to the time variable. Letting the mean value be zero, the first derivative is given by,

$$P^{(1)}(t) = -\left(\frac{At}{\sqrt{2\Pi}\sigma^3}\right) e^{\left(\frac{-t^2}{2\sigma^2}\right)} \qquad (9)$$

The third model is based on the second derivative of the Gaussian pulse and given by,

$$P^{(2)}(t) = A\left(\frac{t^2}{\sqrt{2\Pi}\sigma^5} - \frac{1}{\sqrt{2\Pi}\sigma^3}\right) e^{\left(\frac{-t^2}{2\sigma^2}\right)} \qquad (10)$$

Simulation results

The UWB signal is modelled as Gaussian and simulated as shown in Fig.1,

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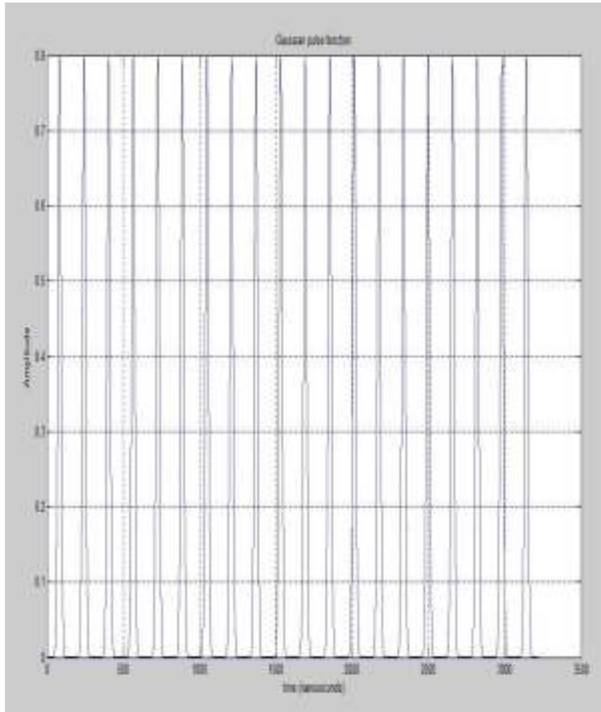

Fig 1 UWB signal at the channel input

The channels characteristics calculated from modified S-V model for CM1, CM2, CM3 and CM4 are shown in figs 2-5.

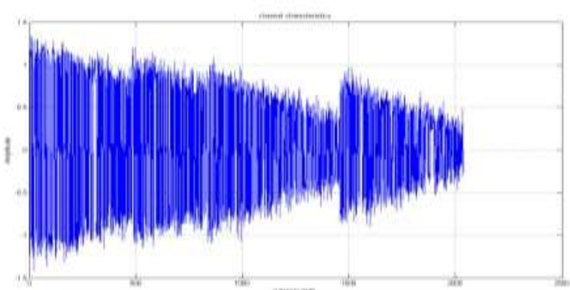

Fig.2 CM1: impulse response, h(t)

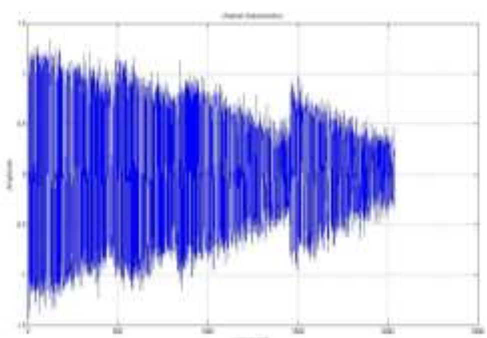

Fig.3 CM2: impulse response, h(t)

