Simulation of Multipath Fading Effects in Mobile Radio Systems

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Abstract— RF (Radio Frequency) signals are transmitted via wireless mobile channel suffer from several effects like small scale fading and signal dispersion and distortion. These effects can be better realized on Rayleigh and Rician multipath fading channels. The performances of these channels are shown with the BER (Bit Error Rate), impulse response, frequency response and multipath components. In addition to this can be realized using different kinds of modulation techniques like BPSK, QPSK, DBPSK, and QAM to simulate the BER response for the AWGN channel, Rayleigh channel and Rician channel. A MATLAB based object oriented implementation of a multipath fading simulator is used. The effects of noise on fading and scattering property of the channel were tested. The results show that the BER performance is improved dramatically in low SNR than in high SNR. This is reasonable since at low SNR, white Gaussian noise dominate the BER error which can be improved by enhancing SNR while in high SNR, phase estimation error dominate the BER error which cannot be improved simply enhancing SNR.

Keywords—Bit Error Rate (BER), Fading, Line of Sight (LOS), Multipath, Rayleigh, Rician

I. INTRODUCTION

In mobile communication systems, the RF signal propagates from the transmitter to the receiver via multiple different paths due to the obstacles and reflectors existing in the wireless channel. These multipaths are caused by mainly small scale fading or large scale fading. The wireless industry has developed and deployed an infrastructure for providing many services for the users. The design, production and deployment of such technological infrastructure have high cost therefore manufacturers search for different alternatives to avoid high costs.

One of these alternatives is simulating a real wireless system. The advantage of simulation is that it allows less expensive testing of designs. In this paper we have simulated and tested multipath fading channel model for wireless communication using MATLAB based approach. Multipath propagation is usually described by Line Of Sight (LOS) and Non Line Of Sight (NLOS) paths as shown in the following figure 1. When the mobile unit is considerably far from the base station, the LOS signal path does not exist and reception occurs mainly from the indirect signal paths. These multiple paths have different propagation lengths, and thus will cause amplitude and phase fluctuations and time delay in the received signal. Therefore, the main effect of multipath propagation can be described in terms of fading and delay spread.

II. FADING

Fading is caused by interference between two or more versions of the transmitted signal which arrive at the receiver at slightly different times. The representation of multipath fading is shown in figure 2.

Fig. 1. Multipath Propagation

A. Small Scale Fading

When the waves of multipath signals are out of phase, reduction of the signal strength at the receiver can occur. This causes significant fluctuations in the received signal amplitude with time leading to a phenomenon known as multipath fading or small scale fading. Small-scale fading is also called Rayleigh fading because if the multiple reflective paths are large in number and there is no line-of-sight signal component, the envelope of the received signal is statistically described by Rayleigh distribution. When there is a dominant non-fading signal component present, such as a line-of-sight
propagation path, the small scale fading envelope is described by Rician distribution and, thus, is referred to as Rician fading.

B. Fast Fading

Rapid fluctuations of amplitude when mobile terminal moves short distance. Fast fading is due to reflection of local objects and motion of user from these objects.

C. Slow Fading

Slow fading arises when there are large reflected and diffracted objects along the transmission path. The motion of the terminal to these distant objects is small and corresponding propagation change slowly. Fast fading (Short term fading): rapid fluctuation is observed over distances of about \( \lambda /2 \). For VHF and UHF, a vehicle travelling at 30 mph can pass through several fast fades in a second. Slow fading effects path loss variation caused by changes in lands cape, i.e., building variation.

\[ f(t) = k_{los} \cos[(2\pi ft + \phi_d) + \sum_{n=1}^{N} a_n \cos(2\pi ft + \phi_n)] \]

(2)

Where \( a_n \) is a random variable corresponding to the amplitude of the \( n^{th} \) signal component, and \( \beta \) is another uniformly distributed random variable corresponding to the phase angle of the \( n^{th} \) signal component.

B. Modelling of Rician Channel

When the received signal is made up of multiple reflective paths plus a significant line of sight (non-faded) component, the received signal is said to be Rician faded signal because the pdf of the RF signal's envelope follows Rician distribution. The received RF signal in this case can be written as

\[ r(t) = k_{los} \cos[(2\pi ft + \phi_d) + \sum_{n=1}^{N} a_n \cos(2\pi ft + \phi_n)] \]

(3)

Where \( k_{los} \) is the amplitude of the direct (LOS) component, \( \phi_d \) is the Doppler shift in frequency along the LOS path, and \( \phi_n \) is the Doppler shift in frequency along the \( n^{th} \) NLOS path signal component.

IV. RESULTS AND ANALYSIS

Figure 4 shows the BER response for the DPSK modulation over the Rayleigh fading channel. The blue color line indicates the theoretical BER response where as the red color line indicates the simulated BER response. As we can observe from the figure that, it’s theoretical and simulated values are almost closer.

The figure 5 shows the BER response for the AWGN, Rayleigh and Rician channel for the BPSK modulation technique. In this figure the green color line indicates that the BER response of the AWGN channel, the red color line for the Rayleigh channel and blue one is for Rician channel. As we can notice from this figure is that for the same bit error rate. The
average symbol energy requirement is less for the AWGN channel compared to that of the fading channels like Rayleigh and Rician channel.

Fig. 5. BER Response for the AWGN, Rayleigh and Rician channel using BPSK modulation

The figure 6 shows BER plot for the AWGN channel, Rayleigh channel and Rician channel for QAM (Quadrature Amplitude Modulation). The yellow color line indicates the BER response for the AWGN channel, the Red colour line indicates the BER response for the Rayleigh channel and green colour line indicates the BER response for the Rician channel. As we can observe from the figure that the requirement of the average symbol energy is more for the Rician channel as compared with that of the AWGN channel and Rayleigh channel for same bit error rate.

Fig. 6. BER Response for the AWGN, Rayleigh and Rician channel using QAM modulation

The figure 7 shows Impulse Response Model of a Multipath Channel. Small-scale variations of a mobile radio signal can be directly related to the impulse response of the mobile radio channel.

Fig. 7. Impulse response

REFERENCES


