Wireless Channel Model for Indoor Environments

Sudesh Singhal (123079004), Gaurang Naik (123079009)
Department of Electrical Engineering
Indian Institute of Technology Bombay
Powai, Mumbai 400076

***Abstract*—Wireless communication has evolved tremendously over the past couple of decades. While complex wireless systems have been designed and implemented, each system needs an accurate and reliable channel model based on its operating environment. In this paper, we have described one such model for the indoor wireless channel - the Saleh Valenzuela model for wideband wireless systems. After a brief overview of the Saleh-Valenzuela model, certain assumptions made in our simulation have been mentioned and finally the results have been presented.**

I. Introduction

Among all the communication systems, wireless communication has always been one of the most attractive and at the same time, design wise most challenging systems. The freedom from wires has made several wireless technologies extremely popular. Wireless devices have been used in several environments, such as indoor environments including large and small buildings, industries, factories etc., and also outdoor environments such as urban, sub-urban and rural areas, grassy lands, plain lands etc. In order to design robust systems that operate in such environments, reliable and accurate channel models need to be prepared and studied and the results need to be compared with practical scenarios. Several models have been proposed by researchers and widely accepted by the designers, both for indoor and outdoor wireless environments. GNURadio is an open source software development toolkit that is widely used by researchers to support wireless communications research as well as to implement real world radio systems. To the best of our knowledge, till date there exists no block in GNURadio for indoor wireless channel model. In this report, we study some of the indoor models for wireless communications and simulate the Saleh-Velenzuela model in MATLAB and Python. We intend to extend the python code to build a corresponding block in GNURadio in future.

II. Saleh-Valenzuela Model

The Saleh-Valenzuela model for indoor multipath propagation [1] presents a simple statistical multipath model for wireless propagation in Indoor environments. in [1], the authors present the results for a medium-sized office building using 10 ns, 1.5 GHz, radarlike pulses for measurements. The delay spread in the experiments ranged upto 200 ns and the rms value was about 50 ns. According to this model, the obstacles in the indoor environments are clustered together and the rays that at arrive at the receiver hence, arrive in clusters. Also see [2]. The model states that the phase of these rays are independent and identical uniformly distributed in [0,2π). The amplitudes of these rays are Rayleigh distributed with variances (i.e. energies) that decay exponentially. The indoor model varies very slowly relative to people's movements. The clusters and the rays within a cluster form a Poisson arrival process, and have exponentially distributed interarrival times.

III. Implementation of the Indoor Channel Model

In our implementation of the Saleh-Valenzuela model, we calculate the Coherence time (T_c) of the channel based on the velocity of the mobile device and the frequency of operation. We then let the channel be approximately flat in this time interval. We have assumed wideband communication system, which we represent by a tapped delay-line model as shown in figure 1.

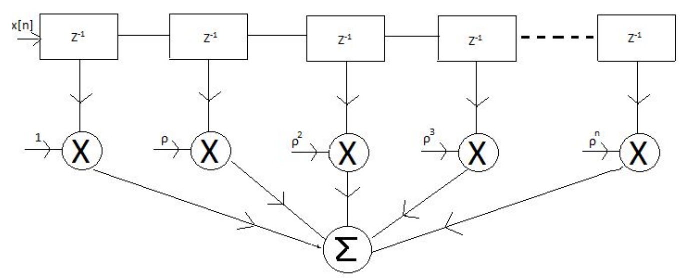

Fig. 1. Tapped delay line model for wideband wireless systems

As stated in [1], the channel remains flat for large intervals in the indoor environments. Morover, in practical environments, the channel does not drastically vary from one coherence time to another. The change in the channel fading coefficients is gradual. We model this by generating correlated Rayleigh random variable at the beginning of every Coherence time interval. A Rayleigh random variable is the magnitude of a complex circularly symmetric Gaussian random variable. Hence, to generate correlated Rayleigh random variable, we generate two independent and identically distributed Gaussian random variables each for the I and Q channels. The correlation is achieved by expressing the correlated Gaussian random variable as a constant times the previous random variable and another constant times a new Gaussian random variable. i.e. $X_I[n+1] = \alpha X_I[n] + \beta X$, and $X_Q[n+1] = \alpha X_Q[n] + \beta X$ where, α,β are constants depending on the channel, and X is a Gaussian random variable. In our model, we take β=$\sqrt{1-\alpha^2}$.

Once the correlated Gaussian random variables are generated for the I and Q channel, we generate the Rayleigh random variable as

$$h[n+1] = \sqrt{X_I[n+1]^2 + X_Q[n+1]^2}.$$

In case of a tapped delay line model, the Saleh-Valenzuela model says that the inter-arrival times for the rays are exponentially distributed random vairables. We have taken the number of multipaths to be 10. This is based on the fact that in an indoor environment, the number of obstacles clustered around the receiver are very large[2]. We choose the patameter λ such that the time difference between the first and the last path is within the delay spread of the indoor channel, which is approximately between 50-100 ns.Figure 2 shows the delay spread for each trial for several trials. The paramete λ is taken to be 5ns. The rms value of the delay spread obtained is about 50 ns, which agrees with the results obtained in [1].

