

PERFORMANCE EVALUATION OF DS-CDMA SYSTEM USING MATLAB

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ABSTRACT

The author evaluated the performance of synchronous DS-CDMA systems over multipath fading channel and AWGN Channel. The synchronous DS-CDMA system is well known for eliminating the effects of multiple access interference (MAI) 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. Different MATLAB functions and MATLAB program segments are explained for the simulation of DS-CDMA system.

KEYWORDS: CDMA system, QPSK, BER, Rayleigh Channel, AWGN channel, MATLAB program segment, Gold Sequence, M- sequence.

I. 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 M-sequence & 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 M & GOLD sequences in a DS-CDMA system need to have good cross-correlation characteristics as well as good autocorrelation characteristics [P. Alexander *et.al*],[E. Dinan *et.al*]. 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. The remainder of the paper is organized as follows. In the next section we present channel modelling. Section 3 deals with modulation and Demodulation scheme used in the system. Section 4 deals with proposed transmitter and receiver model for simulation. Different MATLAB functions, program segments and flow of program segment are explained in the Section 5 & 6 respectively, the paper ends with simulation results and conclusion.

II. CHANNEL MODEL

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. [C.Trabelsi et.al]. 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 [Theodore S. Rappaport].

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[Theodore S. Rappaport].

III. MODULATOR AND DEMODULATOR

A QPSK signal is generated by two BPSK signals. To distinguish the two signals, we use two orthogonal carrier signals. One is given by $\cos 2\pi f_c t$, and the other is given by $\sin 2\pi f_c t$. A channel in which $\cos 2\pi f_c t$ is used as a carrier signal is generally called an in-phase channel, or *Ich*, and a channel in which $\sin 2\pi f_c t$ is used as a carrier signal is generally called a quadrature-phase channel, or *Qch*. Therefore, $d_I(t)$ and $d_Q(t)$ are the data in *Ich* and *Qch*, respectively. Modulation schemes that use *Ich* and *Qch* are called quadrature modulation schemes. The mathematical analysis shows that QPSK [X.Wang et..al]

$$s_n(t) = \sqrt{\frac{2E_s}{T}} \cos\left(2\pi f_c t + (2n-1)\frac{\pi}{4}\right) \quad \text{for } n = 1, 2, 3, 4 \quad (1)$$

This yields the four phases $\pi/4$, $3\pi/4$, $5\pi/4$ and $7\pi/4$ 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,

$$\phi_1(t) = \sqrt{\frac{2}{T_s}} \cos(2\pi f_c t) \quad (2)$$

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 structure is shown below.

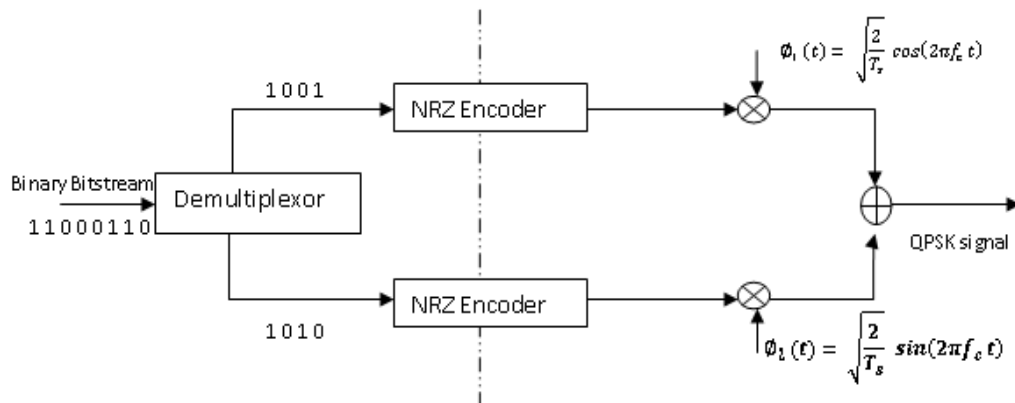


Figure.1 QPSK Modulator

The binary data stream is split into the in-phase and quadrature-phase components. These are then 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 matched filters can be replaced with correlators. Each detection device uses a reference threshold value to determine whether a 1 or 0 is detected as shown in the Figure (2)

