Lab Report:

Digital Communications

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Lab-1

Problem:

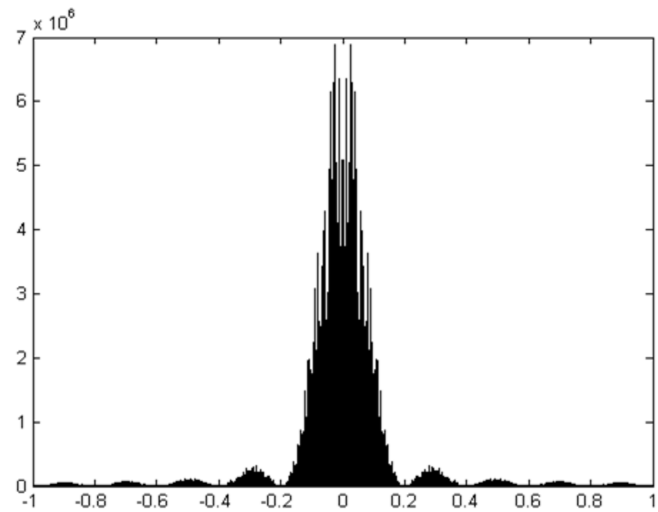
Find PSD of a BPSK modulated sequence with and without filtering.

Method:

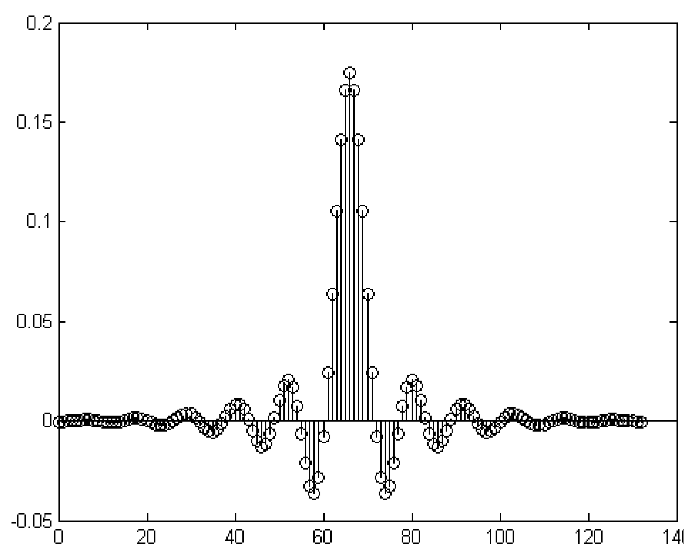
- Uniformly generate a sequence of 8192 bits using randn function.
- Map bit 0 to -1 and 1 to +1.
- Calculate and plot PSD of the above signal by taking FFT and then PSD=abs(FFT)^2.
- Design a low pass FIR filter with cut off freq=0.2π and show its impulse response and freq. response
- Convolve the mapped signal with the impulse response of filter.
- Then plot PSD of filtered signal

Simulation Results:

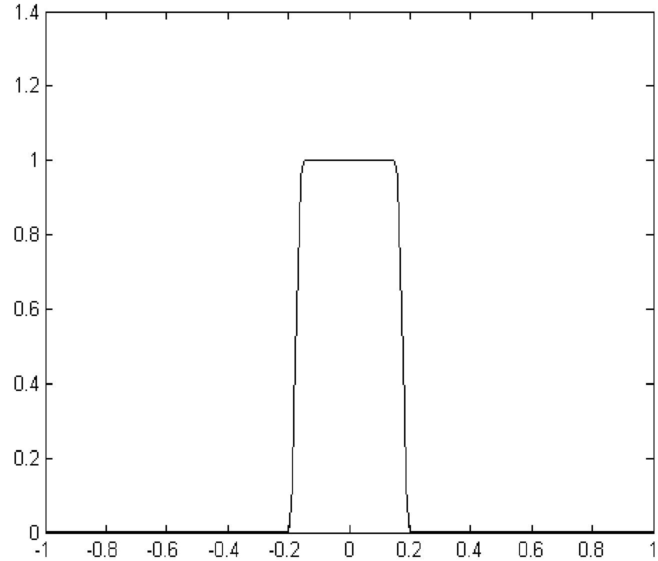
- PSD of input sequence
  Vs freq (pi radians)



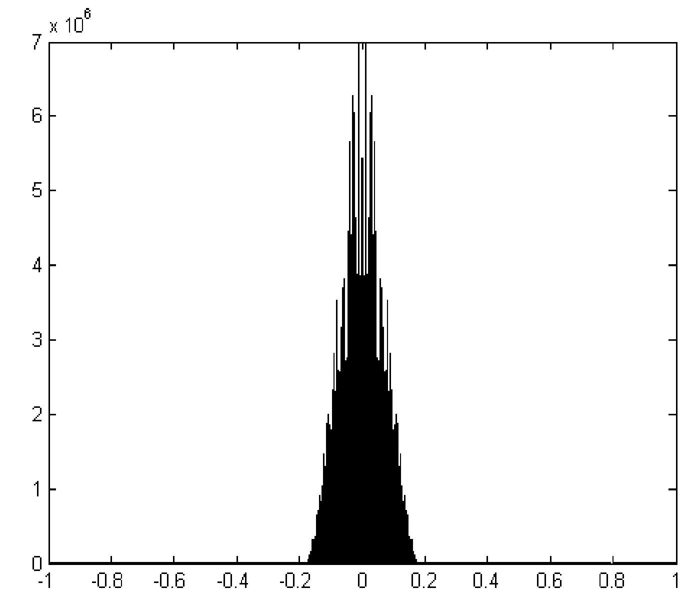
- Impulse response of filter Vs sample indices



- Freq response of filter Vs freq (pi radians)



- PSD of the filtered signal Vs freq (pi radians)



Lab-2

Problem:

- Shift a signal by fractional amount (M/N, N>M)
- Produce the desired spectrum mass

Task 1:

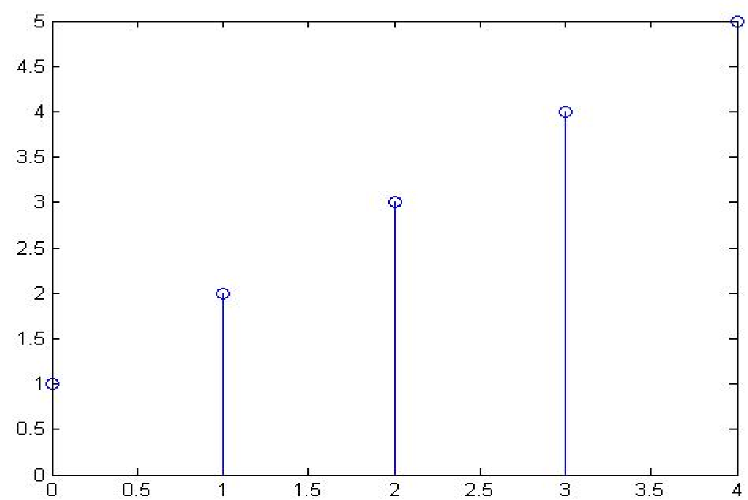
Method:

- Up sample the signal by a factor of N (X=X(n/N)).
- Shift the signal by M. (X=X((n-M)/N))
- Down sample the signal by factor of N. (X=X(n-(M/N)))

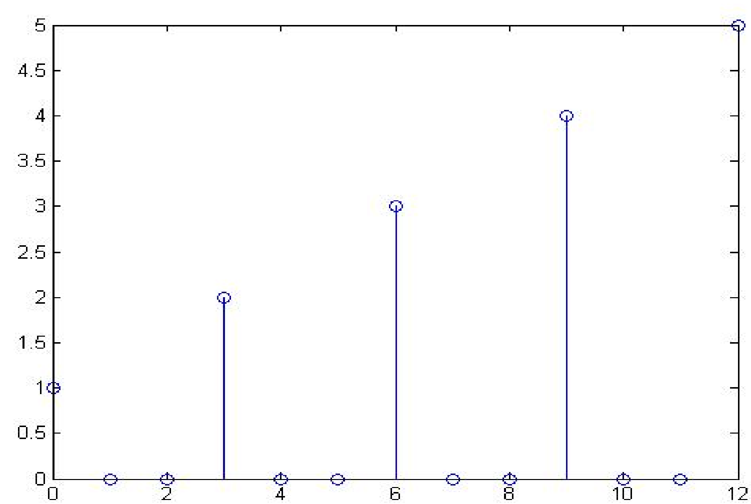
Simulation Results:

Here, M=1, N=3

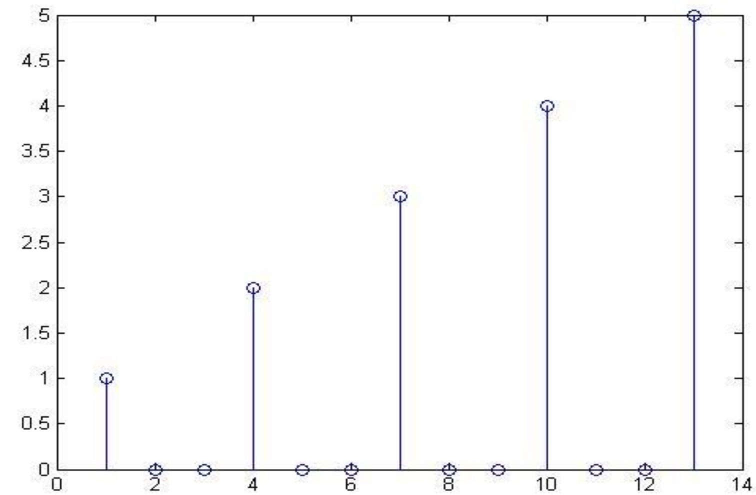
✓ Input Signal Vs Sample Index:



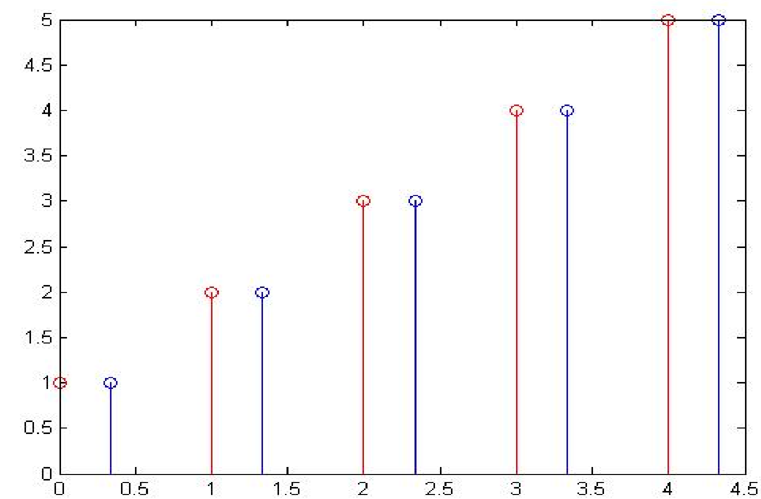
✓ Upsampled Signal Vs Sample Index:



- ✓ Shifted Upsampled Signal Vs Sample Index:



- ✓ Downsampled Signal (Blue) with Input Signal (Red) Vs Sample Index:



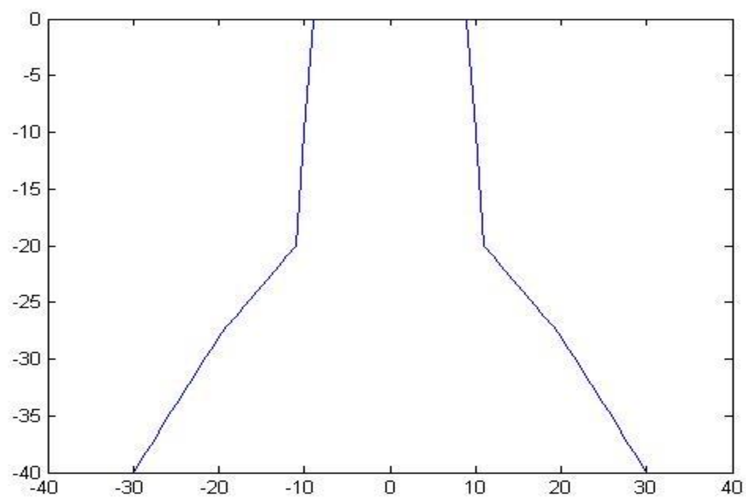
Task 2:

Method:

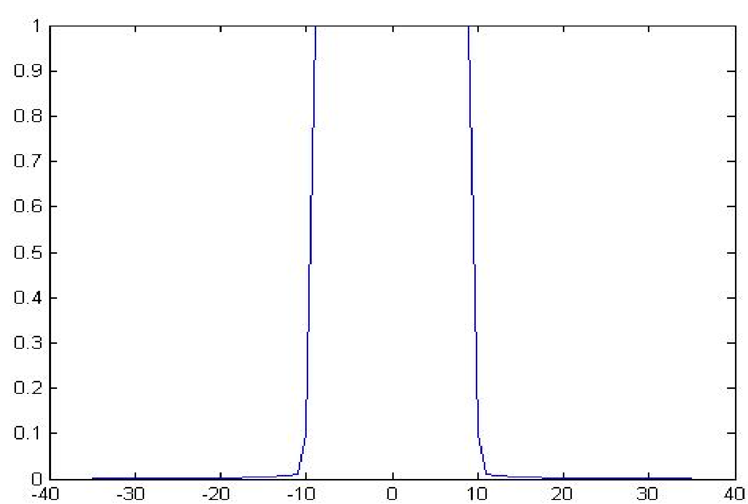
- S(f)out=|H(f)|^2 * S(f) in
- Taking S(f) as white noise which is an impulse in time domain
- |H(f)|^2 has the shape of desired spectrum mass
- Its implemented in the form of FIR filter

Simulation Results:

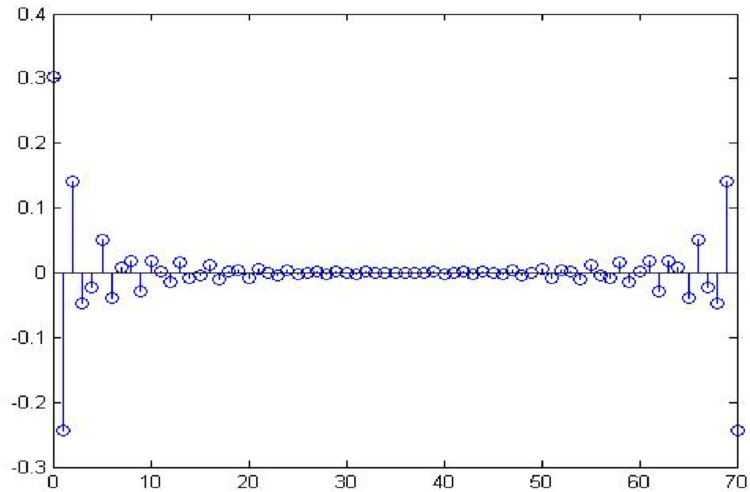
✓ Desired Spectrum Mass ($|H(F)|^2$) in dB Vs Freq. (MHz)



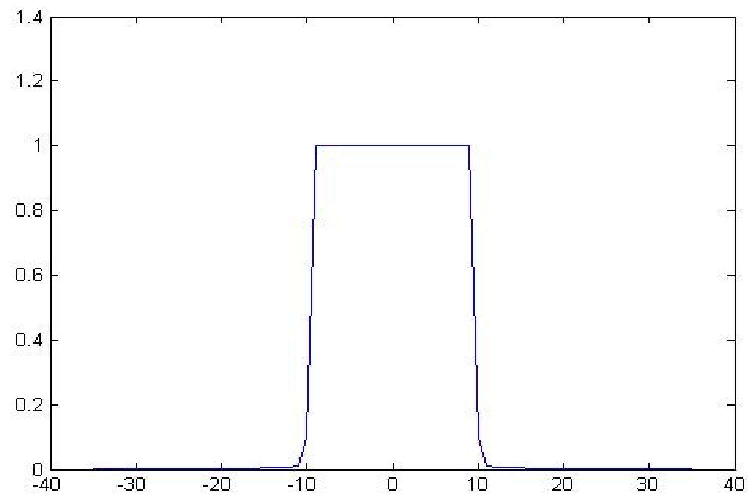
✓ Desired Spectrum Mass ($|H(F)|^2$) Vs Freq. (MHz)



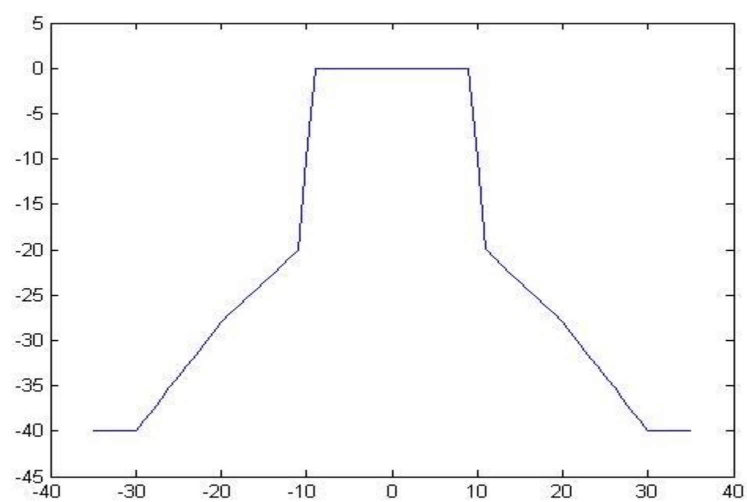
- ✓ Impulse Response Vs Indices



- ✓ PSD of Impulse Response Vs Freq. (MHz)



- ✓ PSD of Impulse Response in dB Vs Freq. (MHz)



Lab-3

Problem:

- Find H matrix when G is given
- Plot BER Vs E_b/N_o for un-coded signal and with hamming code (7, 4)

Task 1:

Given G is,

```
G=    [1  0  0  0  1  0  1  1  1  0  0  0  0  0  0 ;
       0  1  0  0  0  1  0  1  1  1  0  0  0  0  0 ;
       0  0  1  0  0  0  1  0  1  1  1  0  0  0  0 ;
       0  0  0  1  0  0  0  1  0  1  1  1  0  0  0 ;
       0  0  0  0  1  0  0  0  1  0  1  1  1  0  0 ;
       0  0  0  0  0  1  0  0  0  1  0  1  1  1  0 ;
       0  0  0  0  0  0  1  0  0  0  1  0  1  1  1 ];
```

Using relation, $GH^T = [0]$, meaning rows of H are orthogonal to the rows of G. A row of H is found by taking its dot product with each row of G and then solving the 7 equations for the elements of the row. Let $[H_1\, H_2\, H_3\, H_4\, H_5\, H_6\, H_7\, H_8\, H_9\, H_{10}\, H_{11}\, H_{12}\, H_{13}\, H_{14}\, H_{15}]$ be a row of H. Taking its dot product with every row of G. We have,

$$H_1 + H_5 + H_7 + H_8 + H_9 = 0$$
$$H_2 + H_6 + H_8 + H_9 + H_{10} = 0$$
$$H_3 + H_7 + H_9 + H_{10} + H_{11} = 0$$
$$H_4 + H_8 + H_{10} + H_{11} + H_{12} = 0$$
$$H_5 + H_9 + H_{11} + H_{12} + H_{13} = 0$$
$$H_6 + H_7 + H_{12} + H_{13} + H_{14} = 0$$
$$H_7 + H_8 + H_{13} + H_{14} + H_{15} = 0$$

Suppose some values and equate others will give us the values.

$[H_1\, H_2\, H_3\, H_4\, H_5\, H_6\, H_7\, H_8\, H_9\, H_{10}\, H_{11}\, H_{12}\, H_{13}\, H_{14}\, H_{15}] = [0\ 0\ 1\ 0\ 0\ 1\ 0\ 1\ 1\ 1\ 1\ 1\ 1\ 0\ 0]$

From symmetry of G matrix each row is shifted by one bit to right from the above one. Similarly other rows of H can be found by shifting each row by 1 bit to right. The validity of H matrix is proved by relation $GH^T = 0$. This is done using matlab.

Task 2:

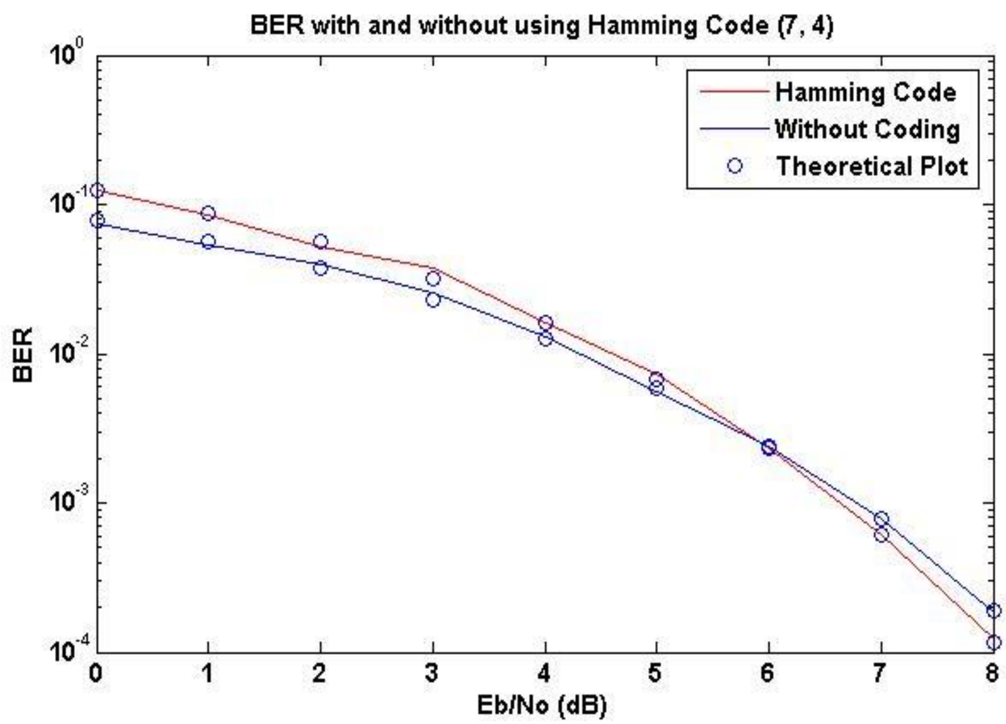
Method:

- Randomly generate a bit and map 0->-1 and 1->1.
- Add AWGN noise with mean 0 and std. deviation = sqrt(Pt/((10^(ENR/10))x(R_B/B)))

- Use hard decision to identify the bit.
- Then find error b/w transmitted and received bit.
- Repeat it till errors collected become 500 and then find BER=500/Bits.
- Repeat the above procedure for different values of ENR.
- For Hamming code, first find H and then G assuming systematic code.
- Now take 4 bits at a time, code them and then map the bits.
- Add AWGN noise and use hard decision. (Pt=0.5, R_B/B=4/7)
- Decode the data and then compare with transmitted bits for error.
- Repeat the steps as mentioned above.

