International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 - 5161

Available at http://inpressco.com/category/ijcet

Research Article

Study and Simulation of DS-CDMA over Communication Channels

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Accepted 02 May 2014, Available online 01 June 2014, **Vol.4, No.3 (June 2014)**

Abstract

Performance of synchronous DS-CDMA systems over multipath fading channel and AWGN Channel is evaluated. The synchronous DS-CDMA system is well known for eliminating the effects of multiple access interference which limits the capacity and degrades the BER performance of the system. This paper investigated the bit error rate (BER) performance of a synchronous DS-CDMA system over AWGN and Rayleigh channel, which is affected by the different number of users, as well as different types spreading codes. The promising simulation results explore the comparative study of different DS-CDMA system parameter and showed the possibility of applying this system to the wideband channel. In this paper, Rayleigh channel and AWGN Channel are introduced and investigated the bit error rate (BER) performance of a synchronous DS-CDMA system over these channels. In the DS-CDMA system, the narrowband message signal is multiplied by a large bandwidth signal, which is called the spreading of a signal. The spreading signal is generated by convolving a GOLD sequence code with a chip waveform whose duration is much smaller than the symbol duration.

Keywords: *BER, AWGN, GOLD Sequence.*

1. Introduction

Direct-sequence code-division multiple access (DS-CDMA) is currently the subject of much research as it is a promising multiple access capability for third and fourth generations mobile communication systems. Code-division multiple access (CDMA) is a technique whereby many users simultaneously access a communication channel. The users of the system are identified at the base station by their unique spreading code. The signal that is transmitted by any user consists of the user's data that modulates its spreading code, which in turn modulates a carrier. An example of such a modulation scheme is quadrature phase shift keying (QPSK). In this Paper, we introduce the Rayleigh channel and AWGN Channel, and investigated the bit error rate (BER) performance of a synchronous DS-CDMA system over these channels. In the DS-CDMA system, the narrowband message signal is multiplied by a large bandwidth signal, which is called the spreading of a signal. The spreading signal is generated by convolving a GOLD sequence code with a chip waveform whose duration is much smaller than the symbol duration. All users in the system use the same carrier frequency and may transmit simultaneously. The receiver performs a correlation operation to detect the message addressed to a given user and the signals from other users appear as noise due to de-correlation. The synchronous DS-CDMA system is presented for eliminating the effects of multiple access interference (MAI) which limits the capacity and degrades the BER performance of the system. MAI refers to the interference between different direct sequences users. With increasing the number of users, the MAI grows to be significant and the DS-CDMA system will be interference limited. The spreading GOLD sequences in a DS-CDMA system need to have good cross-correlation characteristics as well as good autocorrelation characteristics. The goal is to reduce the fading effect by supplying the receiver with several replicas of the same information signal transmitted over independently fading paths.

2. DS-CDMA System

Code division multiple access (CDMA) is a channel access method used by various radio communication technologies. This allows several users to share a band of frequencies. This concept is called multiple access. CDMA employs spread spectrum technology and a special coding scheme to allow multiple users to be multiplexed over the same physical channel. A digital method for simultaneously transmitting signals over a shared portion of the spectrum by coding each distinct signal with a unique code. There are different ways to spread the bandwidth of the signal:

- Direct sequence
- Frequency hopping
- Time hopping
- Chirp spread spectrum
- Hybrid systems

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CDMA is a form of Direct Sequence Spread Spectrum communications. It is a technique whereby many users simultaneously access a communication channel. Here the Rayleigh channel and AWGN Channel are introduced and investigated the bit error rate (BER) performance of a synchronous DS-CDMA system over these channels.

2.1 Rayleigh Fading Channel Model

Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal, such as that used by wireless devices. Rayleigh fading models assume that the magnitude of a signal that has passed through such a transmission medium will vary randomly, or fade, according to a Rayleigh distribution the radial component of the sum of two uncorrelated Gaussian random variables. 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. Rayleigh fading is most applicable when there is no dominant propagation along a line of sight between the transmitter and receiver. Rayleigh fading is a reasonable model when there are many objects in the environment that scatter the radio signal before it arrives at the receiver, if there is sufficiently much scatter, the channel impulse response will be well modelled as a Gaussian process irrespective of the distribution of the individual components. If there is no dominant component to the scatter, then such a process will have zero mean and phase evenly distributed between 0 and 2π radians. The envelope of the channel response will therefore be Rayleigh distributed.

