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Multipath Rayleigh and Rician Fading Channel Simulation Using MATLAB

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ABSTRACT- *In this paper we present a simulation of multipath Rayleigh fading and Recian fading channel. We have used MATLAB software for simulation. Simulation was carried out for two different sample rate 20kb/s and 500 kb/s. This simulation process uses five path propagation models. The data is modulated, encoded and transmitted through a frequency selective and flat Rayleigh and Recian Multipath fading channel. Quadrature phase shift keying (QPSK) modulation technique is used to modulate the data. This paper compares the simulated result of Rayleigh and Recian fading channel.*

KEYWORDS- *Wireless Communication, Multipath, Fading Channel, Rayleigh Fading, Rician Fading*

I. INTRODUCTION

The wireless industry has developed and deployed an infrastructure for providing many services for the users [7]. Much of the current interest is in modeling and simulation of fading in mobile and indoor wireless communications. There has been significant research activity over the past 5-15 years into the performance of wireless channel models. Fading and Multipath occur in much radio communication systems. These effects were first observed and analyzed in troposcatter systems in the 1950s and early 1960s [17]. In a multipath situation, the signals arriving along different paths will have different attenuations and delays and they might add at the receiving antenna either constructively or destructively. If the path lengths and/or the geometry change due to changes in the transmission medium or due to relative motion of the antennas, as in the mobile case, the signal level might be subjected to wild fluctuations [17]. Although the fading mechanisms may be different in different environments, the general concepts of modeling and simulation remain the same. The design, production and deployment of technological infrastructure have high cost therefore manufacturers search for different alternatives to avoid high costs [7]. One of these alternatives is simulating a real wireless system. The advantage of simulation is that allows low-cost and low-risk environment. Simulation allows the designer to determine the correctness and efficiency of a design before the system is actually constructed. Consequently, the user may explore the merits of alternative designs without actually physically building the systems. Simulation helps us to forecast things that have never happened before and to run scenarios outside of historical bounds. In this paper we have simulated and tested multipath fading channel model for wireless communication. In wireless transmission system where a receiver is in motion relative to a transmitter with no line-of sight path between their antennas the Rayleigh fading is a good approximation of realistic channel conditions [7].

II. MULTIPATH FADING CHANNEL

In any wireless communication system there could be more than one path over which the signal can travel between the transmitter and receiver antennas. The presence of multiple paths is due to atmospheric scattering and refraction, or reflections from buildings and other objects [17]. Multipath fading affects the signal in two ways: dispersion and time-variant behavior. If we transmit an extremely short pulse, ideally an impulse, over a time varying multipath path channel, the received signal might appear as a train of pulses [16]. Hence once characteristic of multipath channel is the time spread introduced in the signal that is transmitted through the channel. A second characteristic is due to the time variations in the structure of the medium. As a result of time variations, the nature of the multipath varies with time. That is, if we repeat the pulse- sounding experiment over and over, we shall observe the change in the receive pulse train, which will include changes in the size of the individual pulses, change in the relative delays among the pulses and quit often, changes in the number of pulses observe in the received pulse train [p]. Moreover the time variations appear to be unpredictable to the user of the channel. Therefore it is reasonable to characterize the time variant multipath channel statistically.

We assume that there are multiple propagation paths. Associated with each path has a propagation delay and an attenuation factor. Both the propagation delays and the attenuation factor are time variant as a result of change in structure of the medium. Thus the received signal may be express in the form [p]

$$x(t) = \sum_{n} \alpha_n(t) s[t - \tau_n(t)]$$

Where, $\alpha_n(t)$ is the attenuation factor of the signal received on the nth path and $\tau_n(t)$ is the propagation delay for the nth path.

III. FREQUENCY SELECTIVE AND NON SELECTIVE CHANNEL

The effect of fading can be expressed in terms of coherence bandwidth and coherence time. When an information bearing signal is transmitted through the channel, if the signal band width is smaller than the coherence bandwidth, they will be affected by same type of fading then the channel model is called nonselective or flat fading model. On the other hand, if the signal band width is larger than the coherence bandwidth, they will be affected by same type of fading the channel model is called frequency selective fading model

IV. SYSTEM MODEL

When signal travels from transmitter to receiver due to fading effect of channel, the envelope of received signal follows Rayleigh or Rician distribution. When a there is relative motion between mobile user and base station, the frequency of received signal changes and this phenomenon is called Doppler frequency shift.