- **Simulation Results:**

Plot is B/W BER and ENR(dB) where y-axis is shown on log scale. The blue colour plot shows the relation between an uncoded 4 bit input bits transmitted at a time. The red plot is achieved when the 4 input bits are coded with (7, 4) hamming code.



Lab-4

Problem:

Calculate and plot BER when data is coded using conv. Code for different trace back length of trellis.

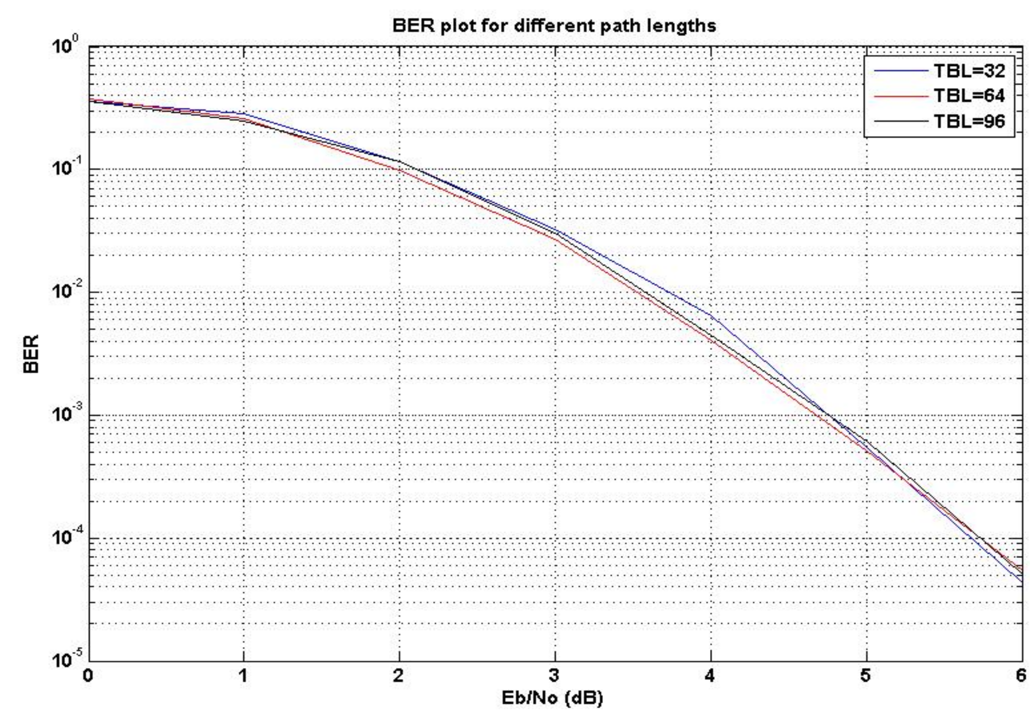
Method:

The generator polynomials are,

g1=[1 0 1 1 0 1 1];
g2=[1 1 1 1 0 0 1];

- Use g1, g2 to form the generator matrix.
- The data is coded (8192 bits) is coded and then mapped.
- AWGN is added.
- Trellis of fixed length is used at receiver due to large memory usage. So that the trace back does not start from the zero state but the state with max. distance metric when the end of trellis length is reached.

Simulation Results:



Lab-5

Problem:

Calculate and plot BER when data is coded using conv. Code with punctured bits.

Method:

Punctured codes are used to increase the data rate. Puncturing means stealing some bits from the coded signal in a specific pattern.

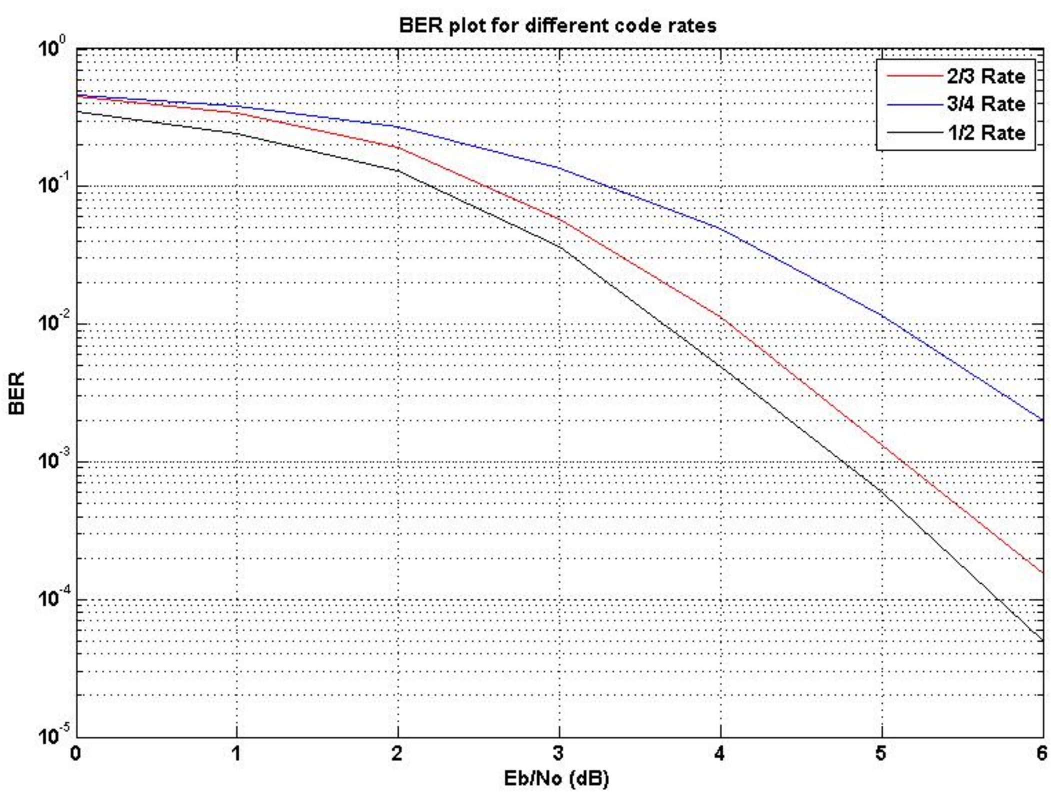
Here, 2/3 and 3/4 rate coder is implemented whose puncturing pattern is represented by,

[1 1 1 0] (Output of 2 input bits) [1 1 1 0 1 0] (Output of 3 input bits)

Where, 0 represents punctured bit.

At receiver the stolen bits are added as either 1 or 0 before the received bits are decoded.

Simulation Results:



Lab-6

Problem:

Calculate and plot BER for following modulation schemes:

- BPSK and QPSK
- 4-PAM, 8-PAM
- 8-PSK, 16-PSK
- 8-QAM, 16-QAM

Method:

Std. Deviation of AWGN = = sqrt(Pt/((10^(ENR/10))x(R_B/B)))

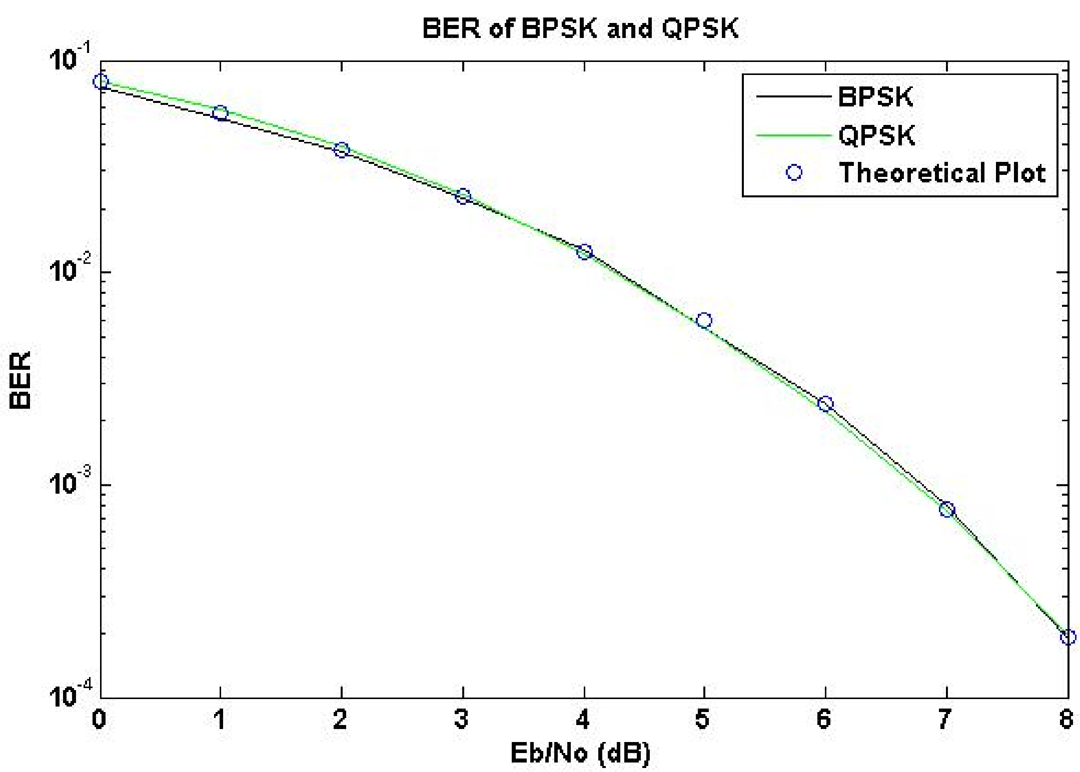
Where,

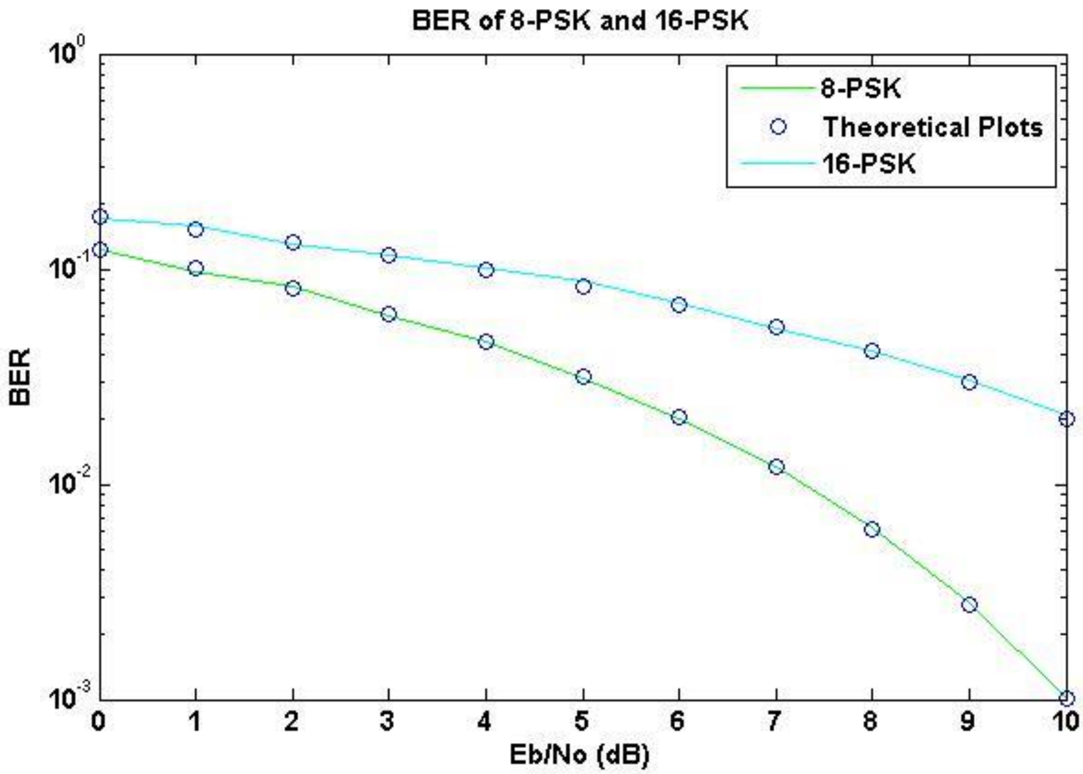
Pt= transmitted power= sum ($I^2 + Q^2$)/2N