2.2 AWGN channel Model

Additive White Gaussian Noise channel model as the name indicate Gaussian noise get directly added with the signal and information signal get converted into the noise in this model scattering and fading of the information is not considered . Additive white Gaussian noise (AWGN) is a channel model in which the only impairment to communication is a linear addition of wide band or white noise with a constant spectral density (expressed as watts per hertz of bandwidth) and a Gaussian distribution of amplitude.

The model does not account for fading frequency selectivity, interference, nonlinearity or dispersion. However, it produces simple and tractable mathematical models which are useful for gaining insight into the underlying behavior of a system before these other phenomena are considered. Wideband Gaussian noise comes from many natural sources, such as the thermal vibrations of atoms in conductors (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 a good model for many satellite and deep space communication links. It is not a good model for most terrestrial links because of multipath, terrain blocking, interference, etc. However, for terrestrial path modeling, AWGN is commonly used to simulate background noise of the channel under study, in addition to multipath, terrain blocking, interference, ground clutter and self interference that modern radio systems encounter in terrestrial operation.

3. Modulation and Demodulation

3.1 Modulation

In digital modulation, an analog carrier signal is modulated by a discrete signal. Digital modulation methods can be considered as digital-to-analog conversion, and the corresponding demodulation or detection as analog-to-digital conversion. The changes in the carrier signal are chosen from a finite number of M alternative symbols (the modulation alphabet).

If the alphabet consists of $M = 2^N$ alternative symbols, each symbol represents a message consisting of N bits. If the baud rate is fs symbols/second, then the data rate is N fs bit/second. In the case of PSK, ASK or QAM, where the carrier frequency of the modulated signal is constant, the modulation alphabet is often conveniently represented on a constellation diagram, showing the amplitude of the I signal at the x-axis, and the amplitude of the Q signal at the y-axis, for each symbol (K. Du *et al*, 2010).

3.2 Demodulation

Demodulation is the act of extracting the original information-bearing signal from a modulated carrier wave. A demodulator is an electronic circuit that is used to recover the information content from the modulated carrier wave. Here QPSK modulation is described. A QPSK signal is generated by two BPSK signals. QPSK uses four points on the 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. When the symbol is changed to next symbol, then the phase of the carrier is changed by 45˚. Table 1 and Fig 1 shows these symbols and their phase change.

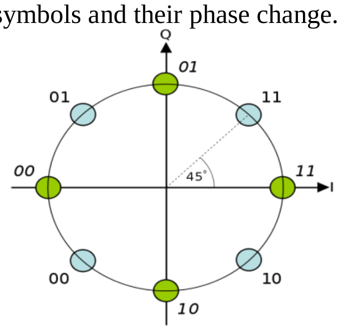

Fig.1 Diagram for QPSK

Table 1 Symbol and Corresponding phase shifts in QPSK

Phase of QPSK	2 bits Input
Π/4	10
3 Π/4	00
5Π/4	01
7Π/4	11

To distinguish the two signals, we use two orthogonal carrier signals. One is given by cos(2πfct), and the other is given by sin(2πfct). A channel in which cos(2πfct) is used as a carrier signal is generally called an in-phase channel, or I_{ch}, and a channel in which sin(2πfct) is used as a carrier signal is generally called a quadrature-phase channel, or Q_{ch}. Therefore, dI(t) and dq(t) are the data in Ich and Q_{ch}, respectively. Modulation schemes that use I_{ch} and Q_{ch} are called quadrature modulation schemes. The first basis function is used as the in-phase component of the signal and the second as the quadrature component of the signal. An illustration of the major components of the transmitter and receiver are shown in Fig.2.