(a) Rayleigh Distribution

This occurs when the envelope of the received signal follows a Rayleigh distribution. Rayleigh distribution is statistically used to model a faded signal, when there is no dominant LOS path. The envelope of the received signal with Rayleigh distribution has the probability density function (pdf) given by [5]

$$p_\alpha(\alpha) = \frac{\alpha}{2\sigma^2}\, exp\left(-\frac{\alpha^2}{2\sigma^2}\right) \quad \alpha \geq 0 \ldots \ldots \ldots \ldots (1)$$

Where, α channel fades amplitude

σ^2 is the time average power of the received signal.

(b) Rician Distribution

The Rician distribution which also occurs as a result of multipath propagation is statistically used to model a distribution when a strong line of sight component is present along with the weaker components. It has the probability density function (pdf) given by [3] as:

$$P_\alpha(\alpha) = \frac{\alpha}{\sigma^2} exp\left[-\frac{\alpha^2 + s^2}{2\sigma^2}\right] I_0\left(\frac{sr}{\sigma^2}\right), \alpha \geq 0 \ldots (2)$$

Where, $I_0(\ldots.)$ is the zero order Bessel function of the first kind.

s is the peak amplitude of the dominant path.

α channel fades amplitude

σ^2 is the time average power of the received signal.

Rician distribution is often described in terms of a parameter, *k*, is known as the Rician factor and is expressed by [3] as:

$$k = 10 \log \frac{s^2}{2\sigma^2}$$

As *s* approaches 0, *k* approaches ∞ dB and as the dominant path decreases in amplitude, the Rician distribution degenerates to a Rayleigh distribution.

(c) Doppler Frequency Shift

Doppler shift is the random changes that occur in a channel introduced as a result of a mobile user's mobility or movement. It is the apparent difference in frequency of the received signals from that of the transmitted signals when there is a relative motion between the transmitter and receiver. This Doppler frequency shift f_d is given in equation (3), where is θ the angle between formed between the incident electromagnetic wave and the moving receiver, *v* is the mobile speed, *f* is the frequency of the carrier and c is the speed of light.

$$f_d = \frac{vf}{c} cos\theta \ \ldots \ldots \ldots (3)$$

V. SIMULATION PARAMETER

Transmitter transmit signal and receiver receive signal in different ways. The simulation process was carried out with random data source and following parameters by using MATLAB.

Table 1. Simulation parameter

Parameters	**Variable**
No of paths between Transmitter and receiver	05
Speed of light	$3x10^8\ m/s$
Delay of first path	$0\ \mu s$
Gain of the first path	0 dB
Second path larger than first path	1.2 km
Average Gain of the second path	-3 dB
Third path larger than first path	2.4 km
Average Gain of the third path	-6 dB
Fourth path larger than first path	3.6 km
Average Gain of fourth path	-9 dB
Fifth path larger than first path	4.8 km
Average Gain of the fifth path	-12 dB
Maximum Doppler shift of diffuse component	200 Hz
Doppler shift of the LOS component	100Hz
Modulation	QPSK
Sample rate	20 kb/s and 500 kb/s
Bits per frame	1000
Number of frames	20

