Performance Study on Effect of Convolution Coding in WCDMA System with AWGN and Multipath Rayleigh Fading Channel

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Abstract- **This paper highlights the performance of Convolutional coding in WCDMA with different channel. The main objective of this project is to investigate the effect of convolutional coding with different channel condition such as AWGN and multipath Rayleigh fading channel with different Doppler shift in WCDMA system. A convolutional code is used to correct and detect any error that is occurs in this communication system. The modulation technique that is used in this project is QPSK. The system model was constructed and simulated using MATLAB software version 6.5. From the result obtained, the system with convolutional coding much better in term of BER compared to the system without channel coding for both type of fading.**

Keywords- **Additive White Gaussian Noise (AWGN), Multipath Rayleigh Fading, Doppler Shift, Wide Code Division Multiple Access (WCDMA), Quadrature Phase Shift Keying (QPSK), Convolutional codes, Bit Error Rates (BER), Signal Energy to Noise Power Density ratio (E_b/N_0).**

I. INTRODUCTION

WCDMA is a wideband digital radio communications technology, which provides new service capabilities, increased network capacity and reduced cost for voice and data services compared to 2G technologies. It provides simultaneous support for a wide range of services with different characteristics on a common 5 MHz carrier [1].

In WCDMA system, there are several process must be involved such as modulation process, encoding, adding channel, demodulation and decoding process. In this report, a comprehensive study is presented of Convolutional code as an encoder and Viterbi as a decoder for the systems, QPSK as modulation and demodulation technique and the AWGN and Multiple Rayleigh fading as the channel.

The type of communication that is used in this project is the digital communication system. QPSK is the digital modulation techniques.

A. Quadrature Phase Shift Keying (QPSK)

Quadrature Phase Shit Keying (QPSK) *is* sometimes known as quaternary or quadriphase PSK, 4-PSK, or 4-QAM [2]. QPSK is one example of M-ary PSK modulation technique which M=4. QPSK uses four points on the constellation diagram, equispaced around a circle. With four phases, QPSK can encode two bits per symbol, shown in the diagram with Gray coding to minimize the BER, twice the rate of BPSK. The phase carrier takes on one of four equally spaced values, such as 0, $\pi/2$, π and $3\pi/2$, where each value of phase corresponds to a unique pair of message bits. Special characteristics of QPSK are twice data can be sent in the same bandwidth compared to Binary PSK (BPSK) and QPSK has identical bit error probability to that of BPSK. When QPSK is compared to that of BPSK, QPSK provides twice the spectral efficiency with the same energy efficiency.

Furthermore, similarly to BPSK, QPSK can be differentially encoded to allow non-coherent detection. Due to these advantages of QPSK, it has been employed as the modulation technique in UMTS 3G wireless cellular networks where the following data rate can be achieved depending on the channel quality [3].

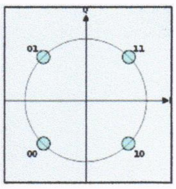

Figure 1: Constellation diagram for QPSK with Gray coding. Each adjacent symbol only differs by one bit

B. Convolutional code

In this project, the channel coding that will be use is the convolutional code. Channel coding is a practicable method to reduce information rate through the channel and increase reliability. Convolutional coding is applied to the multicast modulation system to provide better efficiency [4].This goal is achieved by adding redundancy to the information signal that produced a longer signal bits. It is distinguishable at the output of the channel. As in, convolutional code may be termed as (n,k,m) code where k is the number of bits taken into encoder, n is the number of bits output from the encoder and m is the maximum number of shift register stages in the path to any output bit. The code of shift register stages in the path to any output bit. The code rate (k/n) used in this paper is 1/2 and the constraint length is 9 [5].

C. Additive White Gaussian Noise (AWGN)

The most commonly occurring communications channel is one with additive white Gaussian noise and also is known as AWGN. In communication channel, there are three types of channels which are fading channels, channels in which the noise stems from other users, and AWGN channels [6]. AWGN is famous as the simplest mathematical models that are used in various physical communication channels, including wire lines and some radio channels. This channel model is a linear addition of wideband or called as white noise with a constant spectral density in a Gaussian distribution of noise samples.