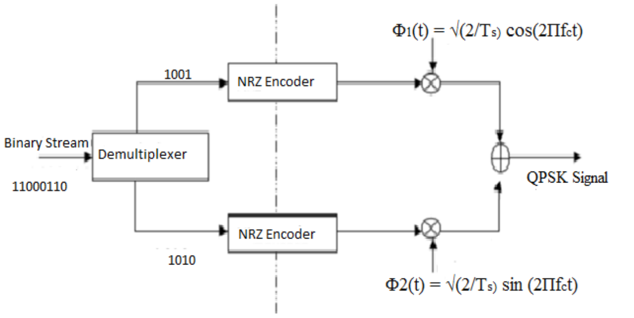

Fig.2 QPSK Modulator

The mathematical analysis shows that QPSK

$S_n(t)=\sqrt{(2Es/T)}\cos(2\Pi fct+(2n-1)\Pi/4)$;

for n=1,2,3,4 (1)

This yields the four phases π/4, 3π/4, 5π/4 and 7π/4 as needed. This results in a two-dimensional signal space with unit basis functions. The even Equation (2) and odd Equation (3) samples of signal are given by,

$\Phi1(t)=\sqrt{(2/Ts)}\cos(2\Pi fct)$ (2)

$\Phi2(t)=\sqrt{(2/Ts)}\sin(2\Pi fct)$ (3)

The binary data stream is split into the in separately modulated onto two orthogonal basis functions. In this implementation, two sinusoids are used. Afterwards, the two signals are superimposed, and the resulting signal is the QPSK signal. Note the use of polar non-return-to-zero encoding. These encoders can be placed before for binary data source, but have been placed after to illustrate the conceptual difference between digital and analog signals involved with digital modulation. In the receiver structure for QPSK replaced with correlators. Each detection device uses a reference threshold value to determine whether a 1 or 0 is detected as shown in the Fig. 3 (E. Dinan *et al*, 1998).

3.3 Pseudo-Random Sequences

A pseudorandom (PN) sequence is a code sequence of 1's and 0's whose autocorrelation has properties similar to those of white noise. Some of the popular PN sequences are Maximal length shift register sequences (m-sequences), gold sequences etc. Here we discuss about Gold Sequence.

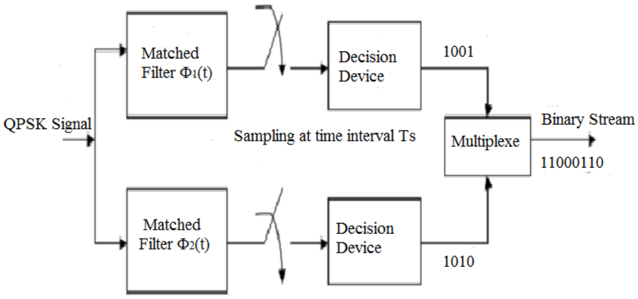

Fig.3 QPSK Demodulator

3.4 Gold Sequences

A Gold code, also known as gold sequence, is a type of binary sequence, used in telecommunication (CDMA) and satellite navigation (GPS). Gold codes are named after Robert Gold. Gold codes have bounded small cross-correlations within a set, which is useful when multiple devices are broadcasting in the same frequency range. A set of Gold code sequences consists of 2^n - 1sequences each one with a period of 2^n - 1. A set of Gold codes can be generated with the following steps. Pick two maximum length sequences of the same length 2^n – 1 such that their absolute cross-correlation is less than or equal to $2^{(n+2)/2}$, where n is the size of the LFSR used to generate the maximum length sequence. The set of the 2^n - 1 exclusive-ors of the two sequences in their various phases (i.e. translated into all relative positions) is a set of Gold codes. The highest absolute cross-correlation in this set of codes is $2^{(n+2)/2}+1$ for even n and $2^{(n+1)/2}+1$ for odd n. The exclusive or of two Gold codes from the same set is another Gold code in some phase. Within a set of Gold codes about half of the codes are balanced the number of ones and zeros differs by only one.

Gold sequences have been proposed by Gold in 1967 and 1968. These are constructed by EXOR-ing two m-sequences of the same length with each other. Thus, for a Gold sequence of length m = 2^l-1, one uses two LFSR, each of length 2^l-1. If the LSFRs are chosen appropriately, Gold sequences have better cross-correlation properties than maximum length LSFR sequences. The Gold Sequence Generator block uses two PN Sequence Generator blocks to generate the preferred pair of sequences, and then XORs these sequences to produce the output sequence, as shown in the Fig. 4.