Simulated result of Rayleigh Fading Channel at 500 kb/s sample rate

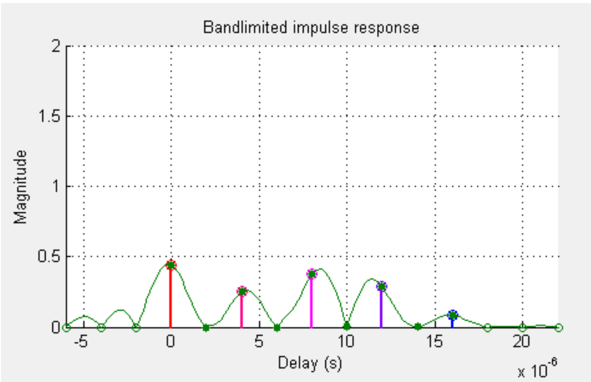

Fig. 1 Impulse Response

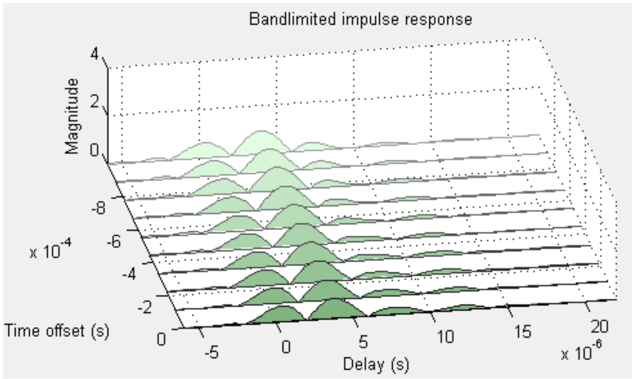

Fig. 3 Waterfall of impulse response

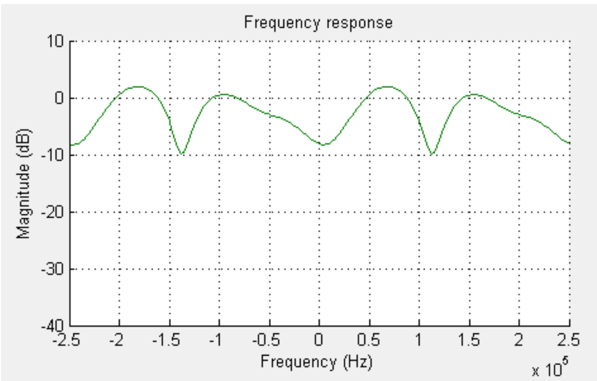

Fig. 2 Frequency Response

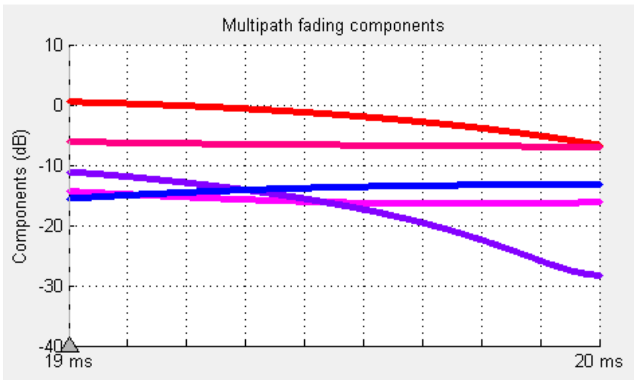

Fig. 4 Multipath fading component

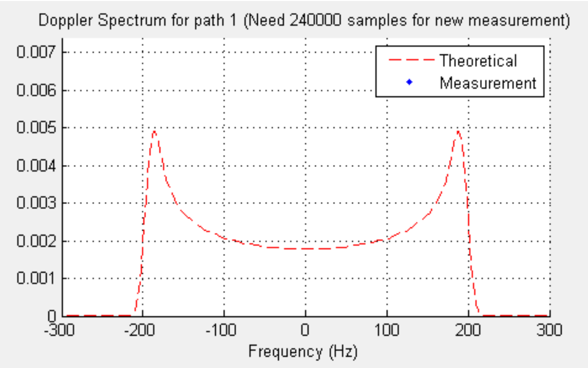

Fig. 5 Doppler spectrum

Simulated result of Rician Fading Channel at 500 kb/s sample rate

Fig. 6 Impulse Response

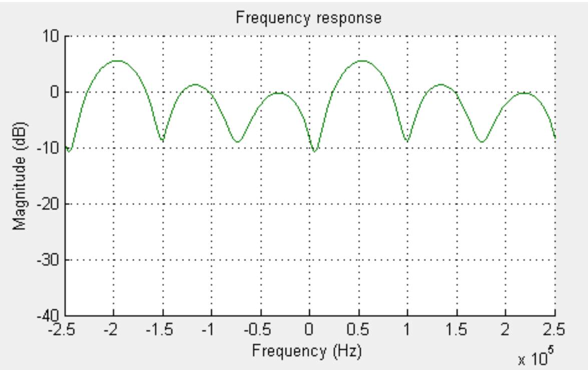

Fig. 7 Frequency Response

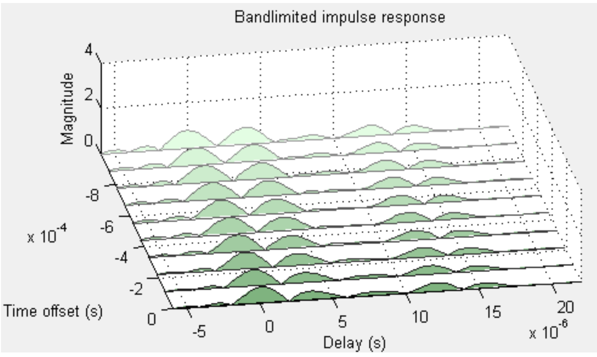

Fig. 8 Waterfall of impulse response

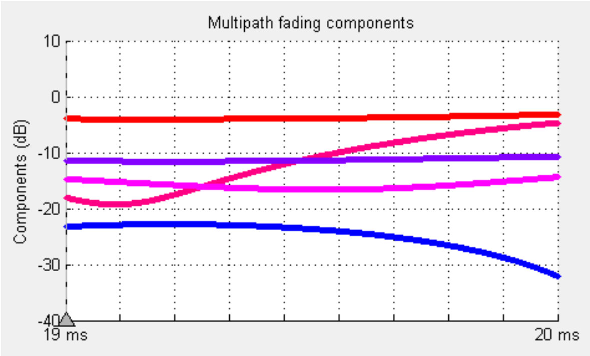

Fig. 9 Multipath fading component

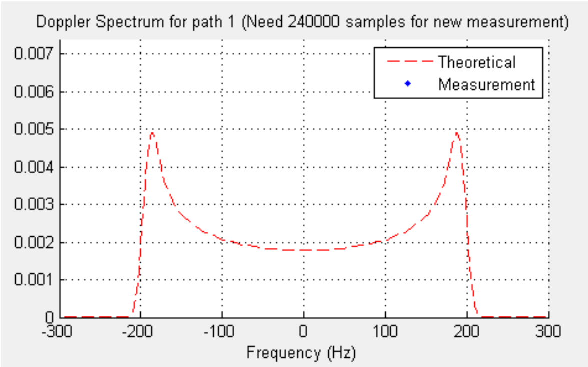

Fig. 10 Doppler spectrum

Simulated result of Rayleigh Fading Channel at 20 kb/s sample rate

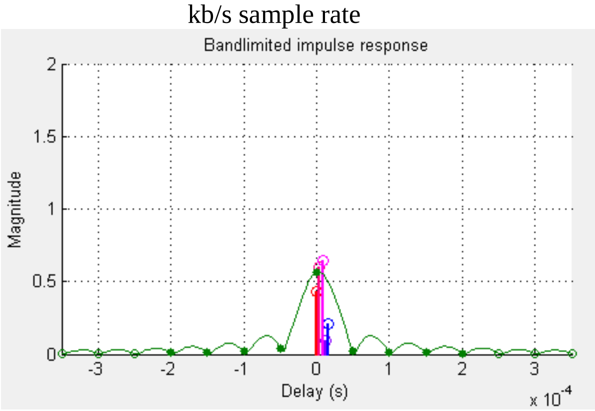

Fig. 11 Impulse Response

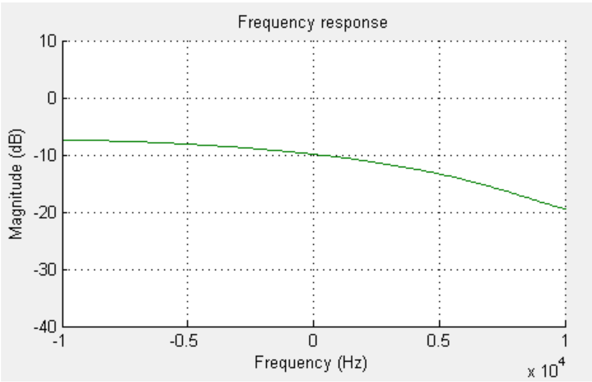

Fig. 12 Frequency Response

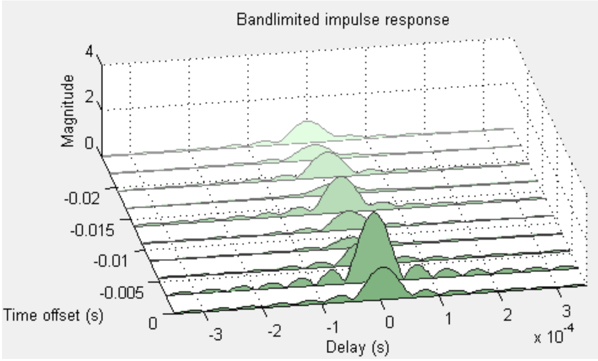