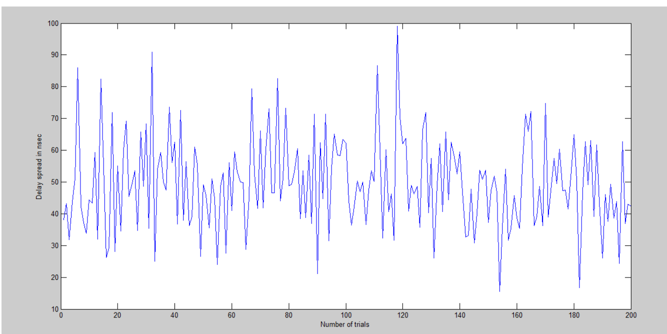

Fig. 2. Delay spread of the channel for several trials

Also, we expect the rays that arrive later must have undergone much more reflections than the ray that arrives first. At each reflection, there is a significant loss in the energy of the wave and as a result, the wave that arrives at the end has the least energy. As stated in [1], we model this phenomenon by each successive random variable having variance that decay exponentially. The exact power delay profile has been studied in [3].

Table I summarizes the parameters specified by the Saleh-Valenzuela model, and the assumptions made in our simulation.

TABLE I
PARAMETERS SPECIFIED BY THE SALEH-VALENZUELA MODEL

Amplitude of the rays	Rayleigh (with decreasing energies for each path)
Phase of the rays	Uniformly distributed in [0,2π)
Number of multipaths	10
Inter arrival times	Exponentially distributed with $\lambda = 5ns$
Energy of each multipath	Decreasing exponentially (We use $\lambda = 0.5$)

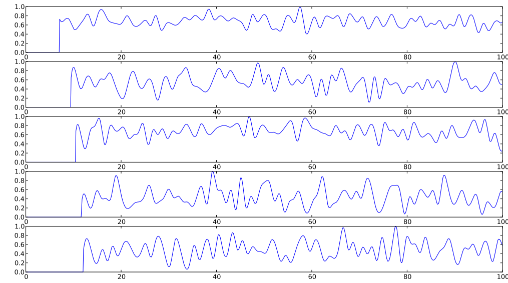

Fig. 3. Results of the simulation - Channel response, Taps 1-5

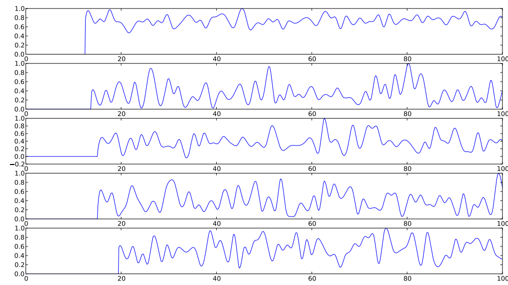

Fig. 4. Results of the simulation - Channel response, Taps 6-10

IV. Plots and Results

In this section, we present the results of the simulation described in the previous section. Figure 3 shows the output of taps 1 to 5, and figure 4 shows the output of the taps 6 to 10. As seen in Figure 3 and 4, each tap has an independent response. The final channel response, which is the sum of all the tap outputs is also shown. Clearly, the most significant contribution to the final channel response is from the first tap. Also, the ray in each tap arrives at random time instants which is exponentially distributed.

Figure (name here) and 5 shows the final channel response and the autocorrelation of the same for another run of the simulation.

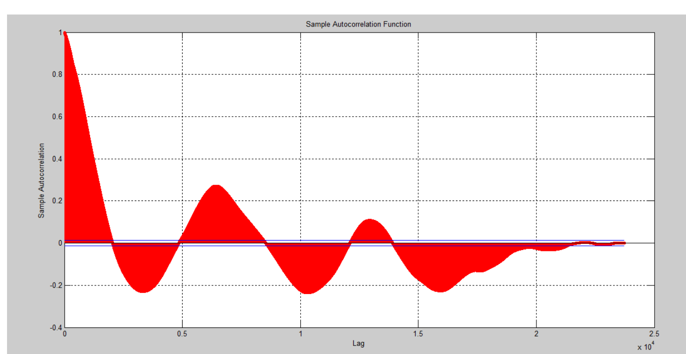

Fig. 5. Final channel response and its autocorrelation

V. Conclusion

In this report, we have simulated the Saleh-Valenzuela model for indoor wireless environment. The amplitudes of the rays arriving at the receiver is Rayleigh distributed, while the phase is uniformly distributed between [0,2π). The arrival of the rays is a Poisson process with a parameter that depends on the delay spread of the channel. Each successive ray has decreasing power since it undergoes larger number of reflections from the clusters.

Acknowledgment

The authors would like to thank Prof. Sibi Raj Pillai, Instructor of the course Wireless and Mobile Communications for giving an opportunity to study and implement a model for indoor wireless propagation.

References

[1] A. Saleh, R. Valenzuela, *A Statistical. Model for Indoor Multipath Propagation*, IEEE Journal on Selected Areas in Communications, Vol. Sac-5, No.2, Feb. 1987.

[2] A. Kumar, R. Bhattacharjee, S. Goel, *A Clustering Based Channel Model for Indoor Wireless Communication*, Department of Electronics & Communication, IIT Guwahati.

[3] S. Mangold, M. Lott, D. Evans, R. Fifield, *Indoor Radio Channel Modeling - Bridging from Propagation Details to Simulation*, Project ATMmobil.