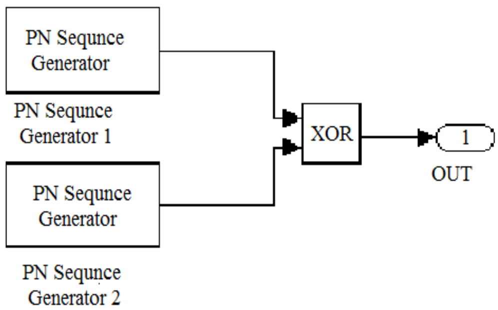

Fig.4 Gold Sequence Generator

Gold (and Kasami) showed that for certain well-chosen m-sequences, the cross correlation only takes on three possible values, namely -1, -t or t-2. Two such sequences are called preferred sequences. Here t depends solely (only) on the length of the LFSR used. In fact, for a LFSR with l memory element.

if l is odd, t = 2(l+1)/2 + 1, and
if l is even, t = 2(l+2)/2 + 1
Here t is the cross correlation.

3.5 Direct Sequence CDMA

CDMA is a Direct Sequence Spread Spectrum system. The CDMA system works directly on 64 kbit/sec digital signals. These signals can be digitized voice, ISDN channels, modem data, etc.
Signal transmission consists of the following steps:

1) A pseudo-random code is generated, different for each channel and each successive connection.
2) The Information data modulates the pseudo-random code (the Information data is “spread”).
3) The resulting signal modulates a carrier.
4) The modulated carrier is amplified and broadcast.

Signal reception consists of the following steps:

1) The carrier is received and amplified.
2) The received signal is mixed with a local carrier to recover the spread digital signal.
3) A pseudo-random code is generated, matching the anticipated signal.
4) The receiver acquires the received code and phase locks its own code to it.
5) The received signal is correlated with the generated code, extracting the Information data.

Code division multiple-access techniques allow many users to simultaneously access a given frequency allocation. User separation at the receiver is possible because each user spreads the modulated waveform over a wide bandwidth using unique spreading codes. There are two basic types of CDMA. Direct-sequence CDMA (DS-CDMA) spreads the signal directly by multiplying the data waveform with a user-unique high bandwidth pseudo-noise binary sequence. The resulting signal is then mixed up to a carrier frequency and transmitted. The receiver mixes down to baseband and then re-multiplies with the binary {± 1} pseudo-noise sequence. This effectively (assuming perfect synchronization) removes the pseudo-noise signal and what remains (of the desired signal) is just the transmitted data waveform. After removing the pseudo-noise signal, a filter with bandwidth proportional to the data rate is applied to the signal. Because other users do not use completely orthogonal spreading codes, there is residual multiple-access interference present at the filter output (F. Adachi *et al,* 2004).

In Direct Sequence spread spectrum transmission, the user data signal is multiplied by a code sequence. Mostly, binary sequences are used. The duration of an element in the code is called the "chip time". The ratio between the user symbol time and the chip time is called the spread factor. The transmit signal occupies a bandwidth that equals the spread factor times the bandwidth of the user data. In the receiver, the received signal is again multiplied by the same (synchronized) code. This operation removes the code, so we recover the transmitted user data.

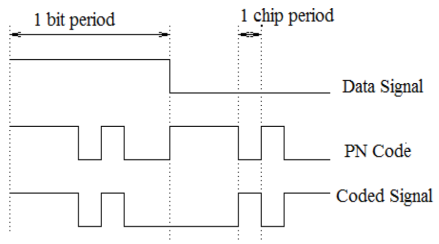

Fig.5 A DS-CDMA signal is generated by multiplication of a user data signal by a code sequence.

A CDMA receiver can retrieve the wanted signal by multiplying the receive signal with the same code as the one used during transmission. So

$$\sum_{n=1}^{N} c_1^2 (nT_c+t_\alpha) = \sum_{n=1}^{N} c_1^2 (nT_c) = N$$

Where c1 is the code sequence used by user 1, Tc is the chip duration, td is a common time offset, shared between transmitter and receiver and N is the length of the code sequence. Note that the receive code must be perfectly time aligned with the transmit code.