Fig. 13 Waterfall of impulse response

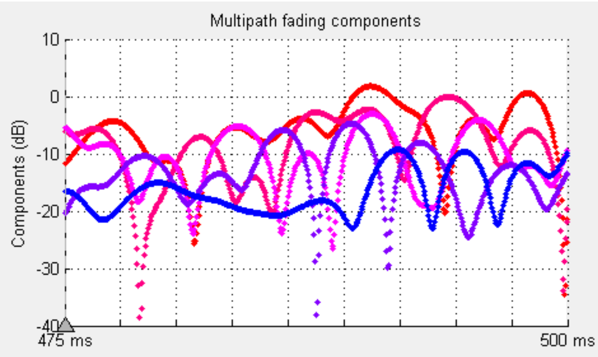

Fig. 14 Multipath fading component

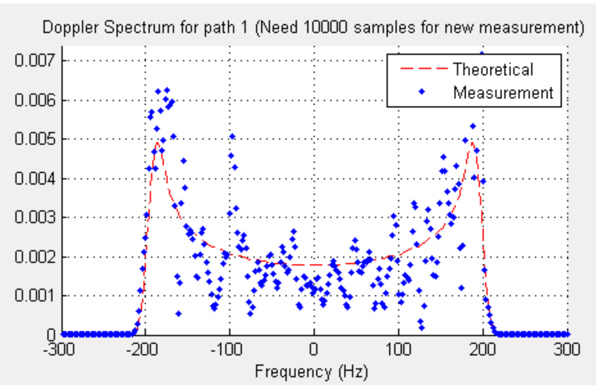

Fig. 15 Doppler spectrum

Simulated result of Rician Fading Channel at 20 kb/s sample rate

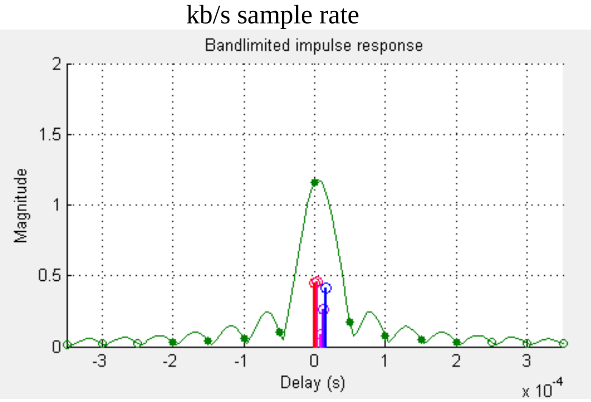

Fig. 16 Impulse Response

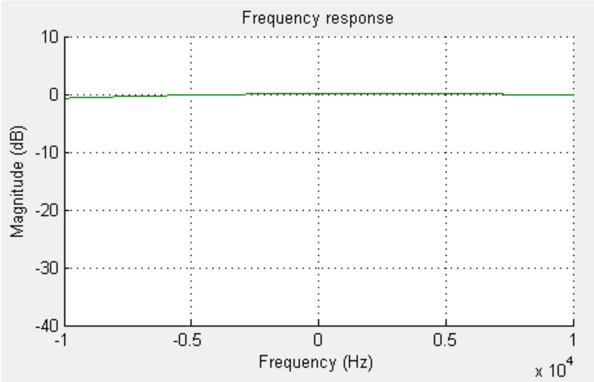

Fig. 17 Frequency Response

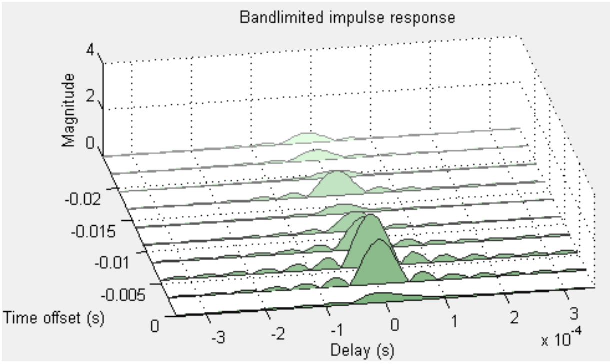

Fig. 18 Waterfall of impulse response

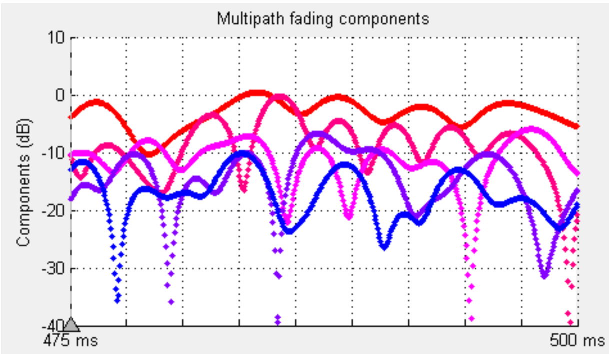

Fig. 19 Multipath fading component

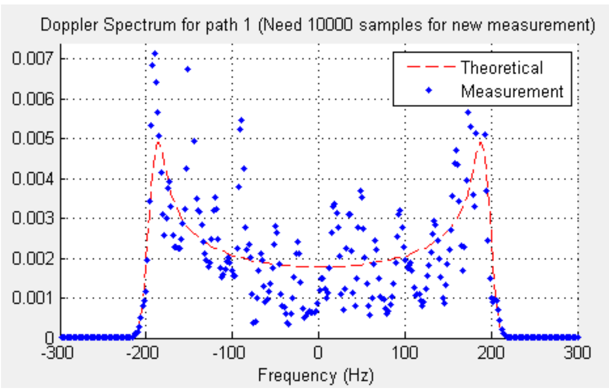

Fig. 20 Doppler spectrum

VI. RESULT AND DISCUSSION

In this section, we have presented the simulation results using MATLAB for two sample rates are: 50kb/s and 20kb/s for Raleigh and Recian fading channel. When the sample rate is 50kb/s then the frequency response of Raleigh and Recian fluctuate shown in fig. 2 and fig. 7. This type of fading is called frequency selective fading. But when we use the sample rate is 20kb/s then the frequency response of Raleigh and Recian