Performance of Convolutional coding with Hard decision Viterbi decoding on BPSK Systems over Noisy Channels

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***Abstract*—The main objective in the design of digital communication system is to receive the data equally like the data sent from the transmitter. Therefore to reduce the impacts of errors in transmitted signal, it is essential to use error control coding. In this paper, the convolution code is used as a channel coding technique and modulation technique used is Binary Phase Shift Keying (BPSK) under Additive White Gaussian Noise (AWGN) and Rayleigh Fading channels. In terms of bit error rate (BER), this research was found that the performance of coded signal is better than uncoded signal.**

***Index Terms*—AWGN, BER, BPSK, Convolutional code, Eb/No.**

I. INTRODUCTION

THE fundamental notion of information theory is that all communication in actual fact is a digital. In general, the function of that communication system is to generating, transmitting and receiving binary data (bits). It is usually some of these bits will be distorted by noise when it transmitted through the communication channel. According to the Shannon theorem [9], it can always be separate the communicating information from a source to destination into source coding and channel coding in order to minimize the problems. In case of source coding, it will convert the input source into binary digits in the transmitter side and this process will be reversed at the receiver side while the channel coding will introduced some redundancy in the information sequence that can be helpful at the receiver to overcome the influences of noise in the transmission of the signal over the channel [5].

Before digital data can be transmitted through a channel, it is necessary to use digital modulation. Modulation is the method of changing some characteristic of a carrier waveform for instance amplitude, phase or frequency. Phase shift keying (PSK) is one form of digital modulation techniques which have constant envelope but irregular phase changes from symbol to symbol.

In binary PSK case, the modulator will represent the digit *0* into waveform $s_0(t)$ and the digit *1* into a waveform $s_1(t)$ and then it is transmitted individually [2]. This is what makes a designer looking for quickest way to transfer all data to the other side with minimal effort, low delay and high quality. In this paper we will present a technique to realize BPSK systems using convolutional codes. This technique had been discussed in several papers but here, we will use two different channels (AWGN and Rayleigh) which affect the BPSK performance (see Fig. 1).

The organization of this paper is as follow. In section II discusses and analyzes the system model. Section III, an overview of the convolutional code technique, BPSK modulation scheme, AWGN and Rayleigh fading are provided. Section IV presents the main concept of BER and also gives the theoretical curves for BPSK over AWGN and Rayleigh channels. Section V describes the simulation results obtained. Finally, conclusions are presented in section VI.

II. SYSTEM MODEL ANALYSIS

In general, mathematical analysis and computer simulation are related to the system model, which is usually a block diagram or functional diagram that illustrates the interconnection of the different subsystems that covers the general system [1]. In this report, the system model is described in figure 1. At the first, convolutional encoder will encoded the information sequence for improving the reliability. Then BPSK modulator will apply to map each of the information sequence into signal waveforms before transmitting over the noisy channel. At the receiving side, these processes will be reversed. To calculate the bit error rate (BER) for this system, it will be done by the difference between the information sequence at the source side and the decoded sequence at the sink side divided by the total number of transmitted bits.

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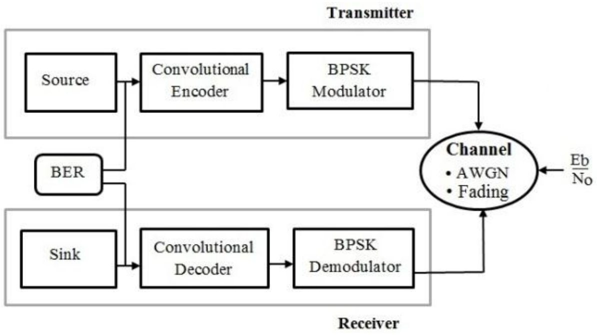

Figure 1: Structure of Convolution code on BPSK signal over AWGN and fading channels

III. Theoretical Background

A. Convolutional codes

Channel coding is used in digital communication systems to keep the digital information from noise and interference and reduce the number of bit errors. In this case, a convolutional code present a method to error control coding in which each *k*-bit information symbol to be encoded is transformed into *n*-bit symbol, but these *n* bits are not only calculated by the current *k*-information bits but also by the previous information bits that are stored within memory devices where k/n is the code rate [13], [14], [2]. Also, convolutional codes do not represent each blocks of bits into blocks of codewords. This means, they take a continuous stream of bits and represent them into an output stream presenting redundancies in the process.