The sources of this wideband Gaussian noise are come from the natural sources. They are several types of natural sources which are the thermal vibrations of atoms in antenna or also referred to as thermal noise or Johnson-Nyquist noise, shot noise, black body radiation from the earth and other warm objects and from celestial sources such as the Sun.

The AWGN channel is also a good model for many satellite and deep space communication links. But this model is not a good model for most terrestrial links. This is because of the several reasons which are multipath, terrain blocking and interference. However this AWGN channel is accepted in terrestrial path modeling, which is commonly used in addition to multipath, terrain blocking, interference, ground clutter and self interference that modern radio systems encounter in terrestrial operation [7].

The AWGN channel rate is given by the Shannon-Hartley theorem:

$$C = B\log_2\left(1+\frac{S}{N}\right) \quad (1)$$

where B is bandwidth, S is signal power and N is noise power within the bandwidth [8]. The AWGN channel is a good code for phase shift keying and quadrature amplitude modulation signal constellation [9].

D. Multiple Rayleigh Fading

Rayleigh fading is the specialised model for stochastic fading when there is no line of sight signal, and is sometimes considered as a special case of the more generalised concept of Rician fading. In Rayleigh fading, the amplitude gain is characterized by a Rayleigh distribution. Rayleigh fading is caused by multipath reception. The mobile antenna receives a large number, say *N*, reflected and scattered waves. Because of wave cancellation effects, the instantaneous received power seen by a moving antenna becomes a random variable, dependent on the location of the antenna. Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal, such as that used by wireless devices [10].

Rayleigh fading is viewed as a reasonable model for tropospheric and ionospheric signal propagation as well as the effect of heavily built-up urban environments on radio signals [11]. Rayleigh fading is most applicable when there is no dominant propagation along a line of sight between the transmitter and receiver. If there is a dominant line of sight, Rician fading may be more applicable.

E. Wide Code Division Multiple Access

Early on this century, code Division Multiple Access (CDMA) is widely used in digital communication system. At that time, CDMA is the most excellent multiple access. As the time goes by, WCDMA is implemented. WCDMA is an enhancement of CDMA which will produce much more benefits. It is a direct spread technology to satisfy ever-increasing demands for higher data rates [12]. It will spread its transmission over a wide, 5MHz carrier. Using WDCMA, user's information bits are spread over wider bandwidth compared to CDMA [13].

In reality, WCDMA networks are true multiservice network whose capabilities are unmatched by any other technology. It will permit very high-speed multimedia services such as full-motion video, internet access and video- conferencing [14]. The project is going to be done to determine whether which channel that give better performance either AWGN or Multipath Rayleigh Fading as the channel.

F. MATLAB simulation

Matlab is a high-performance language for technical computing. It is a software package of simulation, analyzing and modeled in continuous time, sampled time or hybrid [15]. For this project, Matlab Version 6.5.0 is being used to simulate QPSK in WCDMA environment with AWGN and Rayleigh fading channel to compare the bit error rate of both channels using convolutional code.

II. Objective and Scope of Study

The aim of this project is to study the error performance of WCDMA system for convolutional coding in presence of AWGN and Rayleigh multipath fading channel for single user environment. Thus three main objectives have been outlined is to investigate the effect of convolutional coding with different channel condition in WCDMA system, to simulate the system with different channel conditions which are Additive White Gaussian Noise (AWGN) and Rayleigh Multipath Fading with Doppler Shift and to analyze BER for the simulated WCDMA system.

In order to achieve the objectives above, this project has been carried out totally based on simulation using Matlab software. Matlab is used to generate and calculate bit error rate (BER) and signal to noise ratio (SNR) for each predetermined channel condition.

III. Problem Statement

The modulation technique that is used in this project is the QPSK modulation technique. QPSK modulation is one of the digital modulation techniques. The analog modulation signal is not suitable to apply because by using the analog more noise is occurred rather than use the digital modulation technique. In the mean time this analog modulation technique is also caused the cross talk and it is influenced the performance of the transmission signal. Those are the reasons why QPSK is used as the modulation technique in this project. The purpose of using this modulation technique is because the probability of the errors occurs in the system is reduced.