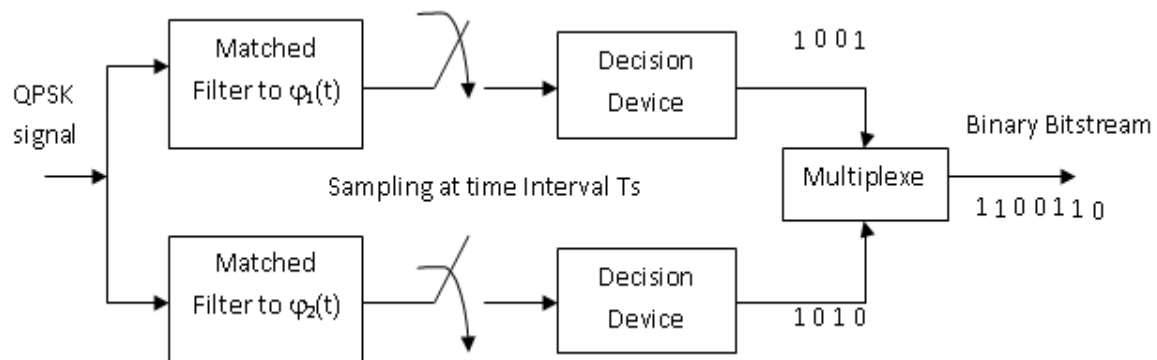


Figure.2 QPSK Demodulator

IV. 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 Figure(3) given below

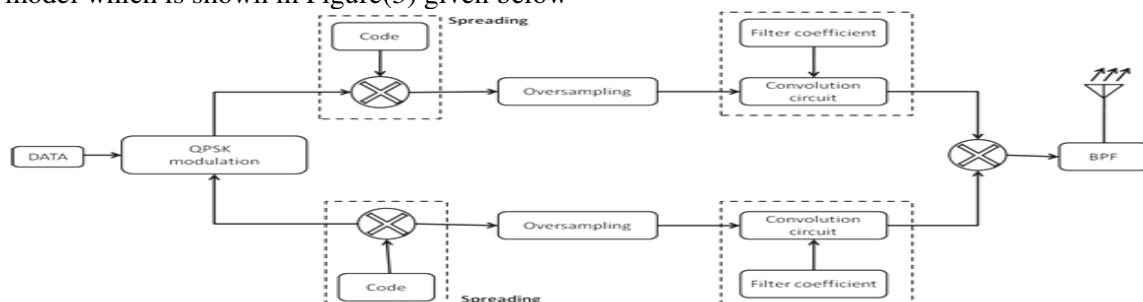


Figure.3 DS-CDMA transmitter

At first, the data generator generates the data randomly, that generated data is further given to the mapping circuit. Mapping circuit which is consisting of QPSK modulator converts this serially random data into two parallel data streams even and odd samples i.e. I_{ch} (in-phase) and Q_{ch} (quadrature phase) [X.Wang.et.al]. This I_{ch} and Q_{ch} are then convolved with codes and spreaded individually by using M-sequence or Gold sequence codes. The spreaded data is given to the oversampler 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 are summed up and passed through Band pass filter (BPF) which is then transmitted to channel.

4.2 Proposed Receiver Model:

The randomly generated data in system which is transmitted through the channel can be received with the proposed receiver model which is shown in Figure (4) given below.

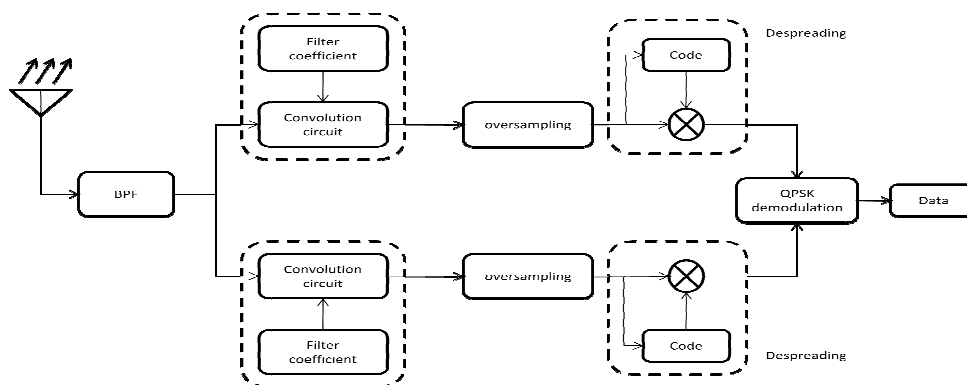


Figure.4 DS-SS receiver

At the receiver, the received signal passes through band pass filter (BPF), where spurious signals are eliminated. Then the signal is divided into two streams and convolved using filter coefficients, by which Inter Symbol Interference (ISI) in the signal is eliminated. This signal is despread using codes, also synchronized. These two despread streams are then fed to a Demapping circuit, which consists of a QPSK demodulator. The demodulator circuit converts the two parallel data streams into a single serial data stream. Thus, the received data is recovered at the end.