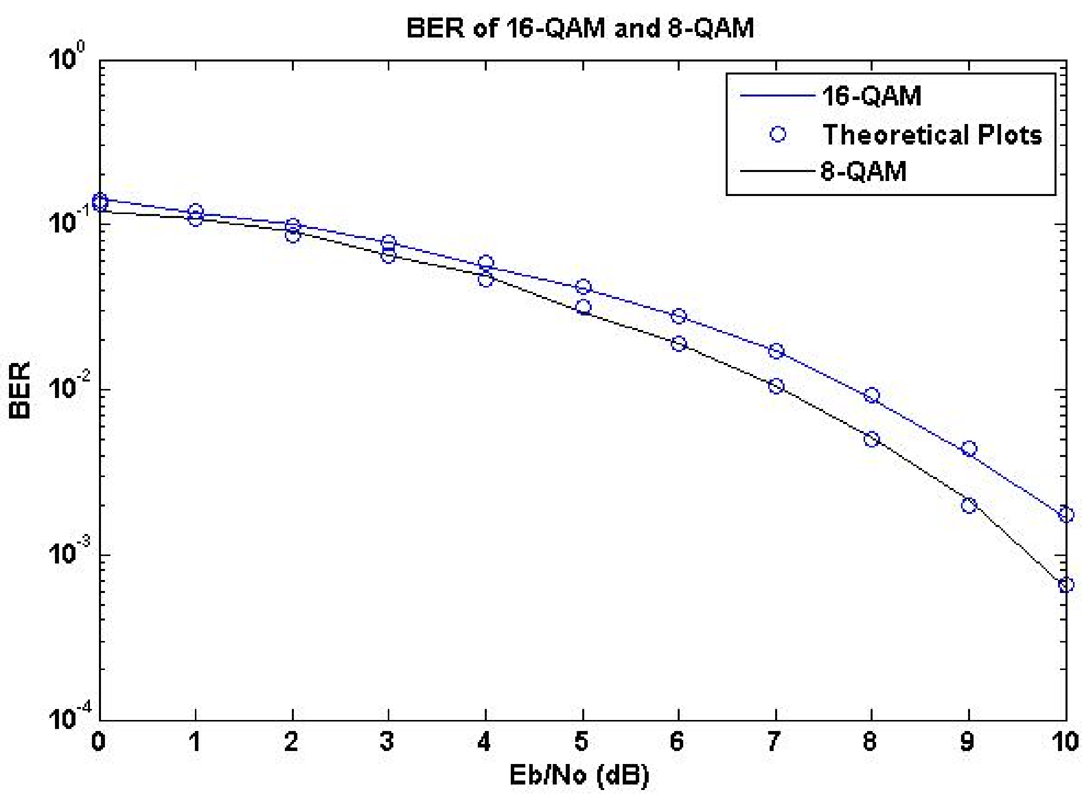
I=In phase arm
Q=Quadrature arm
N=No. of symbols

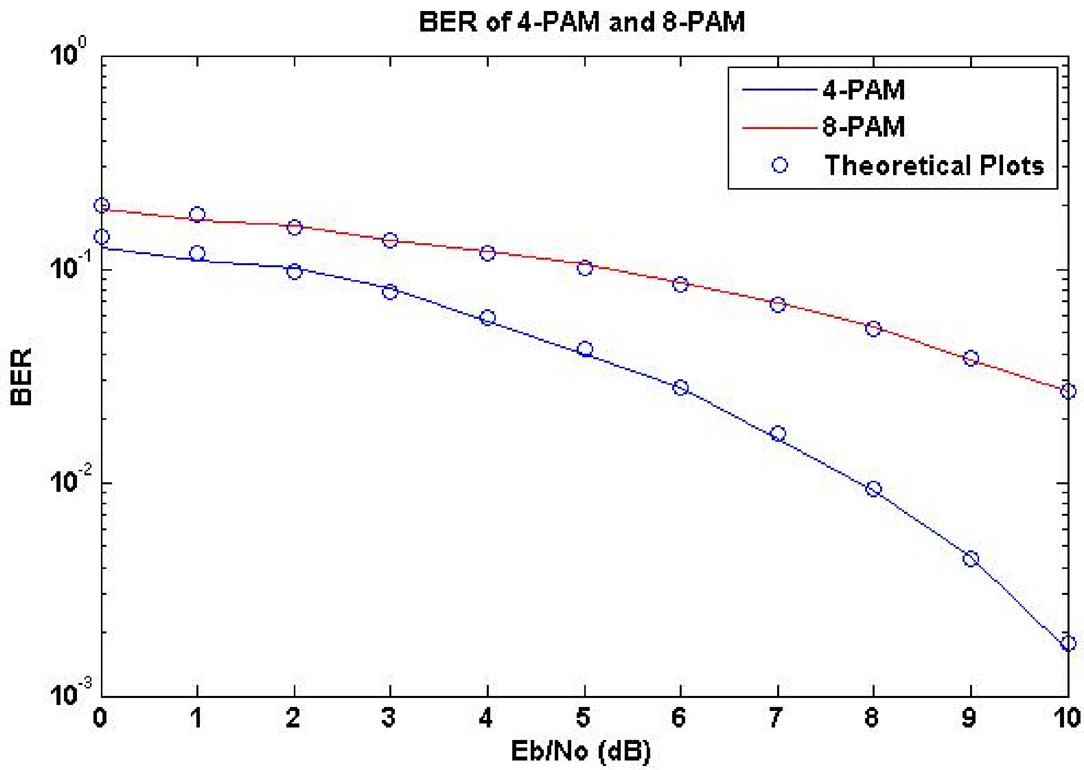
R_B/B = Bandwidth efficiency = Log_2M

Simulation Results:




BER of 8-PSK and 16-PSK
8-PSK
Theoretical Plots
16-PSK
BER
Eb/No (dB)


BER of 16-QAM and 8-QAM
16-QAM
Theoretical Plots
8-QAM
BER
Eb/No (dB)



BER of 4-PAM and 8-PAM
4-PAM
8-PAM
Theoretical Plots
BER
10^{0}
10^{-1}
10^{-2}
10^{-3}
0
1
2
3
4
5
6
7
8
9
10
Eb/No (dB)

Lab-7

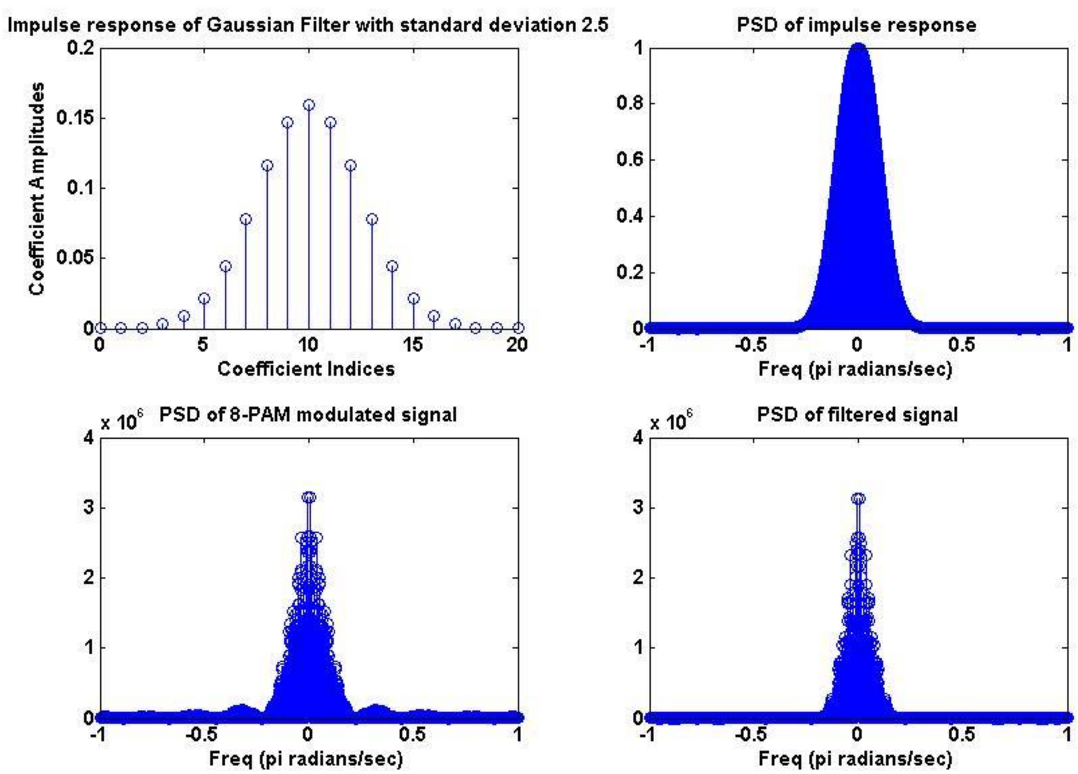
Problem:

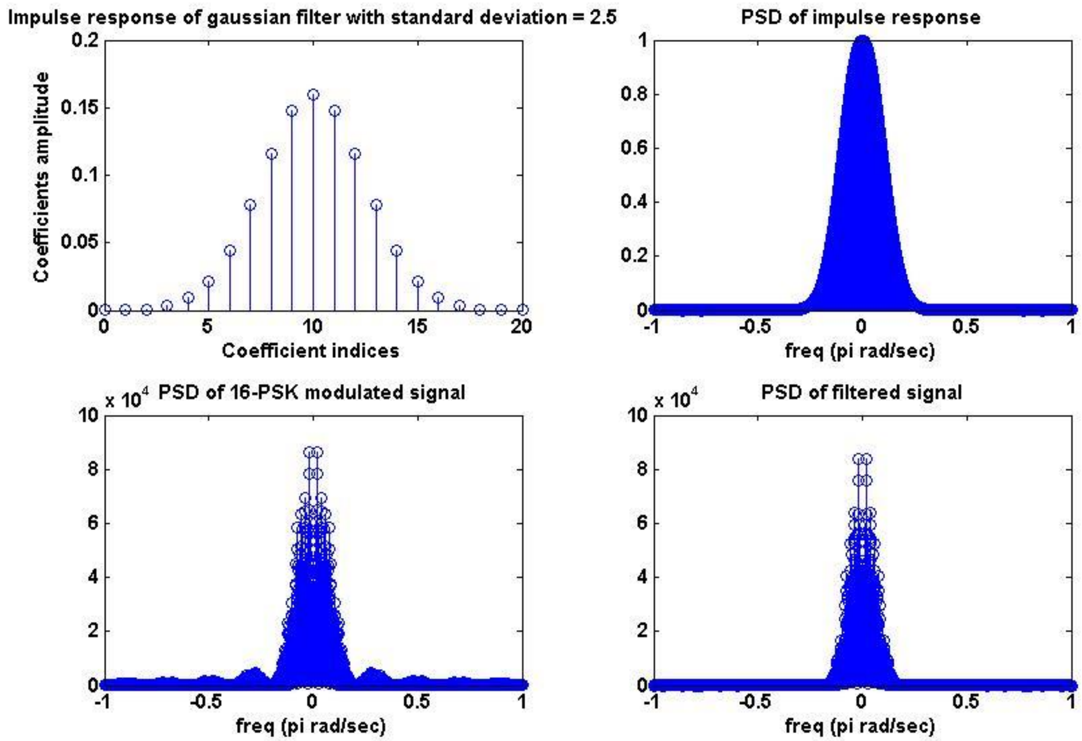
- Show PSD for different modulation schemes when passed through Gaussian, Raised Cosine and Spectral Raised Cosine filter.
- Design correlation receiver.

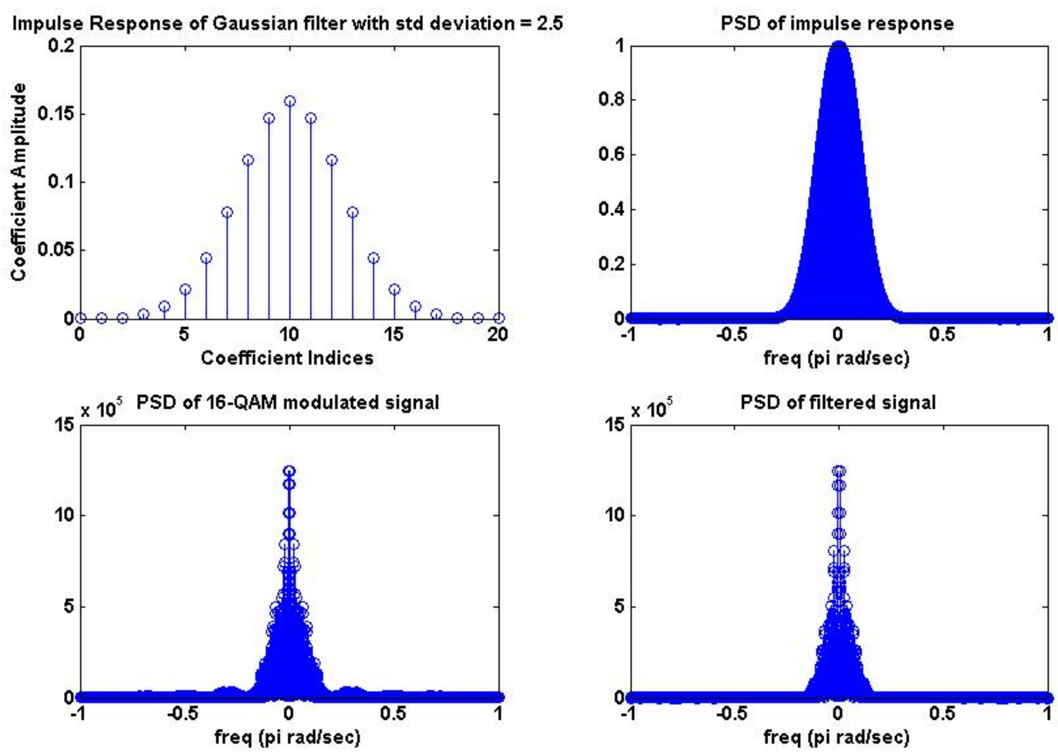
Method:

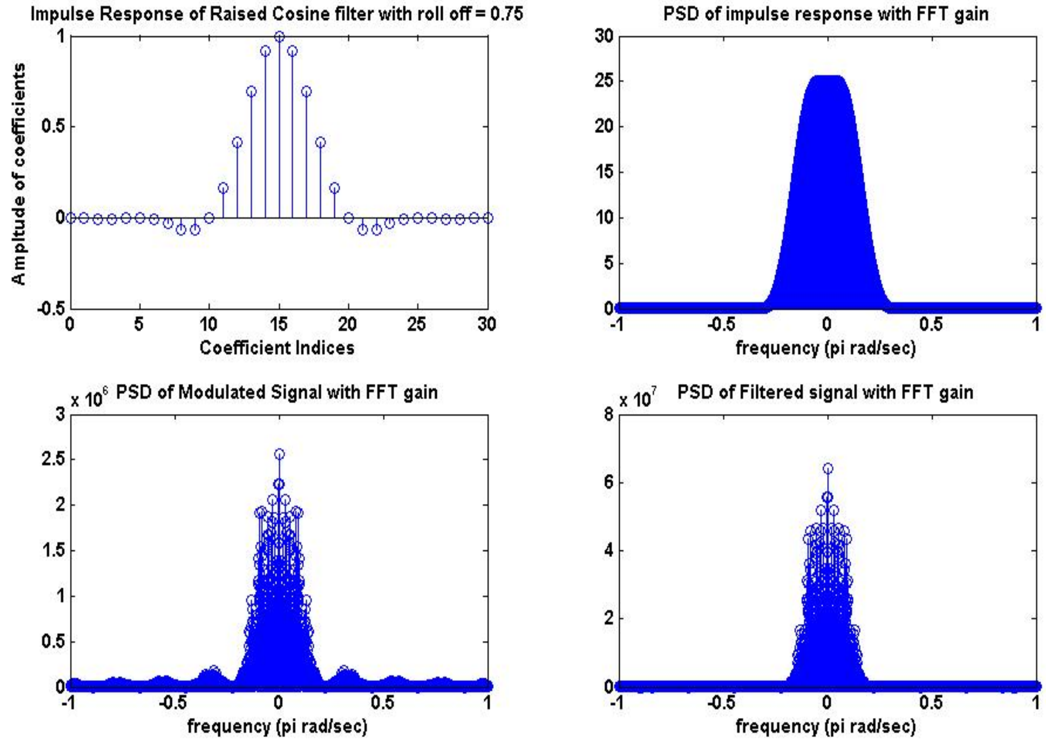
- Transmitter uses an up sampler because the data is to be filtered.
- The receiver has a down sampler (Integrate and Dump)
- Then correlation of the received symbol is taken with all the available symbols, the symbol with max. correlation is chosen to be the received symbol.

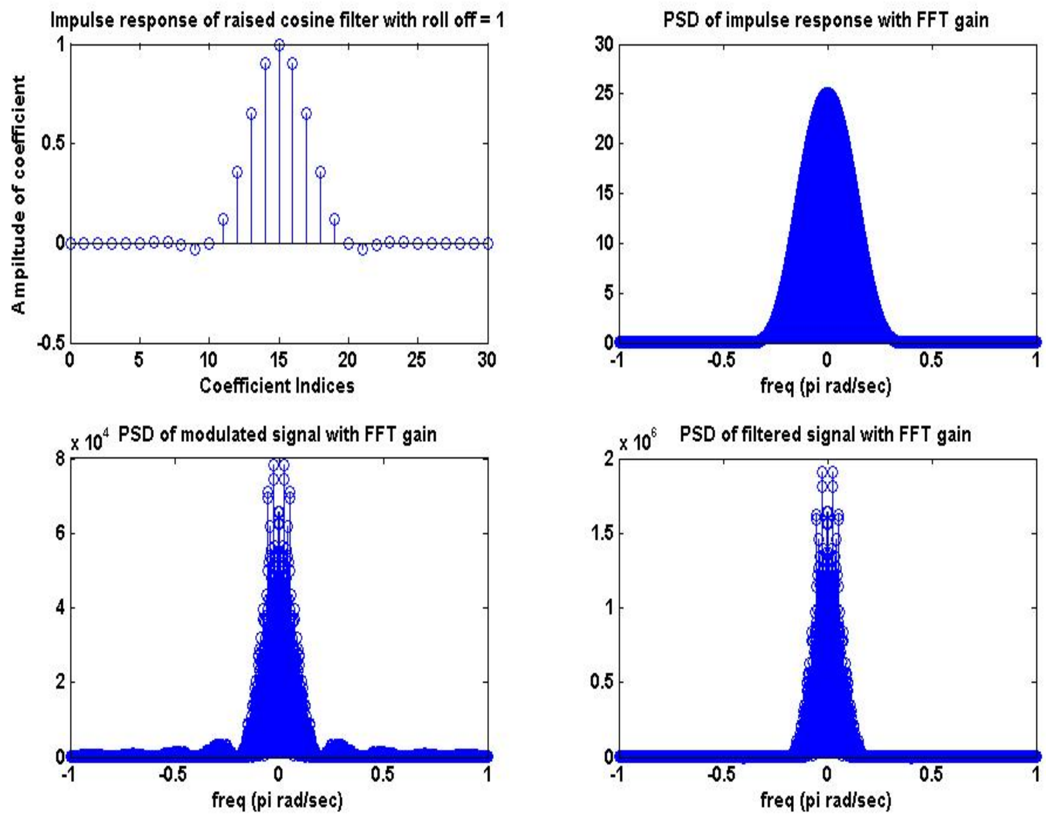
Simulation Results:

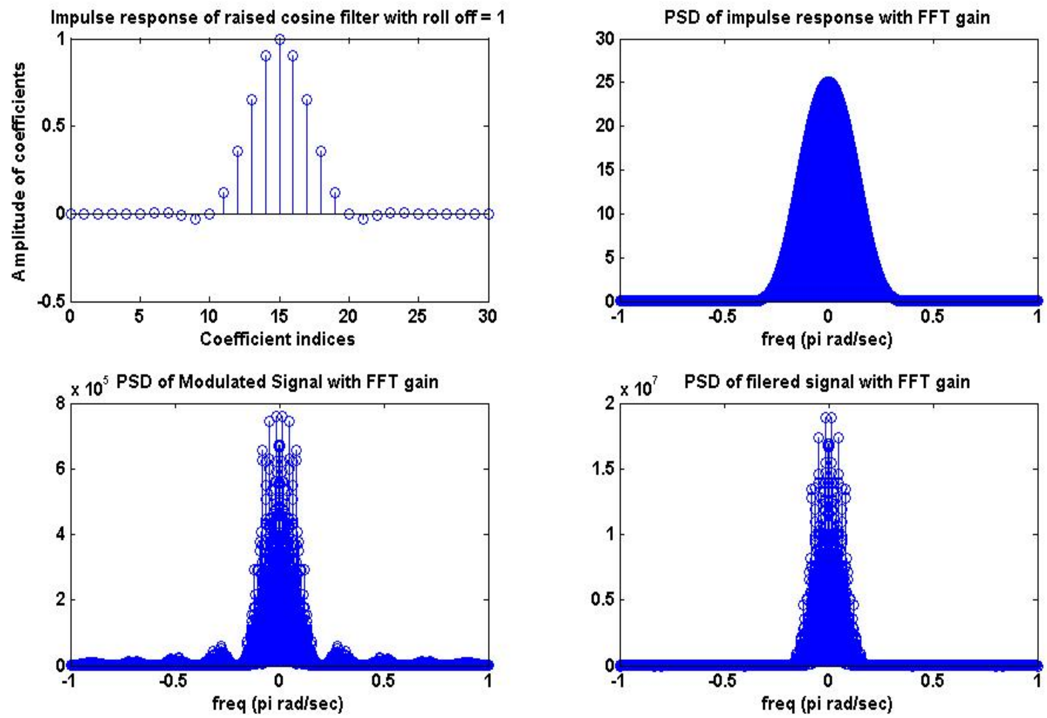


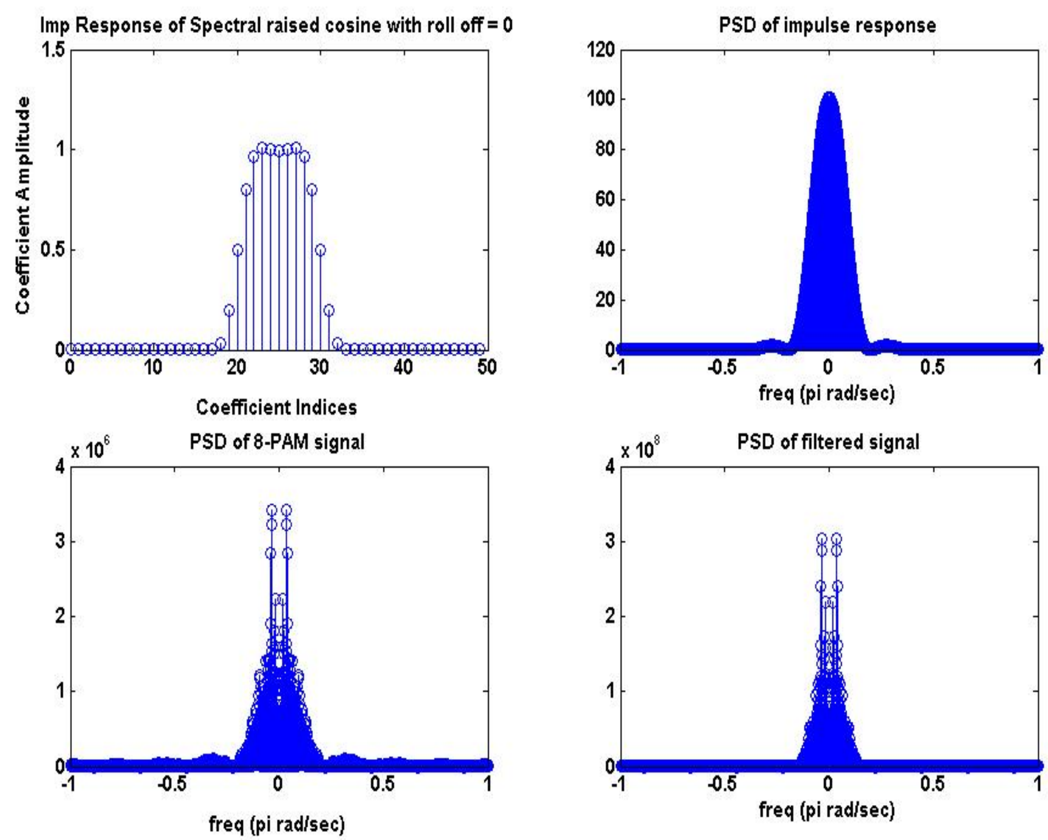

Impulse response of gaussian filter with standard deviation = 2.5
Coefficients amplitude
Coefficient indices
PSD of impulse response
freq (pi rad/sec)
x 10^4 PSD of 16-PSK modulated signal
freq (pi rad/sec)
x 10^4 PSD of filtered signal
freq (pi rad/sec)

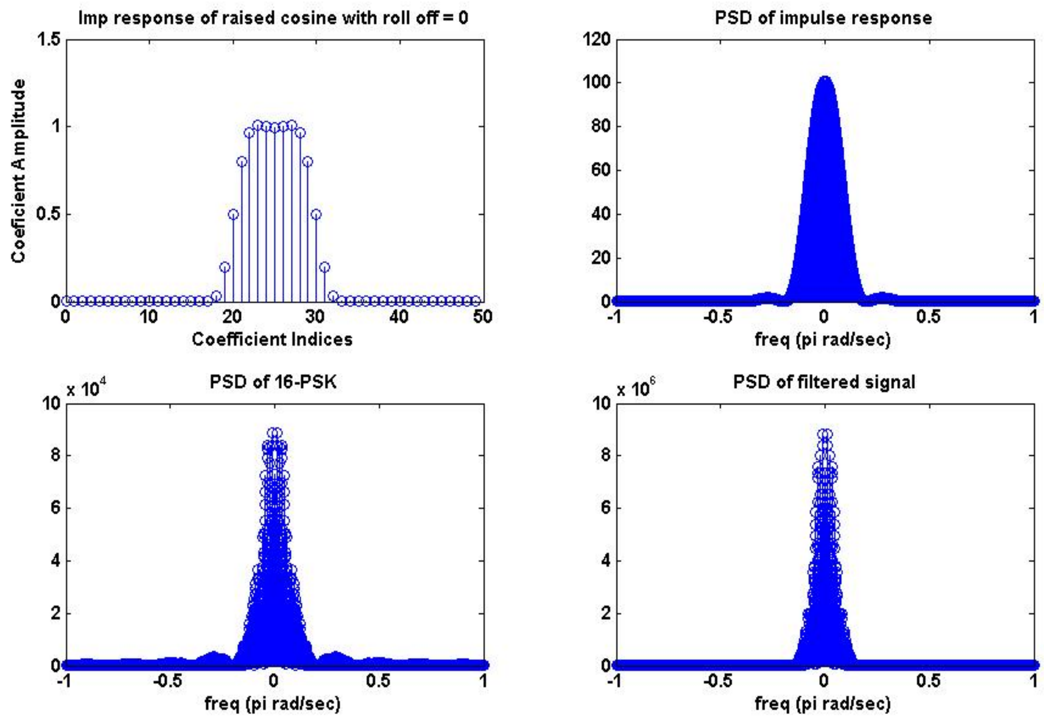

Impulse Response of Gaussian filter with std deviation = 2.5
Coefficient Amplitude
Coefficient Indices
PSD of impulse response
freq (pi rad/sec)
x 10^5 PSD of 16-QAM modulated signal
freq (pi rad/sec)
x 10^5 PSD of filtered signal
freq (pi rad/sec)

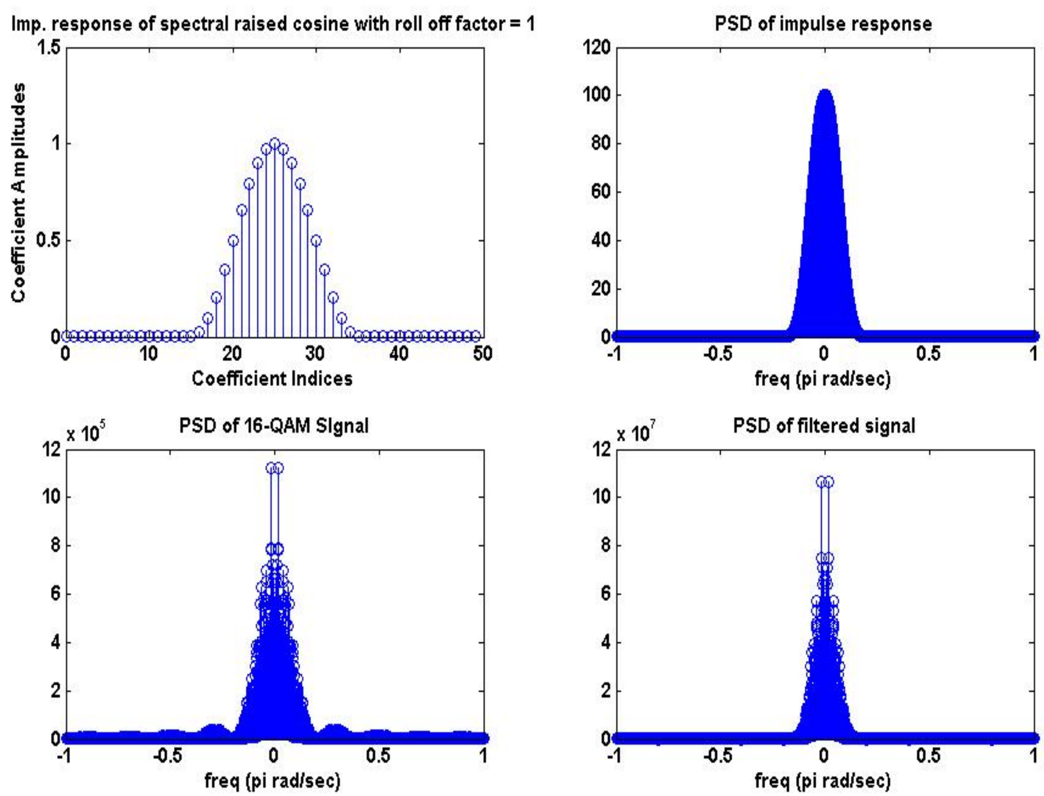

Impulse Response of Raised Cosine filter with roll off = 0.75
Amplitude of coefficients
Coefficient Indices
PSD of impulse response with FFT gain
frequency (pi rad/sec)
x 10^6 PSD of Modulated Signal with FFT gain
frequency (pi rad/sec)
x 10^7 PSD of Filtered signal with FFT gain
frequency (pi rad/sec)