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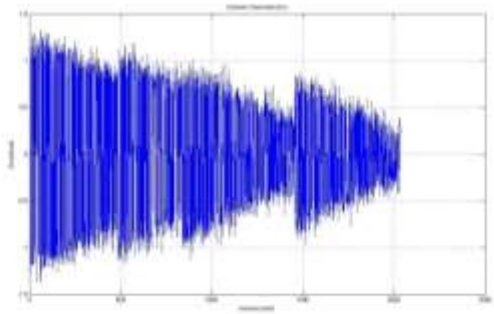

Fig4 CM3: impulse response, h(t)

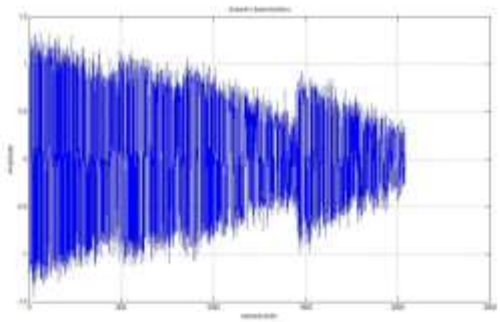

Fig.5 CM4: impulse response, h(t)

The four channel impulse responses are convolved with this input UWB signal to get the channel output, the simulation results are as shown in figs. 6-9.

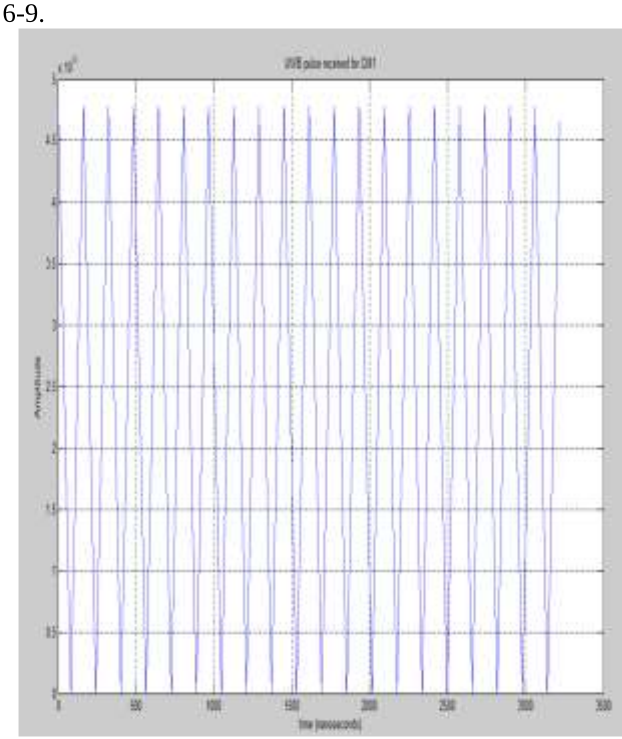

Fig6 CM1: Channel output

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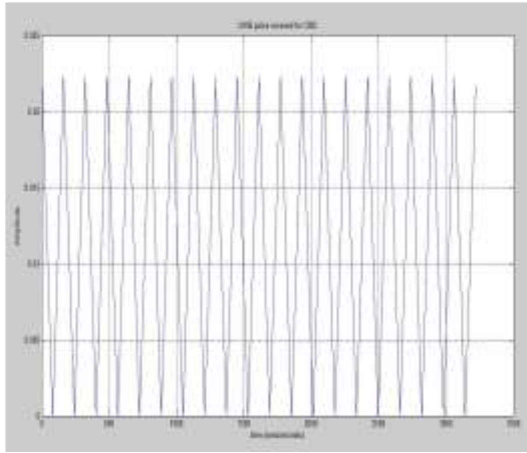