Another problem that is occurred in this project is the error that is occurred during the transmission of the signal. Multipath fading is a common phenomenon in mobile communication. It results from multipath propagation, reflection, refraction and diffraction. It caused communication environment changes quickly and thus introduces more complexities and uncertainties to the channel response. One known solution is by introducing channel coding in communication environment. Convolutional coding is used in WCDMA system due to its relatively good performance and with reasonably simple Viterbi decoding algorithm.

At the transmission part between the transmitter and receiver there is unwanted signal that is known as noise. This noise is occurred when the signal is transmit through the free space. When the signal is arrived at the receiver side this noise must be eliminate from the system. There are two type of channel that is injected in this project. The two channels that are used are the AWGN and Multiple Rayleigh fading channel. These two channels are also the types of noise. These two noises are added of the purpose when all the noise is arrived at the receiver part, it is detected by the system. Once the noise is detected, the elimination of that noise is done by the receiver part.

IV. Methodology

System Model of WCDMA

Model for WCDMA system was constructed as in Figure 2.

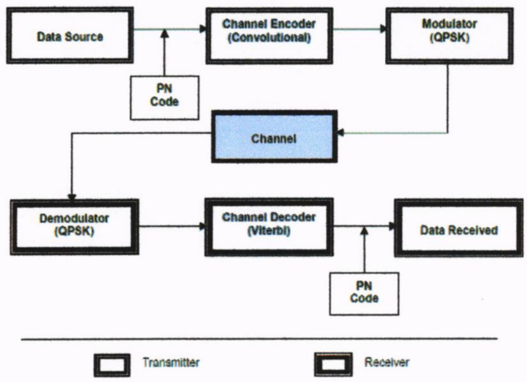

Fig. 2: System model for WCDMA

This system consists of two parts. One is the transmitter part and the other one is the receiver part. The signal at the transmitter part is transmitted to the receiver part through the free space. The signal is modulated by using QPSK during the transmission of the signal.

The signal is encoded by using the convolutional code and the noise was added during the transmission. There are two types of channel that is used in this project which are AWGN and Multiple Rayleigh fading channel. All the signal that is being transmit is decoded back to get the original signal and again the Veterbi decoding is used at the decode part to correct back all the error that occur during the transmission.

All of the process that is involved in the system model above is evaluated by using the simulink and programming software. This evaluation is performed by using MATLAB software version 6.5.0. Fig. 3 below shows the flow chart of this project simulation by using MATLAB. This development of this flow chart is based on the system model of the WCDMA.

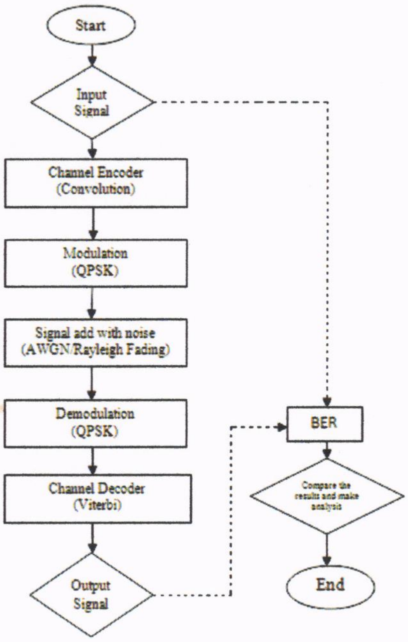

Fig. 3: Software flow chart

V. RESULT AND DISCUSSION

From the simulation process the performance study of BER of AWGN with and without Convolutional coding as shown.

