Performance of RFID with AWGN and Rayleigh Fading Channels for SDR Application

Muhammad Islam, M A Hannan, S. A. Samad and A. Hussain

***Abstract*— Radio Frequency Identification (RFID) is currently the hottest technology in wireless communication, in which data transmission with extreme low power or even without power in tag. Software-Defined Radio (SDR) plays an important role for a wireless communications system where all the signal processing is implemented in software. In this paper, we first build up a wireless communication simulator including Gray coding, modulation, different channel models (AWGN and Rayleigh fading channels) and demodulation. Then, we test the effect of different channel models to the RFID in receiver with BER (bit error rate) plots under Quadrature Amplitude Modulation. At last, we give detail results of the performance of AWGN and Rayleigh fading channels. We will see that in AWGN channel, the data is degraded by random noise; in Rayleigh fading channel, the data is degraded by random noise and block noise.**

***Index Terms*—Modulation, Additive White Gaussian Noise, Rayleigh Fading, Demodulation and Bit Error Rate (BER).**

I. Introduction

Radio Frequency Identification (RFID) is a term for a small, wireless radio system that uses emitted electromagnetic energy for the purposes of identification. In its present form, RFID systems consist of four different elements; a transponder (or tag), an interrogator (or reader), an antenna, and a host computer system that acts as both controller and database [1], [2].

The basic system uses a reader that is networked to a host computer system to transmit an interrogation signal through an antenna to a target tag. The tag harnesses the electromagnetic energy and redirects a response through its own antenna back to the reader; thereby “identifying itself”. The reader then updates the database as to the presence of the tag in its area of coverage [3].

Modern RFID was first developed by scientists at Lawrence Livermore Laboratory when they realized that a receiver when stimulated by radio frequency (RF) power could respond with a coded signal. This system was connected to a computer database and used to control access to a nuclear weapons research facility [4].

RFID technology covers a tremendous range of applications and underlying RF and communication techniques. As a result, a validation and verification testing strategy can benefit greatly from software-defined instrumentation using methodologies similar to another fast-growing RF field, software-defined radio (SDR). SDR provides a radio system’s functional modules (such as modulation/ demodulation, source, coding/decoding and link-layer protocols) through software [5]-[7]. The technology helps build reconfigurable wireless systems that enable dynamic selection of parameters for each functional module. SDR is an important area for research and development in mobile and wireless communications.

Software defined radio (SDR) is an exciting new field for the wireless industry; it is gaining momentum and beginning to be included in commercial and defense products. The technology offers the potential to revolutionize the way radios are designed, manufactured, deployed, and used. SDR promises to increase flexibility, extend hardware lifetime, lower costs, and reduce time to market [8]-[11].

Mobile communications and wireless network have experienced massive growth and commercial success in the recent years. However, the radio channels in mobile radio systems are usually not amiable as the wired one. Unlike wired channels that are stationary and predictable, wireless channels are extremely random and time-variant. It is well known that the wireless multi-path channel causes an arbitrary time dispersion, attenuation, and phase shift, know as fading, in the received signal. Fading is caused by interference between two or more versions of the transmitted signal which arrived at the receiver at slightly different times. To transmit data and RFID information from one location to another without physically connecting together, as in wireless mobility, it is important to choose a suitable modulation scheme to accomplish this purpose. A modulation scheme is a process that uses an information signal to alter some properties of a higher frequency carrier waveform. By modulating each information signal into a different carrier frequency, many information signals can be communicated between distant sender and receiver. Radio waves are used as the transmission medium between the sender and receiver. The choice of modulation and demodulation used for the radio communication system is dependent on the required information transfer rate, the available spectrum to convey the information, and the cost[12]-[15].

There are many types of modulation formats used for the transportation of information [16]-[20]. Three fundamental modulations techniques are used mostly:

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amplitude modulation (AM) phase modulation (PM) and frequency modulation (FM). In AM, the magnitude of carrier is varied according to the magnitude of message signal. While in PM and FM modulations, the angle of the carrier are varied with the magnitude of message signal and the magnitude of carrier is constant [21]-[24].