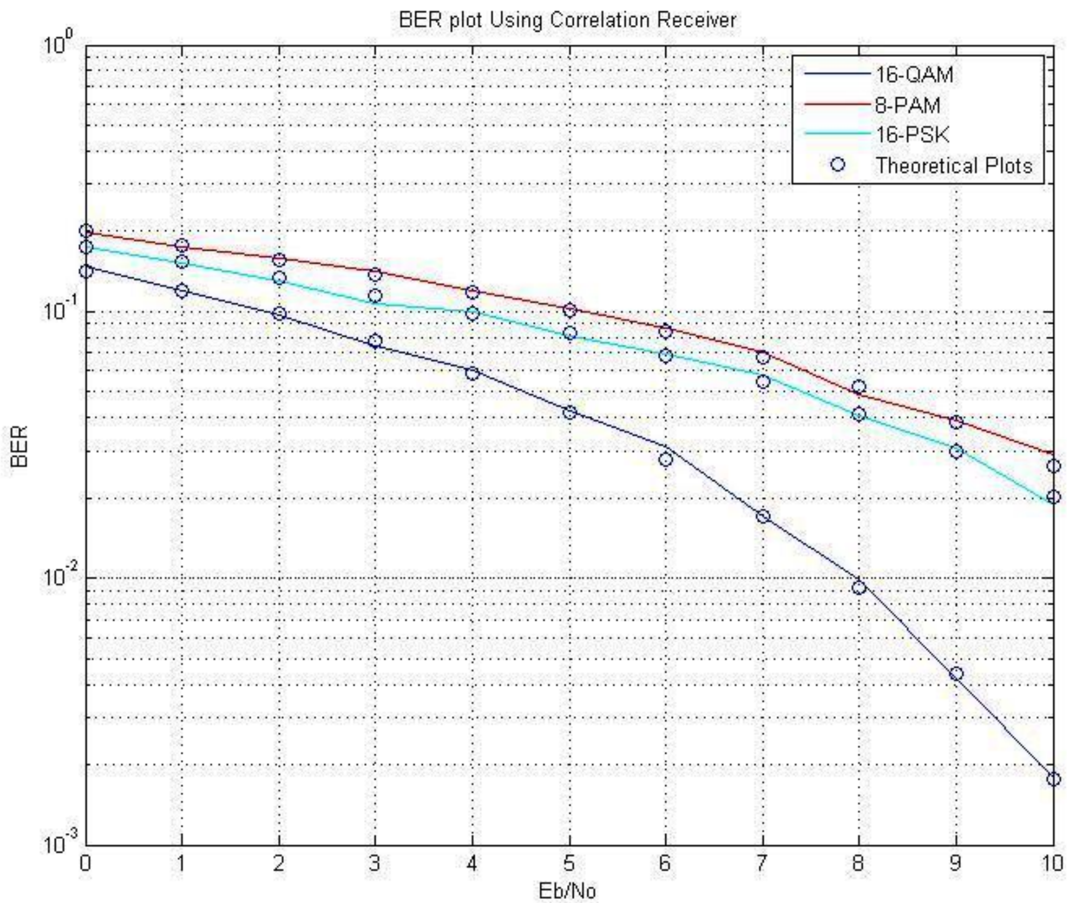

Impulse response of raised cosine filter with roll off = 1
Amplitude of coefficient
Coefficient Indices
PSD of impulse response with FFT gain
freq (pi rad/sec)
x 10^4 PSD of modulated signal with FFT gain
freq (pi rad/sec)
x 10^6 PSD of filtered signal with FFT gain
freq (pi rad/sec)


Impulse response of raised cosine filter with roll off = 1
Amplitude of coefficients
Coefficient indices
PSD of impulse response with FFT gain
freq (pi rad/sec)
x 10^5 PSD of Modulated Signal with FFT gain
freq (pi rad/sec)
x 10^7 PSD of filered signal with FFT gain
freq (pi rad/sec)


Imp Response of Spectral raised cosine with roll off = 0
Coefficient Amplitude
Coefficient Indices
PSD of impulse response
freq (pi rad/sec)
x 10^6 PSD of 8-PAM signal
freq (pi rad/sec)
x 10^8 PSD of filtered signal
freq (pi rad/sec)

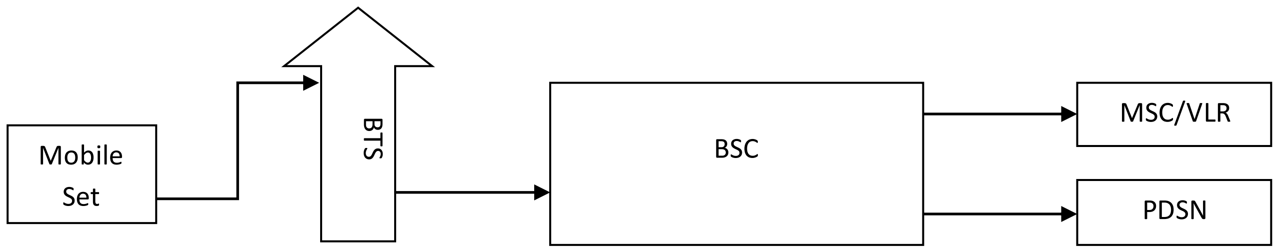

Imp response of raised cosine with roll off = 0
Coeficient Amplitude
Coefficient Indices
PSD of impulse response
freq (pi rad/sec)
PSD of 16-PSK
x 10^4
freq (pi rad/sec)
PSD of filtered signal
x 10^6
freq (pi rad/sec)


Imp. response of spectral raised cosine with roll off factor = 1
Coefficient Amplitudes
Coefficient Indices
PSD of impulse response
freq (pi rad/sec)
PSD of 16-QAM SIgnal
x 10^5
freq (pi rad/sec)
PSD of filtered signal
x 10^7
freq (pi rad/sec)


BER plot Using Correlation Receiver
16-QAM
8-PAM
16-PSK
Theoretical Plots
BER
Eb/No
10^{0}
10^{-1}
10^{-2}
10^{-3}
0
1
2
3
4
5
6
7
8
9
10

Lab-8 & 9

Introduction To CDMA:



- ✓ Um ---> User mobile interface. An open interface b/w MS and BTS.
- ✓ Abis ---> Interface b/w BSC and BTS. It's a closed interface.
- ✓ Ax ---> An open interface b/w MSC/VLR and BSC also b/w BSC and PDSN.

Evolution of CDMA Networks			
Technology	**Freq. BW**	**Service**	**Max. Downlink Rate**
CDMA	1.25MHz	Voice	9.6Kbps
CDMA 2000 1x	1.25MHz	Data	153.6 Kbps
CDMA 2000 1x EVDO	1.25MHz	VOIP	3.1Mbps

Advantages of CDMA:

- Freq. reuse factor is 1.
- More number of users accommodated per channel typically 35.
- 2 times more coverage then GSM
- High spectrum efficiency (4-6 times GSM)
- S/N is very low so, its very hard to track the signal.

Disadvantages of GSM:

- Limited resources (no. of codes are limited)
- CDMA is a self noise system so power should be controlled to avoid interference.
- Soft hands off in CDMA consume resources.
- CDMA does work without GPS.

Lab-8

Problem:

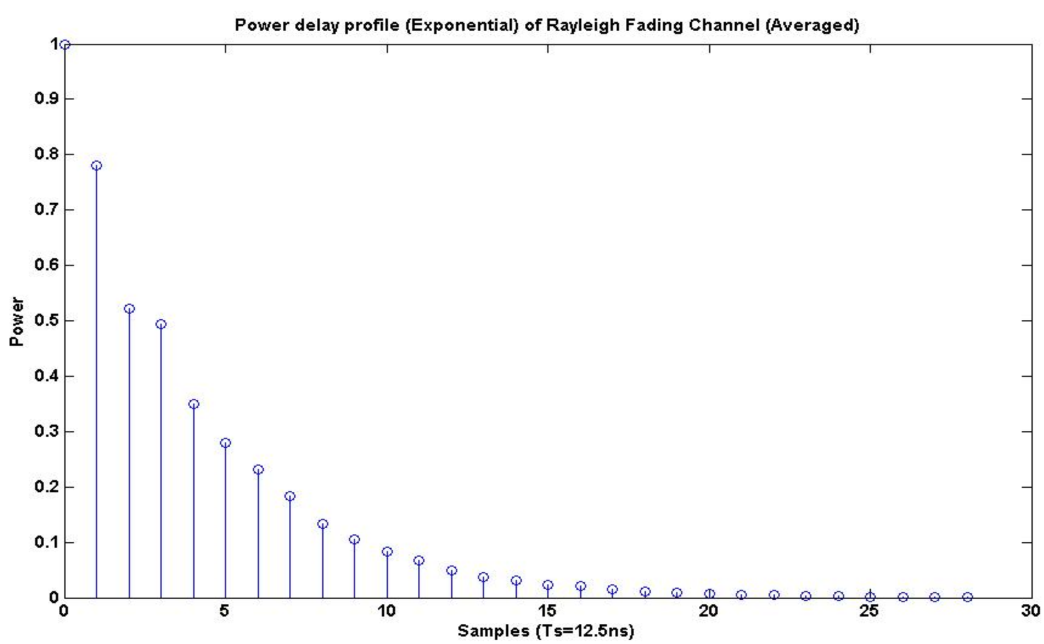
Simulation of Rayleigh fading channel and plot its power delay profile.

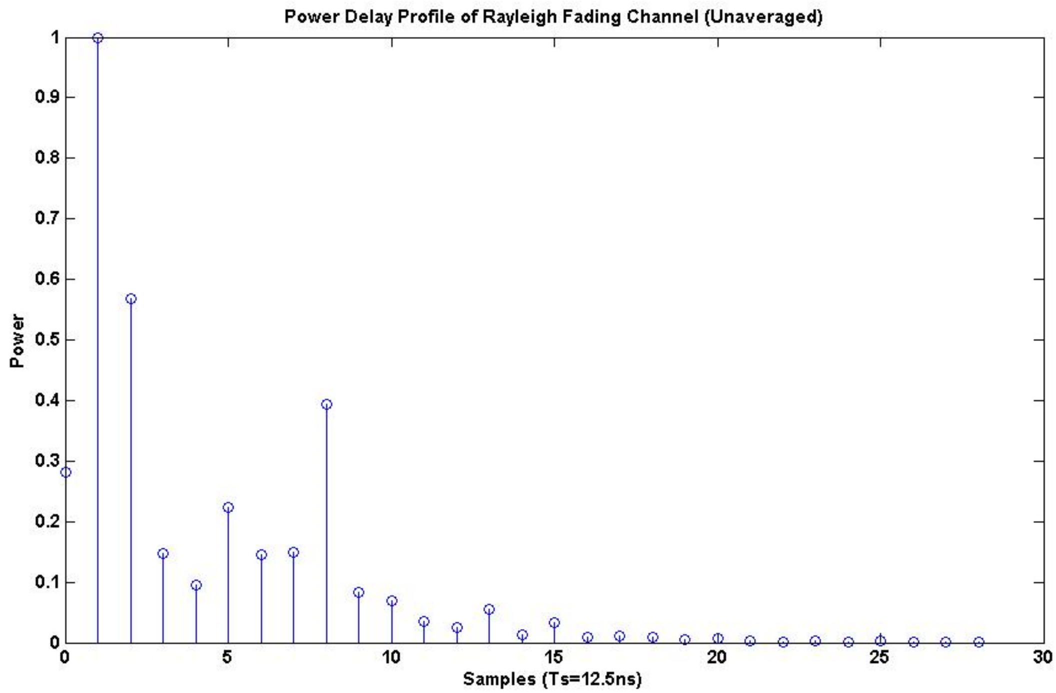
Method:

Ts=12.5 ns
RMS delay spread = 50ns
No. of taps are set according to the threshold which is -30dB

- PDP is exponential with time constant 50 ns.
- Keeping in view the threshold, the samples of PDP are chosen.
- They are normalized by sum of all the samples.
- Then division by 2 gives var. and std. = sqrt(var.)
- Then 2 orthogonal gaussian random variables are generated with mean 0 and std. deviation calculated above.
- The sum of these RV are the taps of an FIR filter which models the channel.