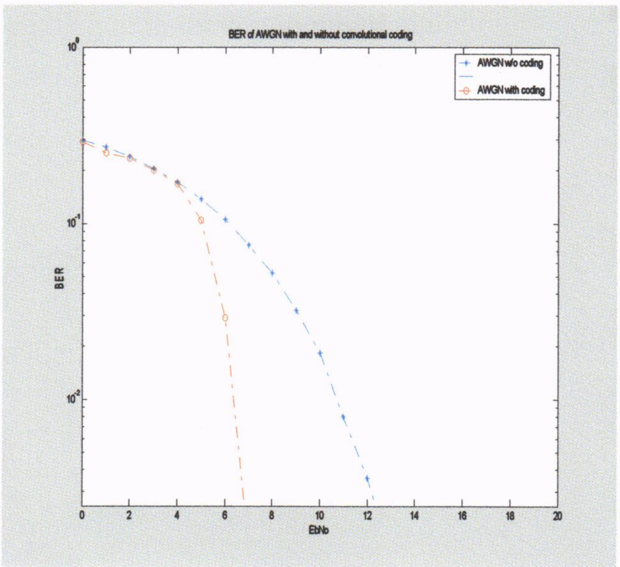

Fig. 4.1: BER of AWGN with and without Convolutional coding

Figure 4.1 shows the performance BER of AWGN channel with convolutional Coding is better from AWGN channel without convolutional coding. At Eb/No = 7dB it shows that AWGN channel with convolutional coding is nearly 10^{-3} while AWGN channel without convolutional coding is only 10^{-1}. The figure below shows the performance study of BER of AWGN and Multipath Rayleigh fading with Doppler shift = 55.56 Hz (speed, v=60 kmph)

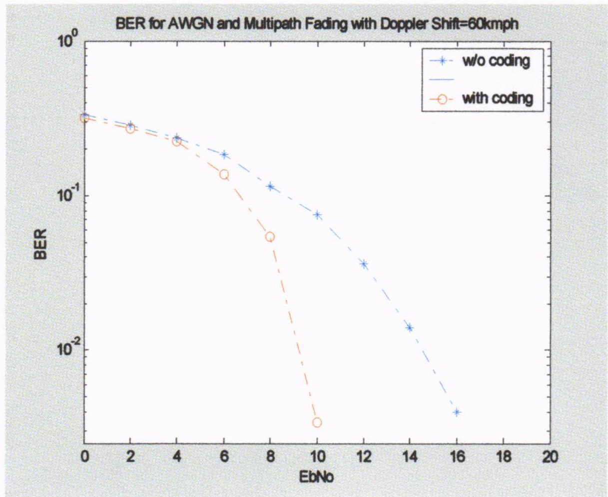

Fig. 4.2

Fig. 4.2: BER of AWGN and Multipath Rayleigh fading with Doppler shift = 55.56 Hz (speed, v=60 kmph)

Figure 4.2 shows the performance Eb/No of AWGN and Multipath Fading with Doppler Shift = 55.56 Hz (speed, v = 60 kmph) channel with convolutional coding is improved about 5 dB at BER = 10^{-2} from the channel without convolutional coding.

The figure below shows the performance study of BER of AWGN and Multipath Rayleigh fading with Doppler shift =83.33 Hz (speed, v=90 kmph*)*

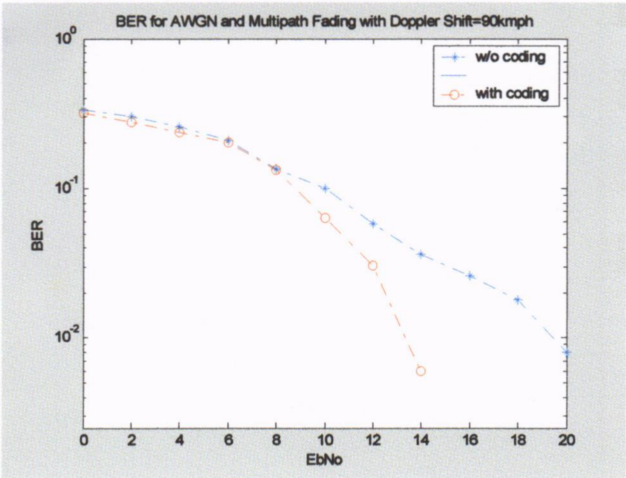

Fig. 4.3

Fig. 4.3: *BER of AWGN and Multipath Rayleigh fading with Doppler shift =83.33 Hz (speed, v=90 kmph)*

Figure 4.3 shows the performance BER of AWGN and Multipath Fading with Doppler Shift = 83.33 Hz (speed, v = 90 kmph) channel with convolutional coding is better from the channel without convolutional coding. The Eb/No is increasing about 6 dB at BER = 10^{-2}. However, as the SNR are getting higher and the capability of channel coding decreasing with the increasing of bit error rate. The Figure below shows the performance study of BER of AWGN and Multipath Rayleigh fading with Doppler shift = 111.11 Hz (speed, v=120 kmph)