AM has many unique qualities with it. However, this form of communication is not used directly in mobile wireless communication system primarily because it is more susceptible to noise. However, a variant of AM, Quadrature Amplitude Modulation (QAM) is recently used predominantly for the demand of higher bandwidth efficiency [8], given the emerging interest in Quadrature Amplitude Modulation (QAM) for data transmission in mobile communications [25], [27].

Due to its high spectral efficiency, multilevel quadrature amplitude modulation (M-QAM) is an attractive modulation technique for wireless communications. M-QAM has been recently proposed and studied for various non-adaptive and adaptive wireless systems [28]-[30] . However, the severe amplitude and phase fluctuations inherent to wireless channels significantly degrade the bit-error rate (BER) performance of M-QAM. That is because the demodulator must scale the received signal to normalize channel gain so that its decision regions correspond to the transmitted signal constellation.

In this paper, we provide a general approach to calculate the exact BER of M-QAM with Rayleigh fading and AWGN channels. We obtained BER using different signal noise radio for both channels.

II. SYSTEM MODEL

In our project, our target is to build up AWGN and Rayleigh Fading channel. Figure 1 shows the block diagram of our model used in the project. Our simulation supports two kinds of source data, either the randomly produced data or RFID data. Both data are ideal to test the channel impact to the BER performance.

After the source data is produced, the pilot data is inserted into head of source data in each coherence time. It is used to estimate the random phase shift of the fading channel and train the decision to adjust the received signal with phase recover. User may set any percentage of the pilot data length to the total data length (pilot data plus source data) in our model. In our simulation, we set the pilot data as 8% of the total data length.

Then, user may choose to use gray coding or not in the simulation. After gray coding, data is mapped from binary data to complex data, and each output datum represents a point in the constellation diagram [5]-[7]. In our model, we use Quadrature Amplitude Modulation (QAM) to modulate the data source.

In our simulation, we simulate two different channels: AWGN channel and Rayleigh fading channel [11], [12]. AWGN channel is very straight forward by just add a white Gaussian noise into signal to meet specified SNR. Section III will show the detail analysis of Channels.

In the receiver side, we need channel estimation for Rayleigh fading channel. Since we use QAM modulation in our model, the channel quadrature information in each coherence time need to be estimated, source data are adjusted by estimated phase for Rayleigh fading channel. The received signal constellations are dynamically showed in the simulation.

Decision device decide each adjusted symbol, correspondent to each point in constellation, to a binary datum. At last, we get the bit error rate by compare source data and received binary data.

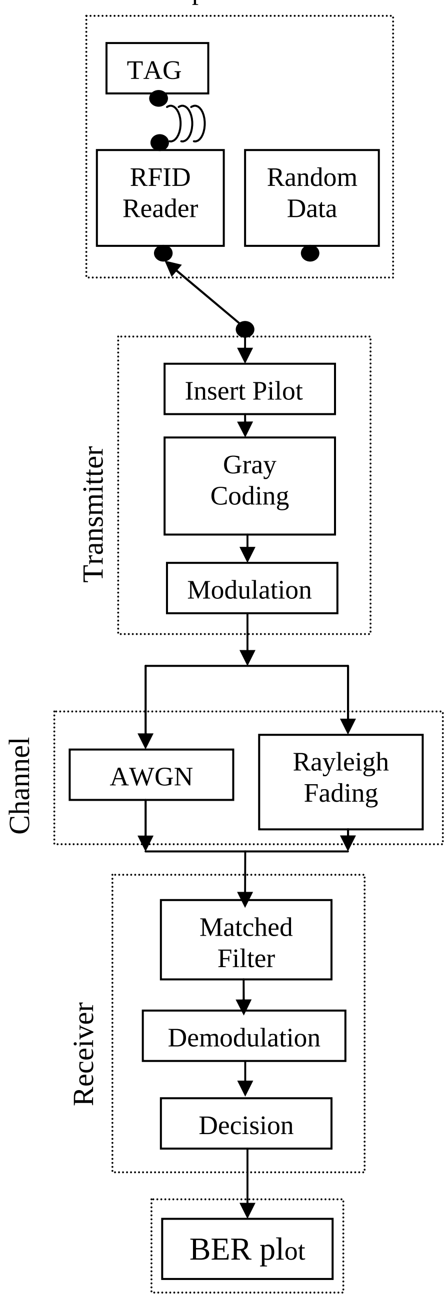

Figure 1: Block diagram for a system Model

III. CHANNEL ANALYSIS

In mobile wireless communication systems, the channel is time varying because of the motion of either the transmitter or the receiver which results in propagation path changes. Figure 1 shows the configuration of the transmitter and receiver. The data is modulated using the desired modulation scheme using Gray coding. After modulation, the signal is

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then transmitted over a channel with flat Rayleigh fading and additive white Gaussian noise (AWGN).