The figure below shows the block diagram of a convolutional encoder which consists of shift register with kL stages where L is called the constraint length of the code. After the k bits have entered the shift register, n-linear combinations of the contents of the shift register are computed and used to generate the encoded waveform [2].

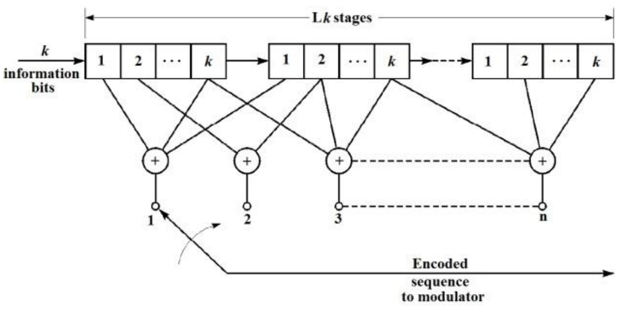

Figure 2: The block diagram of a convolutional encoder [2]

Convolutional codes have been widely used in applications such as mobile telecommunications system, satellite communications and digital broadcasting. This is because they provide efficient error correction and allow simple decoding algorithms [17]. One techniques used to decode the convolutional codes is Viterbi algorithm [20], which gives the maximum probability approximate of a whole transmitted bit streams by minimizing the total error caused by the noisy channel. Viterbi decoding can be done into two approaches which are hard decision and soft decision. In this paper, we will focus on hard decision decoding due to simplicity of implementation. Simply, hard decision decoder is one which receives hard values (In BPSK case, 0s and 1s) from the channel that are used to create the original signal.

B. Binary Phase Shift Keying (BPSK)

In digital communication, a sequence of bits (a stream of ones and zeros) is represented to a waveform for transmission across the channel. A binary waveform can be transmitted by using Amplitude, Frequency, or Phase modulation techniques. Binary phase shift keying is a phase modulation (PM) that uses phase variation to encode bits [10]. It is one of the most important schemes in phase shift keying (PSK) that gives high-level protection against noise and interference.

In BPSK, the binary digital signal modulates the phase of the sinusoidal carrier. Logic “0” is represented by a carrier having a 0° degree phase shift and the modulated signal *m(t)* is given by [11]:

$$m_{BPSK}(t) = A\cos(2\pi f_c t) \qquad (1)$$

On the other hand, logic “1” is represented by a carrier having a 180° phase shift and the modulated signal is

$$\begin{aligned} m_{BPSK}(t) &= A\,cos(2\pi f_c t + \pi) \\ &= -A\cos(2\pi f_c t) \end{aligned} \qquad (2)$$

C. Additive White Gaussian Noise (AWGN)

Gaussian processes take a significant part in communication systems. This is because the thermal noise in electronic devices, which is created by random movement of electrons as a result of thermal effect, can be demonstrated by a Gaussian process [2]. In general, AWGN is used to evaluate the performance of a communication system in terms of noisy channel. According to the [4], the term *noise* means undesirable electrical signals that are existing in electrical systems and the term *additive* means the noise signal *n(t)* is added (and not multiplied) to the signal *s(t)*, this will reduce the receiver capability to make correct symbol decisions and reduce the rate of information transmission. In this case the receiver signal *r(t)* will be

$$r(t) = s(t) + n(t) \qquad (3)$$

Also, the term *white* refers to the noise has the same spectral characteristics for all the frequencies [3], [5]. In other words, it has a flat spectrum and is represented as

$$G_n(f) = \frac{N_0}{2} \qquad watts/herts \qquad (4)$$

Where the $G_n(f)$ is the power spectral density and the factor *1/2* is showed that the half the power is linked with positive frequencies and half with negative frequencies. Finally, the term *Gaussian* [5] denotes that the values of the noise 'n' follow the Gaussian probability distribution function (pdf) and the normalized Gaussian density function of a zero mean process is obtained by assuming that $\sigma = 1$, where σ^2 is the variance of n.