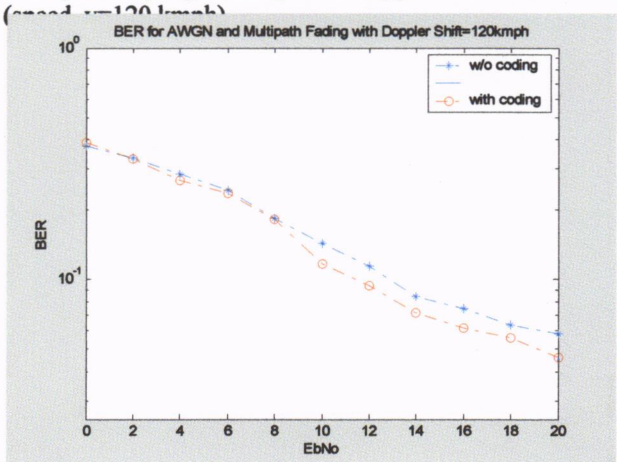

Fig. 4.4

Fig. 4.4: BER of AWGN and Multipath Rayleigh fading with Doppler shift = 111.11 Hz (speed, v=120 kmph)

From Figure 5.4, performance BER of AWGN and Multipath Fading with Doppler Shift = 111.11 Hz (speed, v = 120 kmph) channel with convolutional coding is slightly better from the channel without convolutional coding. However, this can be considered that channel coding is not successful. This is results from irreducible error rate where channel coding has inadequate capability to correct the errors due to very high speed environment. The figure below shows the performance study of BER of AWGN and Multiple Rayleigh Fading without Convolutional coding with different Doppler Shift values

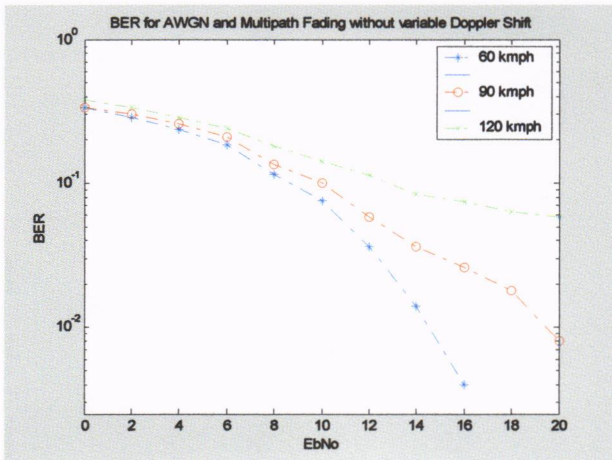

Fig. 4.5 (a)

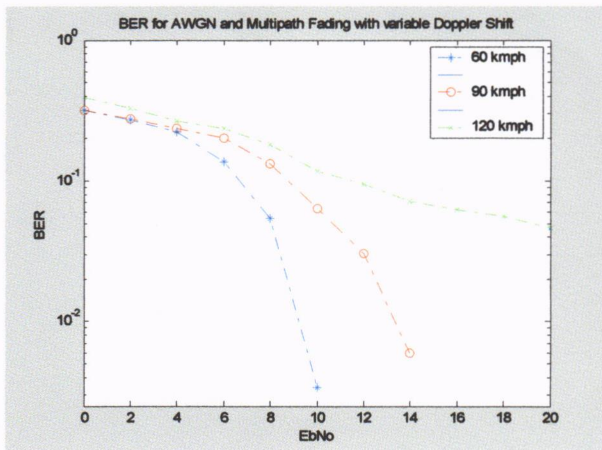

Fig. 4.5(b)

Fig. 4.5 (a) BER of AWGN and Multiple Rayleigh Fading without Convolutional coding with different Doppler Shift values (b) BER of AWGN and Multiple Rayleigh Fading with Convolutional coding with different Doppler Shift values

Figure 4.5 (a) and 4.5 (b) shows the combination of AWGN and Multiple Rayleigh Fading channel with different speeds with and without the existence of convolutional code in the system. Figures illustrate that mobile terminal with lower speed gives better performance of channel coding than other speeds.