V. MATLAB SIMULATIONS

5.1 DS-SS System:

This section shows the procedure to obtain BER of a synchronous DS-SS. In the synchronous DS-SS, users employ their own sequences to spread the information data. At each user's terminal, the information data are modulated by the first modulation scheme. Then, the first bits of the modulated data are spread by a code sequence, such as an M-sequence or a Gold sequence. The 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. The parameters used for the simulation are defined as follows [Hiroshi Harada et.al]:

```
sr = 2560000.0;    % symbol rate
ml = 2;           % number of modulation levels
br = sr * ml;     % bit rate
nd = 200;         % number of symbol
ebn0 = [0:20];    % Eb/No
irfn = 21;        % number of filter taps
IPOINT = 8;       % number of oversample
alfs = 0.5;       % roll off factor
```

The coefficient of the filter is defined as given in the above program segment ,evaluates the performance of QPSK and the MATLAB function *hrollfcoef* is use to evaluate the filter coefficient based on the above parameter.

```
[xh]=hrollfcoef(irfn,IPOINT,sr,alfs,1);
           % T Filter Function
[xh2]=hrollfcoef(irfn,IPOINT,sr,alfs,0 );
           % R Filter Function
```

The parameter for the spread sequences, namely M-sequence and Gold sequences are used. By denoting variables as *seq 1, or 2* a code sequence is selected. Next, the number of registers is set to generate an M-sequence. In synchronous DS-CDMA, the number of code sequences that can be allocated to different users is equal to the number of code lengths. Therefore, the length of the code sequence must be larger than the number of users. To generate a code sequence, we must specify the number of registers, the position of the feedback tap, and the initial values of the registers. To generate a Gold sequence and an orthogonal Gold sequence, two M-sequences are needed. Therefore, the following parameters are used. By using these parameters, a spread code is generated, and the generated code is stored as variable *code*.

```
user = 3           % number of users
seq = 1;           % 1:M-sequence 2:Gold
stage = 3;         % number of stages
ptap1 = [1 3];     % position of taps for 1st
ptap2 = [2 3];     % position of taps for 2nd
regi1 = [1 1 1];   % initial value of register for 1st
regi2 = [1 1 1];   % initial value of register for 2nd
```

Here, *code* is a matrix with a sequence of the number of users multiplied by the length of the code sequence. An M-sequence is generated by MATLAB function *mseq.m*, and a Gold sequence is generated by MATLAB function *goldseq.m*. An orthogonal Gold sequence can be generated by adding a 0 bit of data to the top or bottom of a Gold sequence. Because the generated code sequence consists of 0 and 1, the program converts it into a sequence consisting - 1 and 1.

```
switch seq
case 1           % M-sequence
    code = mseq(stage,ptap1,regi1,user);
case 2           % Gold sequence
    m1 = mseq(stage,ptap1,regi1);
    m2 = mseq(stage,ptap2,regi2);
    code = goldseq(m1,m2,user);
end

code = code * 2 - 1;
clen = length(code);
```

When *rfade* is 0, the simulation evaluates the BER performance in an AGWN channel. When *rfade* is 1, the simulation evaluates the BER performance in a Rayleigh fading environment [C.Trabelsi et.al].

```
rfade = 1;         % Rayleigh fading 0:nothing 1:consider
itau = [0,8];      % delay time
dlvl1 = [0.0,40.0]; % attenuation level
n0 = [6,7];        % number of waves to generate fading
th1 = [0.0,0.0];   % initial Phase of delayed wave
itnd1 = [3001,4004]; % set fading counter
now1 = 2;          % number of directwave + delayed wave
tstp = 1 / sr / IPOINT / clen; % time resolution
fd = 160;          % doppler frequency [Hz]
```

```
flat = 1; % flat Rayleigh environment
itndel = nd * IPOINT * clen * 30; % number of fading counter to skip
```

Then, the number of simulation loops is set. The variables that count the number of transmitted data bits and the number of errors are initialized.

```
nloop = 10; % simulation number of times
noe = 0;
nod = 0;
```

The transmitted data in the in-phase channel and quadrature phase modulated by QPSK are multiplied by the code sequence used to spread the transmitted data. The spread data are then oversampled and filtered by a roll-off filter and transmitted to a communication channel. Here, MATLAB functions *compoversamp2.m*, *compconv2.m* and *qpskmod.m* used for oversampling filtering, and modulation, filter parameter *xh* form T-filter is provided in *compconv2* function.

```
data = rand(user,nd*ml) > 0.5;
[ich, qch] = qpskmod(data,user,nd,ml); % QPSK modulation
[ich1,qch1] = spread(ich,qch,code); % spreading
[ich2,qch2] = compoversamp2(ich1,qch1,IPOINT); % over sampling
[ich3,qch3] = compconv2(ich2,qch2,xh); % filter
```

Above program segment demonstrate the transmitter section of the DS-CDMA system. During this process *ich1,qch1* get transformed into *ich3* and *qch3*. The signals transmitted from the users are synthesized by considering the *if-else* statement depending upon the number of user *ich4* and *qch4* is generated

```
if user == 1 % transmission based of Users
    ich4 = ich3;
    qch4 = qch3;
else
    ich4 = sum(ich3);
    qch4 = sum(qch3);
end
```