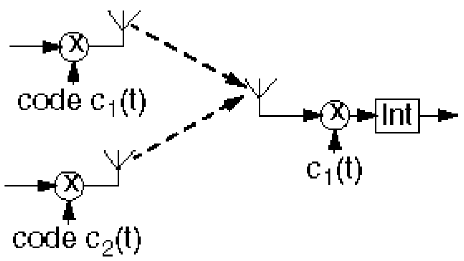

Fig.6 Different CDMA users use different codes. In this example the receiver sees the signal from user 1, while the signal from user 2 is heavily attenuated by the correlators (multiplier and integrator) in the receiver.

4. Proposed System Model

4.1 Proposed Transmitter Model

The randomly generated data in system can be transmitted with the help of proposed transmitter model which is shown in Fig.7

At first, the data generator generates the data randomly, that generated data is mapping circuit. Mapping circuit which is consisting of QPSK modulator converts this serially random data into two parallel data streams even and odd samples. This individually by using Gold sequence codes .The spreaded data is given to the over sampler circuit which converts unipolar data into bipolar one, then this oversampled data is convolved using with help of filter coefficients of T filter. Then these two individual data streams summed up and passed through Band pass filter (BPF) which is then transmitted to channel.

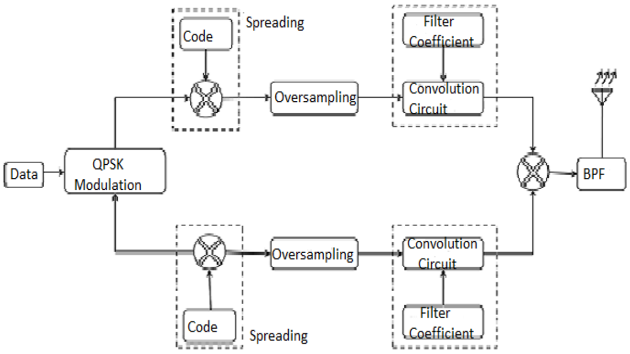

Fig.7 DS-CDMA Transmitter

4.1 Proposed Receiver Model

The randomly generated data in with the proposed receiver model which shown in Fig.8.

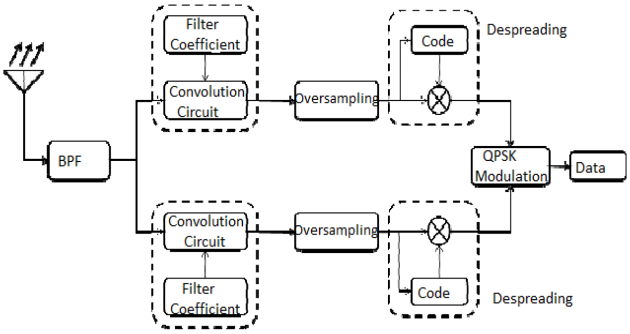

Fig.8 DS-CDMA Receiver

At the receiver, the received signal passes through band pass filter (BPF). Where eliminated. Then signal divided into two streams and convolved using filter co-efficient,by which Inter Symbol Interference (ISI) in the signal is eliminated. This signal is dispreaded using codes, also synchronized. This two dispreaded streams are then faded to Demapping circuit which is consisting of QPSK demodulator. Demodulator circuit converts the two parallel data streams into single serial data stream. Thus the received data is recovered at the end (S. Moshavi *et al*).

5. Simulation Environment

This chapter shows the procedure to obtain BER of a synchronous DS-CDMA, users employ their own the information data are modulated by the first modulation modulated data are spread by a code spread data of all the users are transmitted to the base station at the same time. The base station detects the information data of each user by correlating the received signal with a code sequence allocated to each user. In the simulation, QPSK is used as the modulation scheme.

5.1 Simulation Procedure

In order to simulate the system following step are:

1) Initialized the common variable.
2) Initialized the filter coefficient.
3) Select the switch for m-sequence and gold sequence.
4) Generate the spreading codes.
5) Initialize the fading by using variable fade.\
6) Define the variables for signal to noise ratio and the number of simulation requires as the data is random BER must have the average value of number of simulation.
7) Simulate the system by using the proposed transmitter and receiver for different type of channel and codes (Z. Zvonar *et al*).