A. Additive White Gaussian Noise Channel

The simplest type of channel is the Gaussian channel. It is often referred to the additive white Gaussian noise (AWGN) channel. Basically, it is the noise generated in the receiver side if we assume that the transmitter is ideal and noiseless. This type of noise is assumed to have a constant power spectral density over the whole channel bandwidth and its amplitude probability density function (PDF) obeys the statistics of a Gaussian distribution.

Gaussian noise is very important in the analysis of communication system performance. The classical AWGN channel is always considered as the starting point to develop basic systems performance. Also, according to central limit theorem [22], even when there are a larger number of non-Gaussian independent noise sources, the mobile channel noise may still be approximated with a Gaussian distribution. This feature allows for simpler analysis of the communication system.

B. Raleigh Fading Channel

In a mobile radio communication system, one of the most devastating phenomena is fading. Fading is the direct result of multi-path propagation where radio waves propagate along different paths before arriving at the receiver antenna. These radio waves may arrive at receiver after different delays, with different amplitudes, and with different phases. Because there are so many different received signal components, constructive and destructive interference results in fading.

Thus, in a multi-path fading channel, when a signal pulse is transmitted, the mobile receives the superposition of many pulses. These multi-paths cause a wide fluctuation in the received signal magnitude, which makes reliable transmission of information a challenge

Given all the discussions above, the frequency non-selective and slow Rayleigh fading channel can be approximated into a multiplicative factor of the transmitted signal. Therefore, with the noise, the received signal can be expressed as

$$r(t)= s(t)c(t)+ n(t)$$

where r(t) is the baseband received signal, c(t) denotes the multiplicative fading distortion and its envelope has a Rayleigh distribution, s(t) is the transmitted baseband signal and n(t) is the additive white Gaussian noise with zero mean and power spectral density $N_{0.}$
The channel model also can be illustrated as in Figure 2.

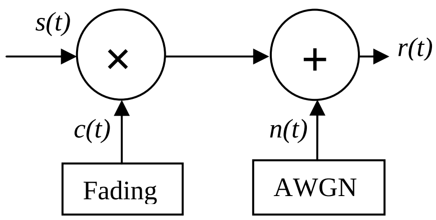

Figure 2: Transmission channel model

IV. Results and performance

A. Performance in AWGN Channel

This study finds that the Quadrature Amplitude Modulation has good performance over a wide range of SNR (signal to noise ratio) in AWGN channels. Figure 3 illustrates the probability of false acquisition of QAM in the AWGN channel. The simulation results show that with the increase of the frame observation length, the probability of true pilot symbol detection increases, which is consistent with theoretical analysis. However, in this plot, figure 3(d) is better than figure 3(e) when SNR is equal to 15 dB. It is an unexpected result. But with the SNR is increased, figure 3(e) shows stable and better performance than figure 3(d) and it is still consistent with the theoretical analysis. Table 1 shows the simulation results in term of BER vs SNR for AWGN channel by varying the values of Eb/No in the range of 0 to 25 in db.

Table 1: BER vs SNR for AWGN channel

Signal-to-Noise Ratio Eb/No	Number of Error	Bit Error Rate (BER)
0	6	0.25
5	5	0.208333
10	4	0.166667
15	3	0.125
20	2	0.0833333
25	1	0.0416667