The synthesized signal is contaminated in a Rayleigh fading channel as shown in below program segment. In reality, the transmitted signals of all users are contaminated by distinctive Rayleigh fading. However, in this simulation, the synthesized signal is contaminated by Rayleigh fading. Function *sefade.m* used to consider the Rayleigh fading

```
if rfade == 0
    ich5 = ich4;
    qch5 = qch4;
else % fading channel
    [ich5,qch5] = sefade(ich4,qch4,itaui,dlv11,th1,n0,itnd1,now1,...
        ..length(ich4),tstp,fd,flat);
    itnd1 = itnd1 + itndel;
end
```

At the receiver, AWGN is added to the received data, as shown in the simulation for the QPSK transmission in Program Segment (5). Then, the contaminated signal is filtered by using a the root roll-off filter. Below program segment calculate the attenuation and add AWGN to the signal *ich6* and *qch6* and transform the signal to *ich8* and *qch8* using the filter coefficient *xh2*.

```
spow = sum(rot90(ich3.^2 + qch3.^2)) / nd; % attenuation Calculation
attn = sqrt(0.5 * spow * sr / br * 10^(-ebn0(i)/10));
snrlnr=10.^(ebn0(i)/10);
attnNEW=sum(attn)/400;
```

```

[ich6,qch6] = comb2(ich5,qch5,attn);           % Add White Gaussian Noise (AWGN)
[ich7,qch7] = compconv2(ich6,qch6,xh2);        % filter
sampl = irfn * IPOINT + 1;
ich8 = ich7(:,sampl:IPOINT:IPOINT*nd*clen+sampl-1);
qch8 = qch7(:,sampl:IPOINT:IPOINT*nd*clen+sampl-1);

```

The resampled data are now the synthesized data of all the users. By correlating the synthesized data with the spread code used at the transmitter, the transmitted data of all the users are detected. The correlation is performed by Program,

```

[ich9 qch9] = despread(ich8,qch8,code);        % despreading

```

The correlated data are demodulated by QPSK. [Fumiyuki ADACHI] Then, the total number of errors for all the users is calculated. Finally, the BER is calculated.

```

demodata = qpskdemod(ich9,qch9,user,nd,ml);    % QPSK demodulation
noe2 = sum(sum(abs(data-demodata)));
nod2 = user * nd * ml;
noe = noe + noe2;
nod = nod + nod2;