6. Result and Discussion

6.1 Simulation Results

Table 2 Theoretical value of AWGN and Rayleigh Channel

AWGN Channel		
S.no.	**Eb/No**	**BER**
1	0dB	0.0786
2	1 dB	0.058
3	2 dB	0.0385
4	3 dB	0.023
5	4 dB	0.0127
6	5 dB	0.0061
7	6 dB	0.0024
8	7 dB	0
9	8 dB	0
10	9 dB	0
11	10 dB	0
12	11 dB	0
13	12 dB	0
14	13 dB	0
15	14 dB	0
16	15 dB	0
17	16 dB	0
18	17 dB	0
19	18 dB	0
20	19 dB	0
21	20 dB	0

Rayleigh Channel		
S.no.	**Eb/No**	**BER**
1	0 dB	0.146
2	1dB	0.127
3	2 dB	0.109
4	3 dB	0.0925
5	4 dB	0.0775
6	5 dB	0.0642
7	6 dB	0.053
8	7 dB	0.043
9	8 dB	0.0355
10	9 dB	0.029
11	10 dB	0.0235
12	11 dB	0.019
13	12 dB	0.0155
14	13 dB	0.0125
15	14 dB	0.01
16	15 dB	0.008
17	16 dB	0.0065
18	17 dB	0.005
19	18 dB	0.004
20	19 dB	0.0035
21	20 dB	0.0025

6.2 *Result Obtained*

6.2.1 BER performance of DS CDMA System in AWGN Environment with Gold Sequence

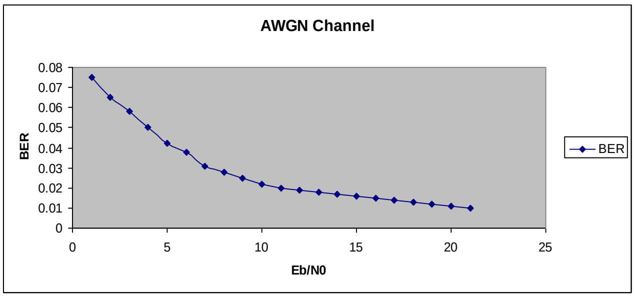

Fig.9 Performance of DS CDMA System in AWGN Environment with Gold Sequence (Theoretical value)

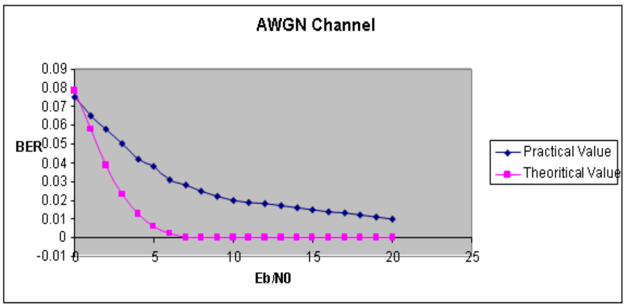

Fig.10 Performance of DS CDMA System in AWGN Environment with GOLD Sequence

6.2.2 BER performance of DS CDMA System in Rayleigh Environment with Gold Sequence:

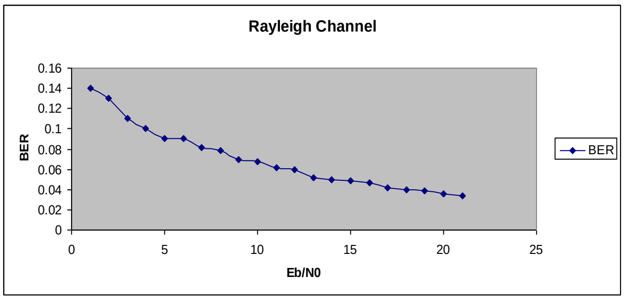

Fig.11 Performance of DS CDMA System in Rayleigh Environment with Gold Sequence (Theoretical value)