$$p(r) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left[-\frac{1}{2}\left(\frac{r-s}{\sigma}\right)^2\right] \quad (5)$$

D. *Rayleigh Fading*

The transmission of digital radio systems normally consists of a large number of scatters that come from multiple propagation paths. This multipath propagation happens when the electromagnetic energy transmitting the modulated signal into more than one path before reaching the receiver due to reflection and refraction, this causes delay and attenuation to the transmitted signal [5]. This is what known as a Rayleigh fading channel. One of the best solutions to this phenomenon is by doing a channel coding. In this case, the received signal in Rayleigh fading channel is [17]

$$r(t) = h(t) * s(t) + n(t) \quad (6)$$

Where *h(t)* is a factor of Rayleigh multipath channel.

IV. Bit Error Rate (BER)

An important measure for any digital communication systems is the bit error rate. According to the [7] and [6], BER is the ratio of incorrectly transmitted bits to correctly transmitted bits. In other words, it is defined as

$$BER = \frac{number\ of\ bits\ received\ in\ error}{total\ number\ of\ bits\ transmitted}$$

In fact, the error occurs during the transmission process due to noise, distortion, interference or bit synchronization errors. It is a suitable method used to compare the ability of the system with different techniques to show which one is good than the other techniques. Therefore to show the performance of the BPSK system in the existence of noisy channels, it is good idea to plot the BER against Eb/N0 (Energy per bit to Noise power density) to see the behaviour of that system. By definition [8], the propapility of bit error P_e for a BPSK transmission in the presence of AWGN is:

$$P_e = Q\left(\sqrt{\frac{2E_b}{N_0}}\right) = \frac{1}{2} erfc\sqrt{\frac{E_b}{N_0}} \quad (7)$$

Also, in the presence of Rayleigh fading is [18]:

$$P_e = \frac{1}{2}\left(1 - \sqrt{\frac{E_b/N_0}{1+E_b/N_0}}\right) \quad (8)$$

And the error function *erfc* for a variable *x* is:

$$erfc(x) = \frac{2}{\sqrt{\pi}} \int_x^{\infty} e^{-x^2}\, dx \quad (9)$$

The theoretical BER vs. EbNo curves for BPSK obtained by using MATLAB is shown in figure 3 and 4.

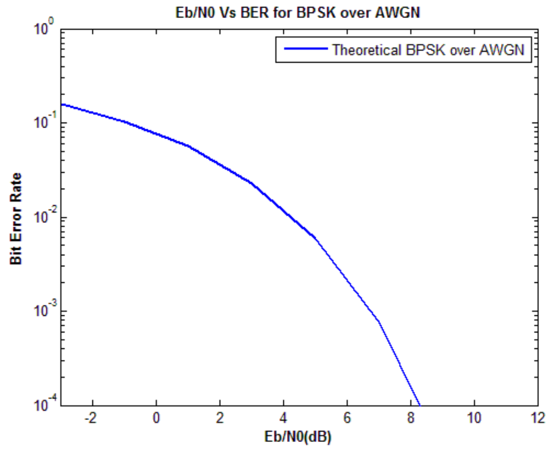

Figure 3: Bit error rate probability for theoretical BPSK system over an AWGN channel

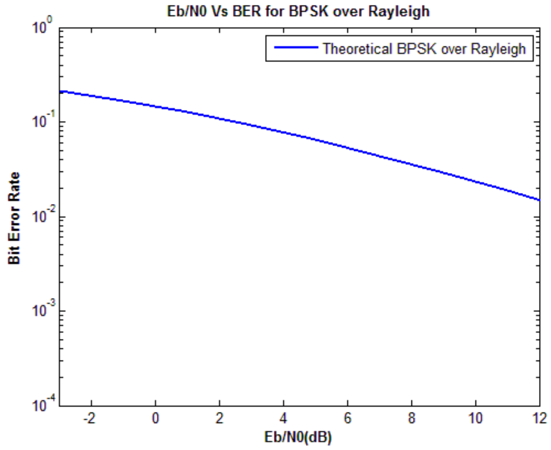

Figure 4: Bit error rate probability for theoretical BPSK system over a Rayleigh channel