fading channel are almost constant shown in fig. 12 and fig. 17. This type of fading is called frequency flat fading. For sample rate 20kb/s the multipath fading component fluctuate more than the 50 kb/s sample rate. Doppler spectrum for both types of fading channel for different sample rate are shown in fig.5, fig. 10, fig. 15 and fig, 16. From this figure we see that for sample rate 20kb/s the theoretical and measurement result Doppler shift are different. The response of the channel is time variant and unpredictable. All responses shown in figure are snapshot at the time. But their response will be different if run the pregame for different time. If the bandwidth is too small for the signal to resolve the individual components, the frequency response is approximately flat because of the minimal time dispersion caused by the multipath channel. This kind of low-dispersion multipath fading is often referred to as narrowband fading, or frequency-flat fading. When we increase the signal bandwidth to 500 kb/s, we see much greater distortion in the signal. This distortion is ISI that comes from time dispersion of the wideband signal. The channel's delay span (for fifth path 16 microseconds) is now larger than the QPSK symbol period (4 microseconds), so the resultant band limited impulse response is no longer well-approximated by a sinc pulse.

VII. CONCLUSION

In this paper, multipath fading channel model has been simulated. We have used QPSK modulation to test the effect of fading channels to the received signal. There are various properties of the fading channel such as Doppler spread, path loss, time delay are taken into consideration while we simulate the characteristics of the channel. In this paper we have simulated mainly two types of fading environment. They are frequency selective fading and flat fading. For signal bandwidth 20kb/s channel act as flat fading and bandwidth 50kb/s channel act as a frequency selective fading. Among two types of fading the Rayleigh distribution is the best model to be adopted by communication systems.

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