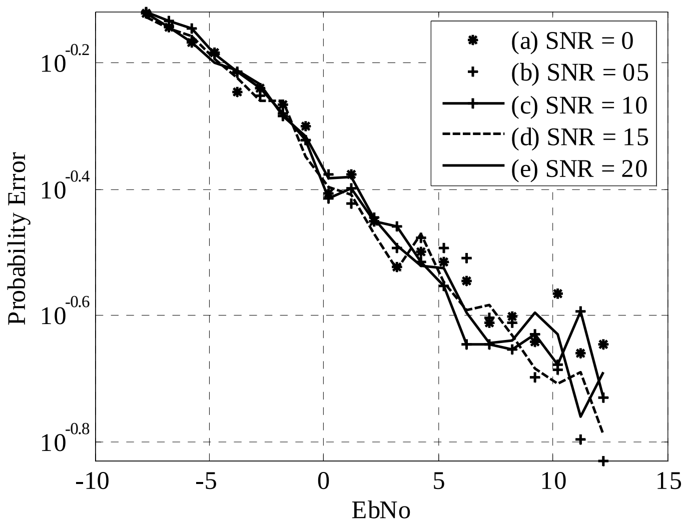

Figure 3: Performance Analysis of QAM Modulation in AWGN for SDR at Different SNR

B. Performance in Rayleigh Fading Channel

The performance in the Rayleigh fading channel is more complicated than the performance in the AWGN channel. However, based on the high SNR signal processing approximations, the frame synchronization criteria for fading channel, are as easy to be implemented as those in the AWGN channel. The simulation results shown in Fig. 1.3

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illustrate the probability of false acquisition of QAM in Rayleigh fading channel when Doppler shift and SNR are known. The performance of synchronization is poor under low SNR; however it becomes quite good in moderate to high SNR range due to the high SNR approximations. In figure 4(e) and figure 4(f), the mean times to acquisition calculated based on the probabilities of false acquisition are illustrated. It is apparent that the longer the pilot sequence is used, generally the better the performance of correct pilot symbol detection, however the longer time is taken to converge to synchronization.

Comparing the performance in the fading channel with the performance in the AWGN channel, it is obvious that in AWGN channel the frame synchronization system works better than in fading channel. It is easy to understand that, in the analysis of the performance of a communication system, AWGN is always used to give an upper bound performance, because the AWGN condition is the simplest case in wireless communication environment. Table 2 shows the Rayleigh fading channel simulation results in term of BER vs SNR by varying the values of Eb/No in the range of 0 to 25 in db.

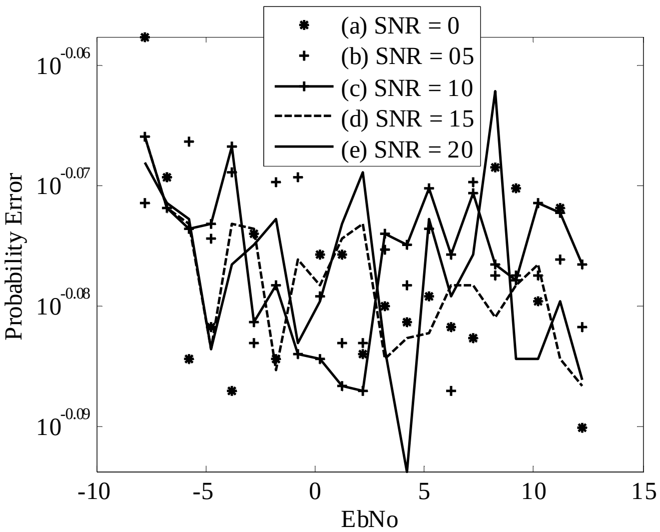

Figure 4: Performance Analysis of QAM Modulation in Rayleigh fading Channel for SDR at different SNR

Table 2: BER vs SNR for Multipath Rayleigh Channel

Signal-to-Noise Ratio Eb/No	Number of Error	Bit Error Rate (BER)
0	8	0.291667
5	7	0.25
10	5	0.166667
15	4	0.125
20	3	0.0833333
25	2	0.0416667

V. Conclusion

We have studied the effect of fading amplitude and phase estimation error on the BER of 16-QAM and 64-QAM over flat Rayleigh fading and AWGN channels. The results are obtained by averaging SNR. From the simulation results is shown in Figure 5, we can see that in Matlab QAM has the best performance of BER versus SNR in AWGN channel. As a conclusion, in the case when bit transmission rate is high requirement, we can use the QAM as modulation scheme for better transmission performance.

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