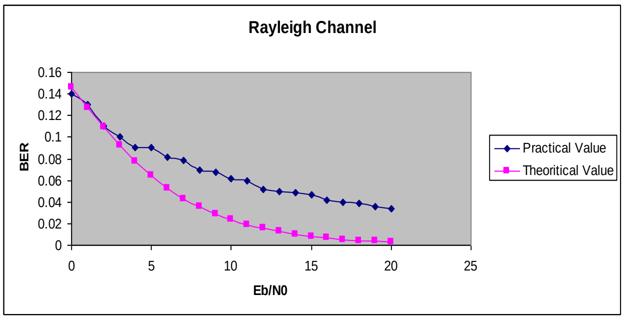

Fig.12 Performance of DS CDMA System in Rayleigh Environment with Gold Sequence

6.2.2 BER Performance of DS CDMA System in AWGN & Rayleigh Environment with Gold sequence

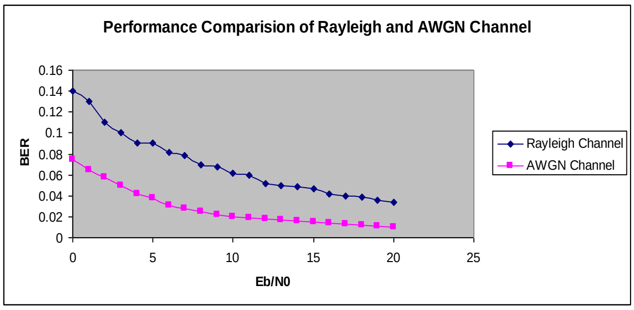

Fig.13 Performance of DS CDMA System in AWGN & Rayleigh Environment with Gold sequence (Theoretical value)

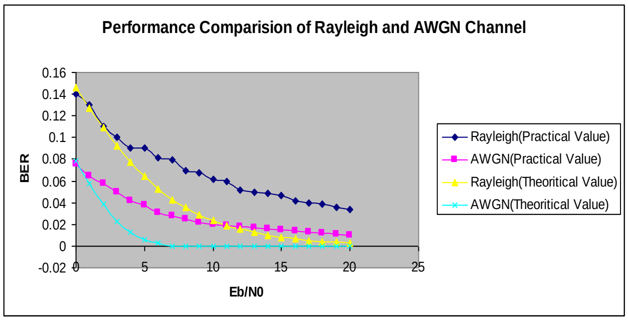

Fig.14 Performance of DS CDMA System in AWGN & Rayleigh Environment with Gold sequence

In AWGN environment, when gold sequence is used, for the one user the practical BER value is shown in Fig 9. In Fig 10, show the both practical BER value and theoretical value of BER for AWGN environment with gold sequence. In Rayleigh environment, when gold sequence is used, for the one user the practical BER value is shown in Fig 11. In Fig 12, show the both practical BER value and theoretical value of BER for Rayleigh environment with gold sequence initially the practical BER value is same as the theoretical value, and with increasing SNR the practical value increases as compared to the theoretical value of BER. In Fig 13 shows the theoretical value of both environment AWGN or Rayleigh with gold sequence. In Fig 14 we consider both RAYLEIGH environment and AWGN environment with gold sequence is used, initially the BER theoretical and practical value is nearly same. But, as the SNR value increases in case of the AWGN, the practical BER value increases rapidly as compared to the theoretical value, and in case of Rayleigh the practical value approaches to the theoretical value.

Conclusion

In AWGN environment, when gold sequence is used, for the one user the practical BER value is nearly approaches to the theoretical value of BER. In RAYLEIGH environment, when gold sequence is used, at the initial SNR value the practical and theoretical value of BER are same, as the SNR increases the practical BER value increases as compared to the theoretical value of BER. When the gold sequence is considered in AWGN environment, with single user, initially the practical BER value is same as the theoretical value, and with increasing SNR the practical value increases as compared to the theoretical value of BER. When either sequence is used in the system for AWGN and Rayleigh environment, initially the BER theoretical and practical value are nearly same. But, as the SNR value increases in case of the AWGN, the practical BER value increases rapidly as compared to the theoretical value, and in case of Rayleigh the practical value approaches to the theoretical value.

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