```

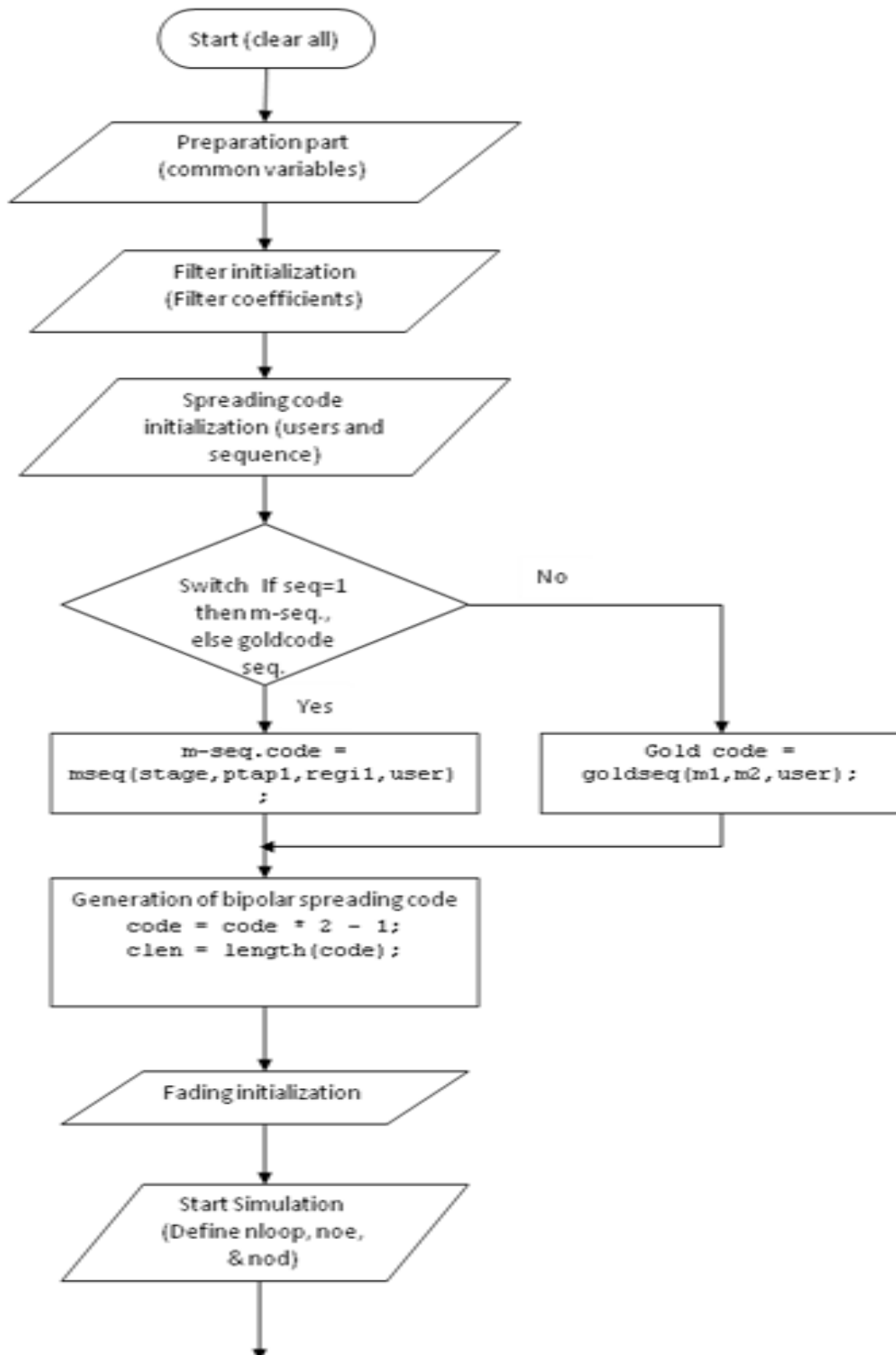
VI. SIMULATION FLOWCHART

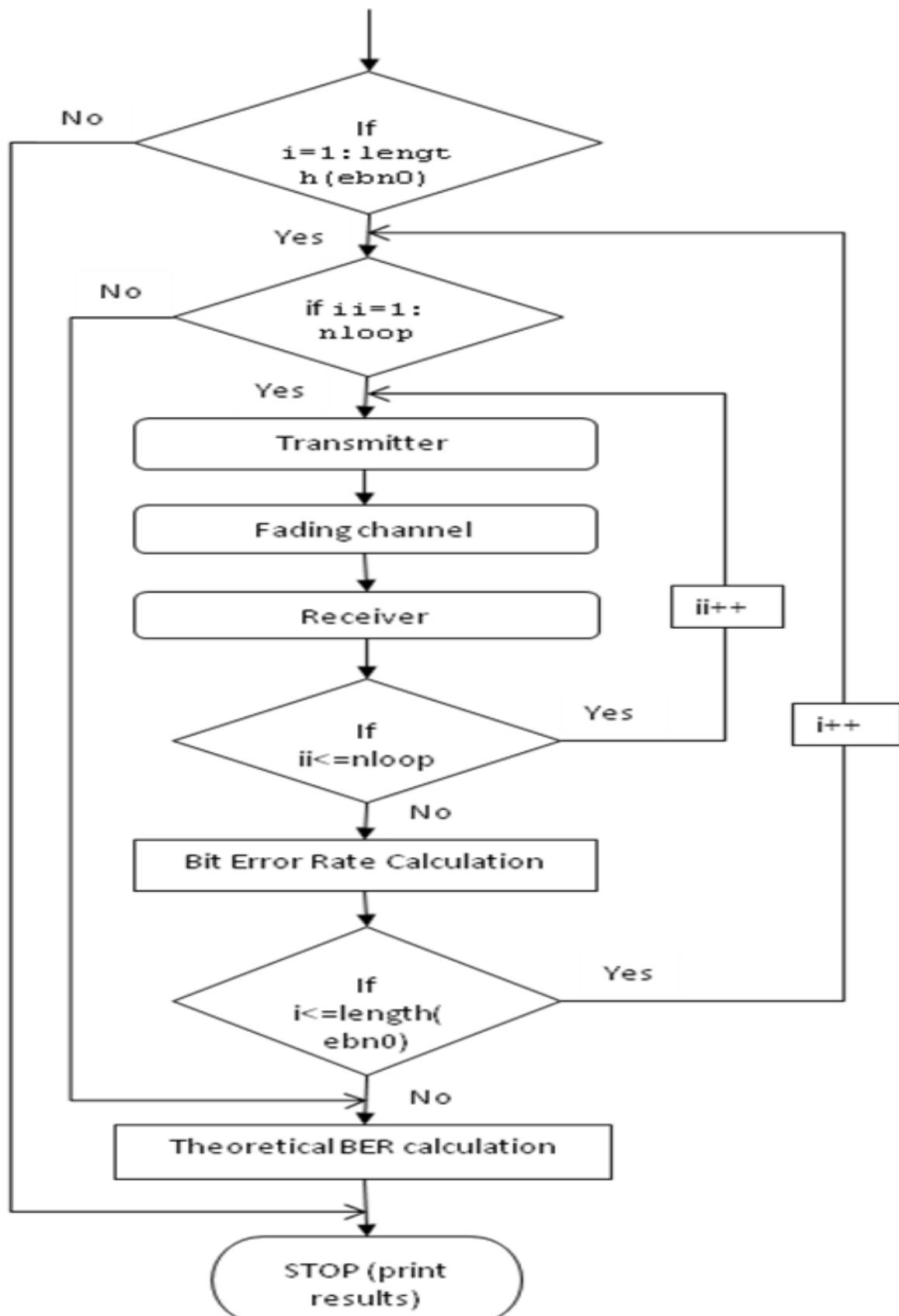
In order to simulate the system following step are