V. Implementation

A. *Simulation System*

The simulation models the effect of adding the AWGN and Rayleigh channel on a BPSK modulated signal. Bit error rate is measured after decoding the received signal in the receiver. Figure 5 and 6 shows the simulation result of BER versus Eb/N0 for BPSK uncoding and coding respectively. The results show that BER is decreasing by increasing the Eb/N0 from -2 to 12 dB, which means decreasing of the noise effect for both cases.

B. *Comparative Results*

In this part, the goal of making the comparative performance analysis between the simulation results with theoretical curve is for authentication. It can be seen from the figures below, the theoretical curve is the same as the simulation curve, which confirms the code provided. Also, it shows the error probability for BPSK over AWGN channel declines fast with increasing EbNo while for Rayleigh channel is much worse. Finally, figure 6 confirms that the coded curve is low error rate than those uncoded curves. Most importantly, the coded curve shows reduction in power or EbNo, for example, from 8 dB to 4 dB. Hence, the coding gain G is given by [5] will be:

$$G_{dB} = \left(\frac{E_b}{N_o}\right)_{uncoded\ (dB)} - \left(\frac{E_b}{N_o}\right)_{coded\ (dB)} \quad (10)$$

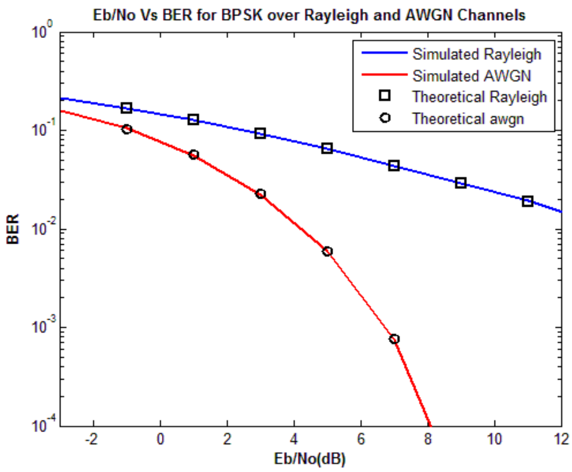

Figure 5: BER simulations for uncoded BPSK Performance over AWGN and Rayleigh channels

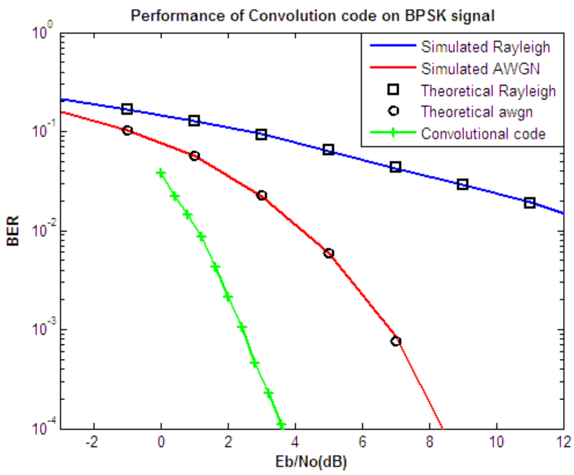

Figure 6: Comparison performance between coded and uncoded BPSK

VI. CONCLUSION

In this paper, A MATLAB simulation was carried out in order to study the performance of convolutional coding over the AWGN and Rayleigh channels which is used to correct errors in those noisy channels. Also, a comparison study is done between uncoded and coded BPSK. It is found that convolutional coding has improved the BER of the channel and this is should be taken into account when designing the BPSK systems over noisy channels.

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