Fig.7 CM2: Channel output

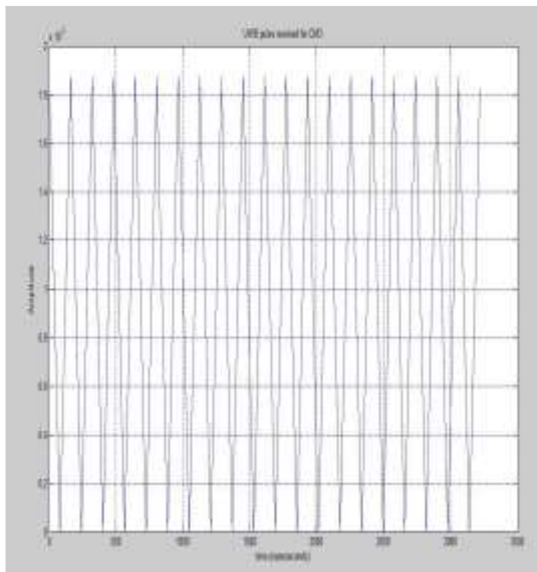

Fig8 CM3: Channel output

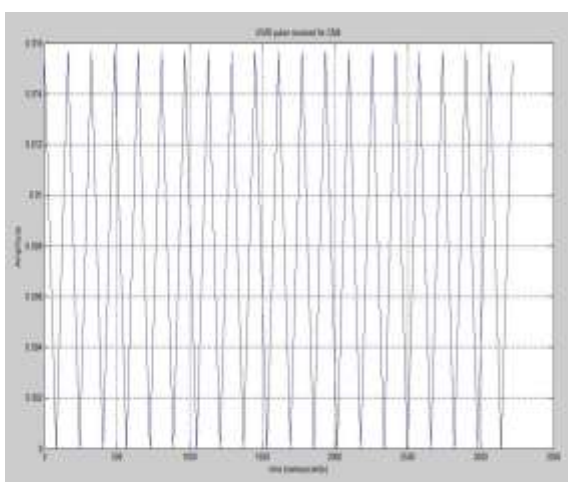

Fig.9 CM4: Channel output

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Conclusions

From the simulation results we observed that for the UWB input peak value of 0.8V, the peak channel output values for CM1, CM2, CM3, CM4 are 5mV, 25mV, 2mV, 16mV respectively. The channel characteristics of the four channel models are also shown.

Target Channel Characteristics[5]	CM 1[1]	CM 2[2]	CM 3[3]	CM 4[4]
τ_m [ns] (Mean excess delay)	5.05	10.38	14.18	
τ_{rms} [ns] (rms delay spread)	5.28	8.03	14.28	25
NP10dB (number of paths within 10 dB of the strongest path)			35	
NP (85%) (number of paths that capture 85% of channel energy)	24	36.1	61.54	
Model Parameters				
Λ [1/nsec] (cluster arrival rate)	0.0233	0.4	0.0667	0.0667
λ [1/nsec] (ray arrival rate)	2.5	0.5	2.1	2.1
Γ (cluster decay factor)	7.1	5.5	14.00	24.00
γ (ray decay factor)	4.3	6.7	7.9	12
σ_1 [dB] (stand. dev. of cluster lognormal fading term in dB)	3.4	3.4	3.4	3.4
σ_2 [dB] (stand. dev. of ray lognormal fading term in dB)	3.4	3.4	3.4	3.4
σ_x [dB] (stand. dev. of lognormal fading term for total multipath realizations in dB)	3	3	3	3
Model Characteristics[5]				
τ_m	5.0	9.9	15.9	30.1
τ_{rms}	5	8	15	25
NP10dB	12.5	15.3	24.9	41.2
NP (85 percent)	20.8	33.9	64.7	123.3
Channel energy mean (dB)	–0.4	–0.5	0.0	0.3
Channel energy standard deviation (dB)	2.9	3.1	3.1	2.7

[1] This model is based on LOS (0–4 m) channel measurements.
[2] This model is based on NLOS (0–4 m) channel measurements.
[3] This model is based on NLOS (4–10 m) channel measurements.
[4] This model was generated to fit a 25 ns RMS delay spread to represent an extreme NLOS multipath channel.
These characteristics are based on a 167 ps sampling time.

Table1: Multipath channel target characteristics and model parameters.

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