VI. CONCLUSION

For this project, it is highlighted the performance of convolutional coding using AWGN and Multipath Rayleigh fading as the channel in the WCDMA system. WCDMA system was designed to withstand with interference and fading in communication channel. However, other elements such as channel coding, interleaving or equalizer are needed for a system in order to sustain in any type of environment especially in multipath fading channel.

As general overview, it is concluded that this project is achieved the entire objective. All of the performance in this project is simulated by using the MATLAB software version 6.5.0.From the observations and the analysis that is made in this project, it is shown that the capability of channel coding in performing error correction and detection in communication channel. From the simulation, the results demonstrated that the convolutional coding is a good means of channel coding for AWGN channel and Multipath Rayleigh Fading channel. However, as the speed of mobile terminal increases the capability of convolutional coding is also decreases.

VII. FUTURE WORK

In the future, this project can be improved by doing the modification in this system. As the project completed, there are several enhancement can be done to improve the current work. This project can be improved in order to get better quality and the better performance. This is the suggestions that can be applied in the future research to improve the system.

The order that is used can be higher. This can be expanded by using 16-QAM. Besides that the research can improve the performance by making the higher order of QAM will give better performance.

The future research also can be done by generate binary data sources for various data rates since 3G system has capability to support variable data rates such as 144kbps and 2Mbps. Implementation of multi user system which the design is more related to the real environment. It is proposed that Rician fading is included in the channel. Then, comparison can be made between these channels. The future research also can be use different channel coding scheme has been determined by 3GPP. It includes convolutional code with coding rate =1/3 and turbo code. Thus a comparison study between those coding schemes is essential to determine which coding scheme is more suitable for a system with different channel conditions. It is also proposed that implementation of interleaver in the system in order to overcome the problem of irreducible error rate.

REFERENCES

[1] Telecom space 'WCDMA' http://www.telecomspace.com/cdma-wcdma.html, accessed on April 1, 2010.

[2] Communications Systems, H. Stern & S. Mahmoud, Pearson Prentice Hall, 2004, p283

[3] Couch, Leon W. II (1997). *Digital and Analog Communications*. Upper Saddle River, NJ: Prentice-Hall. ISBN 0-13-081223-4.

[4] Micheal B.pursley and John M. shea, *Convolutionally Encoded Phase-Shift-Key Modulation for Multimedia Multicast Transmission in Mobile Wireless Network*, IEEE Military Communication Conf, Oct 1996; vol. 1, pp.210-214

[5] Michael B. Pursley and John M. Shea, *Multicast Transmission With nonuniform PSK Modulation and convolutional coding over Raleigh fading Channel*, 1997.

[6] Anderson, John B, *Digital Transmission Engineering*. Institue of Electrical and Electronics Engineers, New York, 1999, pp. 46-45.

[7] Harold P.E. Stern, Samy A. Mahmoud, *Communication Systems*, Pearson Prentice Hall, 2004, pp. 133-136.

[8] Peter Sweeney, *Error Control Coding*. John Wiley & Sons, LTD, 2002, pp. 18-24.

[9] E. Biglieri, M. Luise, *Coded Modulation and Bandwidth-Efficient Transmission*. Elseiver Science Publishes B.V, 1992, pp.305-309.

[10] John G. Proakis (1995). *Digital Communications* (3rd ed.). Singapore: McGraw-Hill Book Co. pp. 767–768. ISBN 0-07-113814-5

[11] Bernard Sklar (July 1997). "Rayleigh Fading Channels in Mobile Digital Communication Systems Part I: Characterization". *IEEE Communications Magazine* 35 (7): 90–100. doi:10.1109/35.601747+ISSN+0163-6804.

[12] Wayne Tomasi, *Electronic Communication Systems, 5th Edition*, Pearson Prentice Hall, 2004

[13] Laurence B.Milstein, Fellow, *IEEE, wideband code Division Multiple Access.*

[14] Andrei Dulski, Hans Beijner and Hans Herbertsson, *Rural WCDMA-Aiming For Nationalwide Coverage with One Network, One Technology, and One Service Offering*

[15] William J Palm III, *Basic Engineering Series and Tools, Introduction to Matlab 7 for Engineer*