- Initialized the common variable
- Initialized the filter coefficient
- Select the switch for m-sequence and gold sequence
- Generate the spreading codes
- Initialize the fading by using variable rfade
- 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.
- Simulate the system by using the proposed transmitter and receiver for different type of channel and codes
- Theoretical value of BER for Rayleigh channel and AWGN channel can be calculated by

$$BER_{theoretical}(AWGN) = \frac{1}{2} \operatorname{erfc}(\sqrt{E_b/N_0}) \quad \text{-----}(3)$$

$$BER_{theoretical}(Rayleigh) = \frac{1}{2} \left[1 - \frac{1}{\sqrt{1 + \frac{E_b}{N_0}}} \right] \quad \text{-----}(4)$$





VII. SIMULATION RESULTS OBTAINED

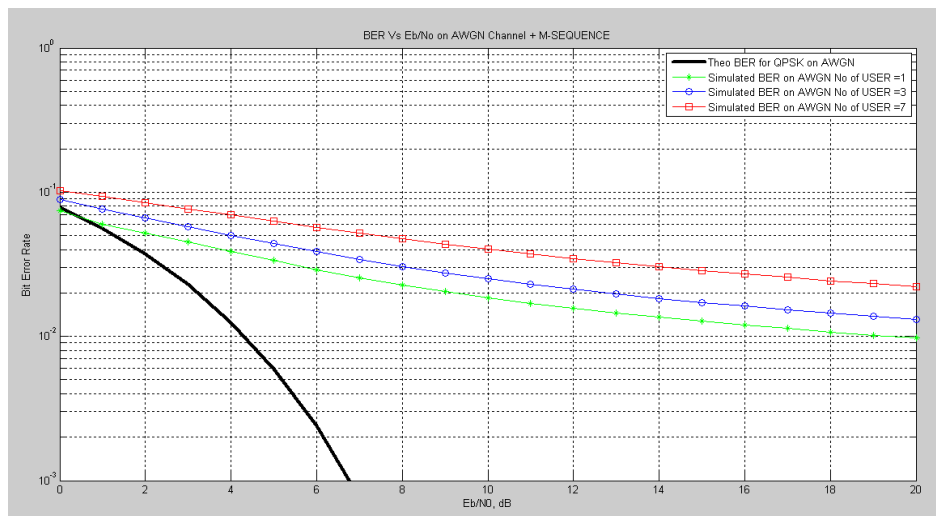


Figure.6 Performance of DS CDMA System in AWGN Environment With M Sequence

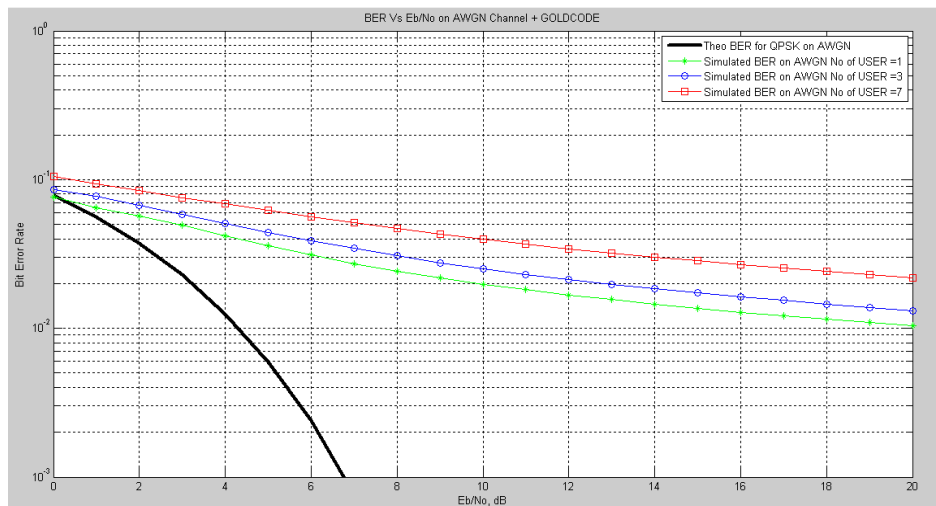


Figure.7 Performance of DS CDMA System in AWGN Environment With GOLD Sequence

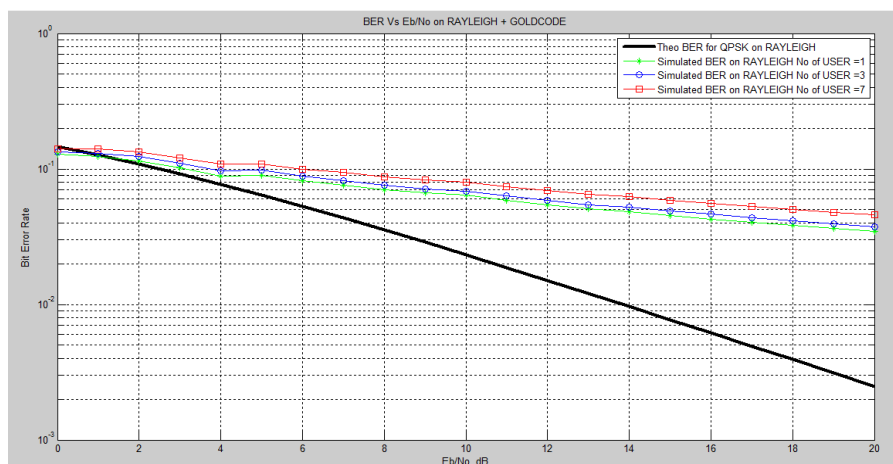


Figure.8 Performance of DS CDMA System in Rayleigh Environment With Gold Sequence

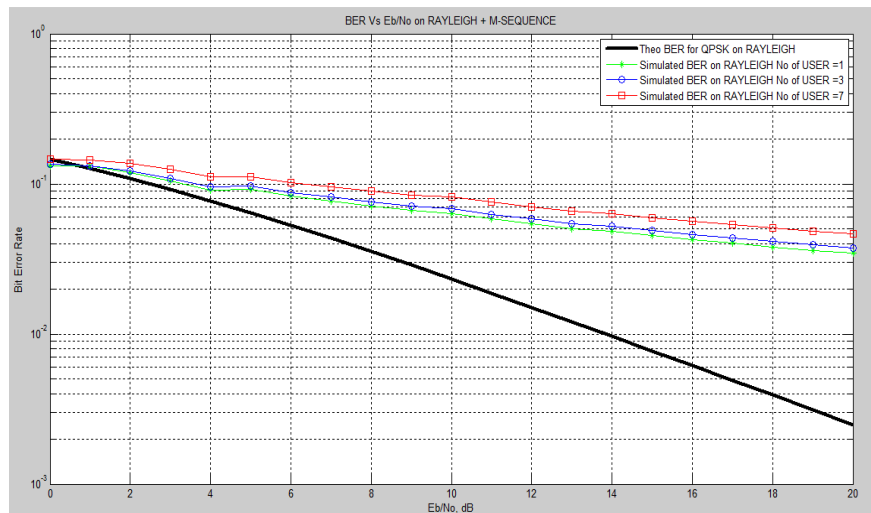


Figure.9 Performance of DS CDMA System in Rayleigh Environment With M Sequence

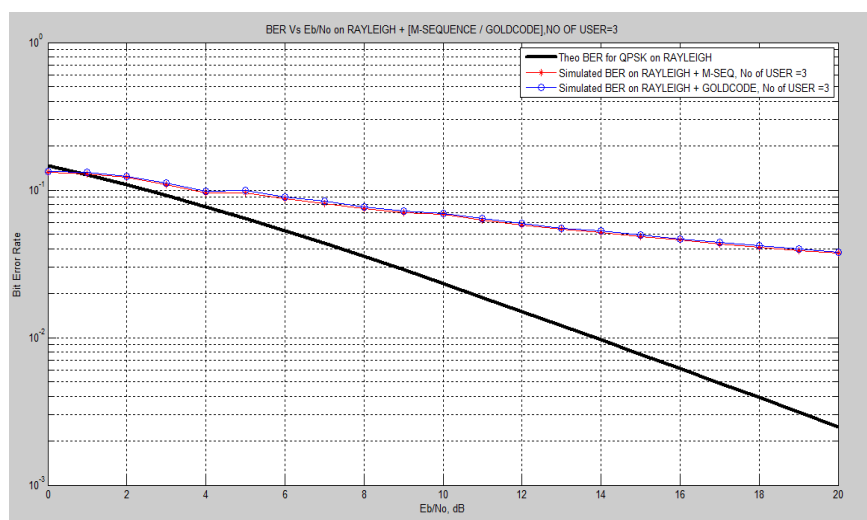


Figure.10 Performance of DS CDMA System in Rayleigh Environment With M & Gold Sequence

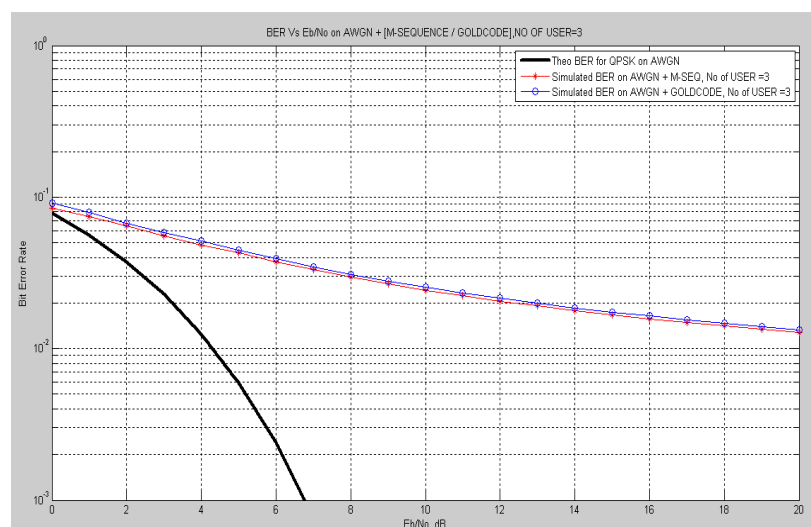


Figure.11 Performance of DS CDMA System in AWGN Environment With M & GOLD Sequence

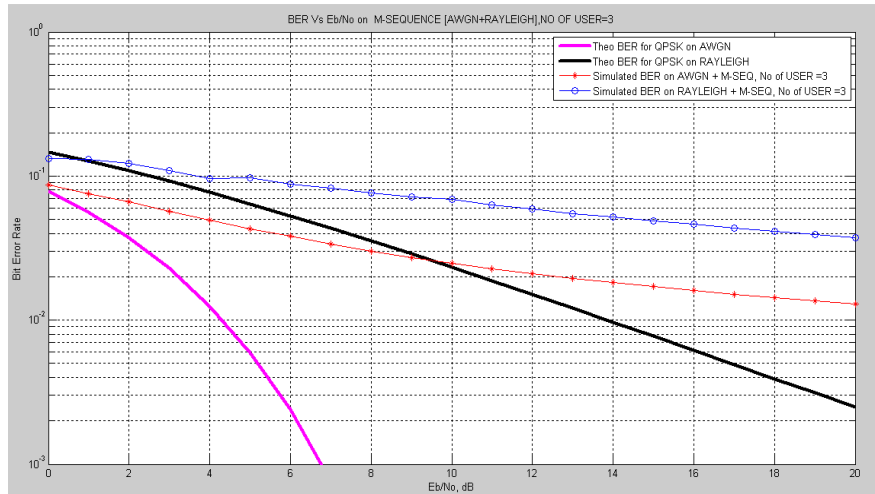


Figure.12 Performance of DS CDMA System in AWGN & Rayleigh Environment With M Sequence

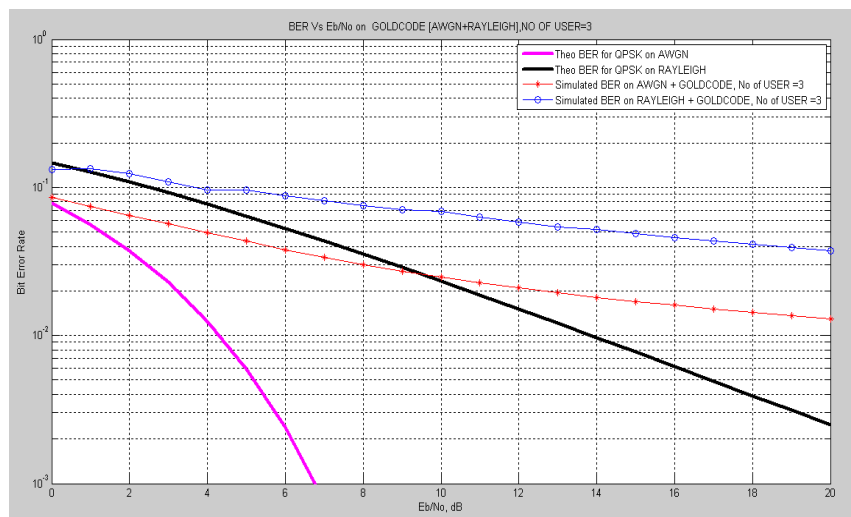


Figure.13 Performance of DS CDMA System In AWGN & Rayleigh Environment With Gold sequence

VIII. RESULTS AND CONCLUSION

In AWGN environment, when gold sequence or m sequence is used, for the different users the practical BER value for the minimum number of user is nearly approaches to the theoretical value of BER. In RAYLEIGH environment, when gold or m 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 m sequence and gold sequence is considered in RAYLEIGH environment, at initial state the practical BER value and theoretical BER is same. But as the SNR increases, the practical BER value increases rapidly as compared to the theoretical BER value. When the m sequence and 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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