Simulation Results:



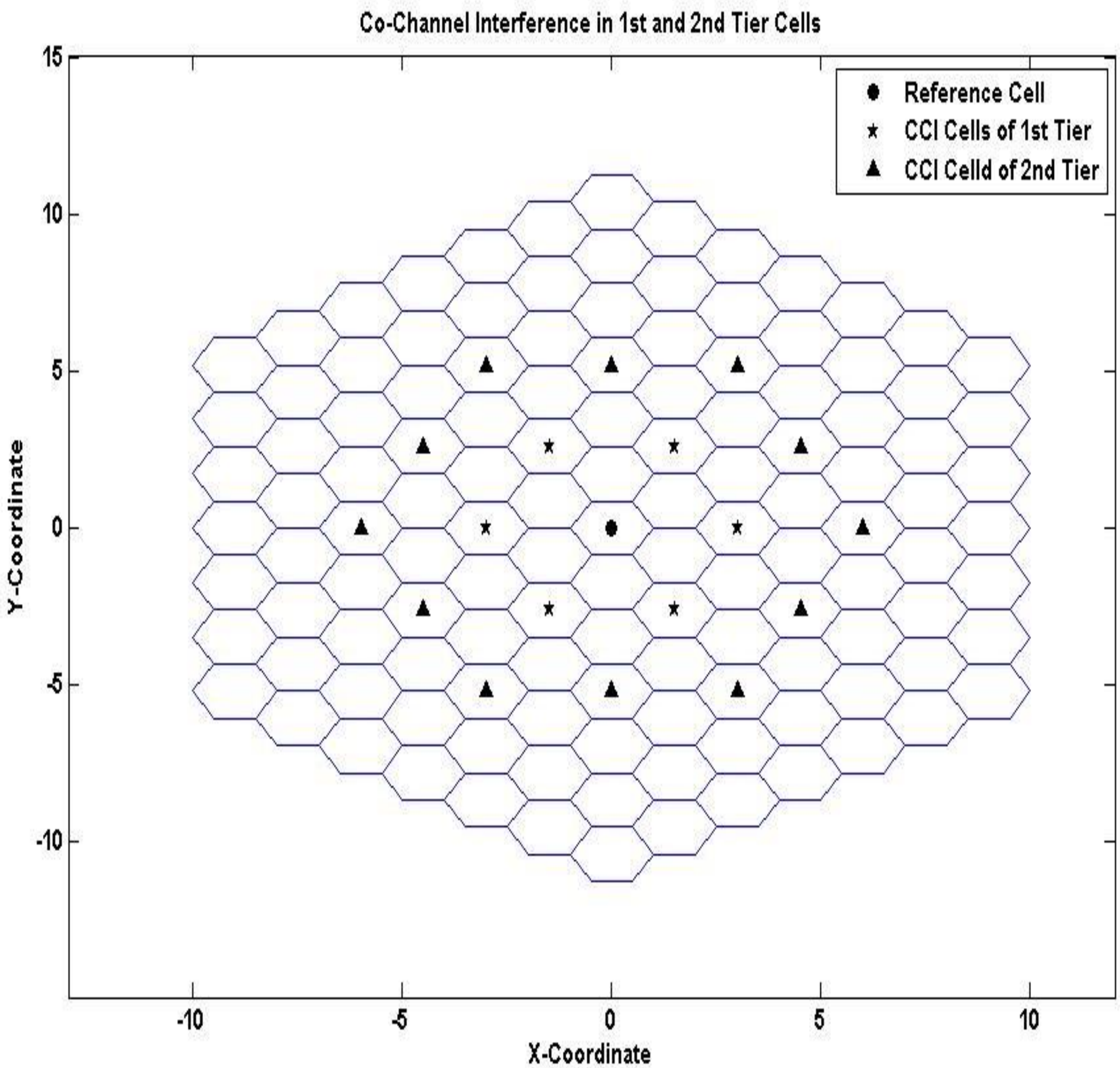

Power Delay Profile of Rayleigh Fading Channel (Unaveraged)
Power
Samples (Ts=12.5ns)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
5
10
15
20
25
30

Lab-11

Object:

Show CCI (Co-Channel Interference) for an omni-directional antenna using Hexagonal Chart.

Simulation Results:

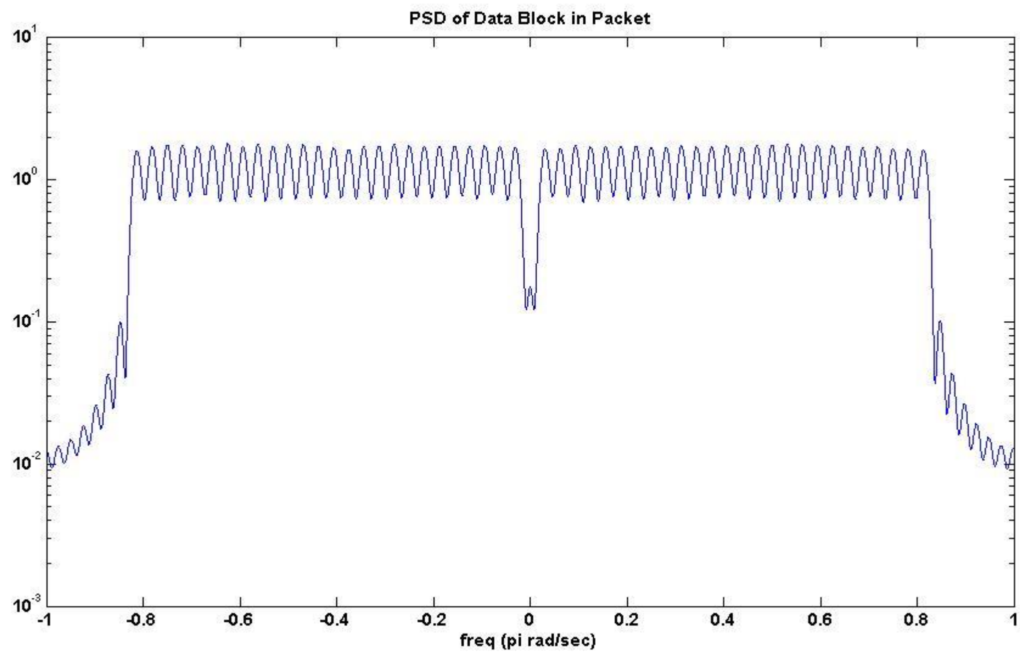


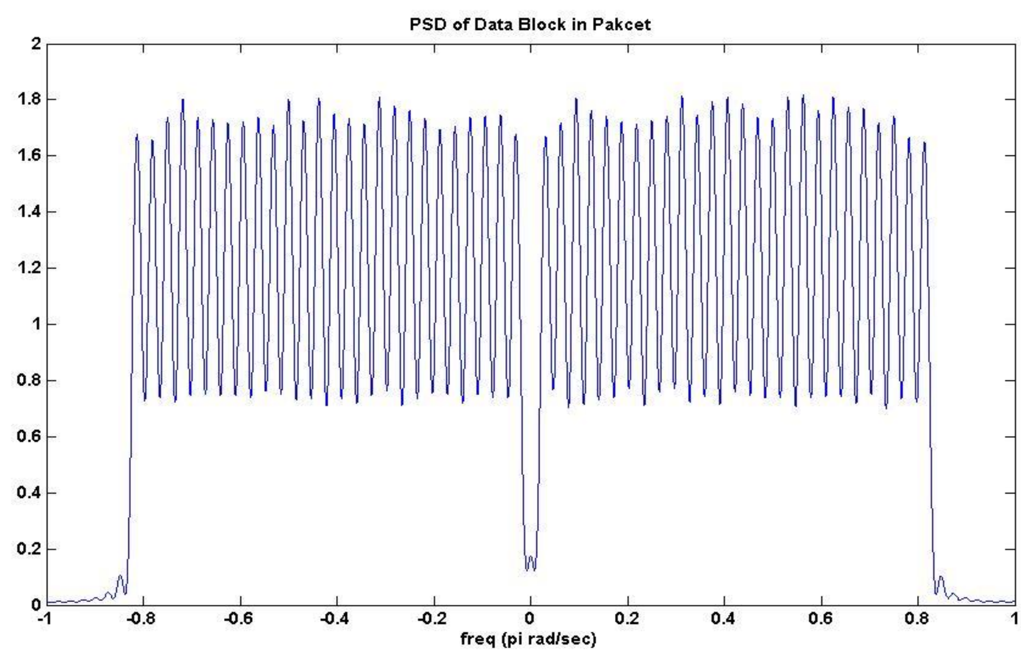
Lab-12

Problem:

Simulation of 802.11a (WIFI) transmitter and show PSD of the packet.

Simulation Results:





Lab-13

Problem:

Estimation of frequency offset in OFDM Systems.

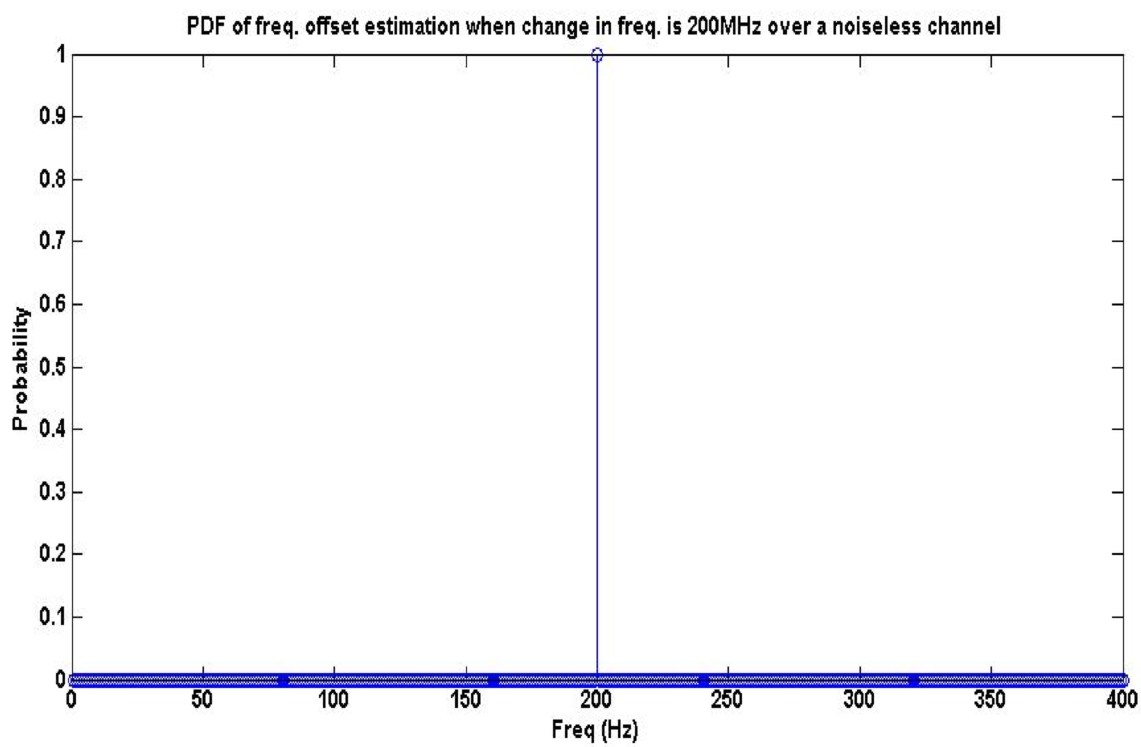
Method:

The preamble contains 10 same symbols in STS (Short Training Sequence), a guard interval and 2 same symbols in LTS (Long Training Sequence). The STS is used in coarse freq. estimation. Following relation is used,

OFFSET = phase[(r((k+16)T_S))* conj((r(kT_S)))]/32πT_S

Where, r=received packet

Simulation Results:



Lab-14

Problem:

Timing offset estimation in OFDM systems.

Method:

The timing estimation is calculated by following relation,

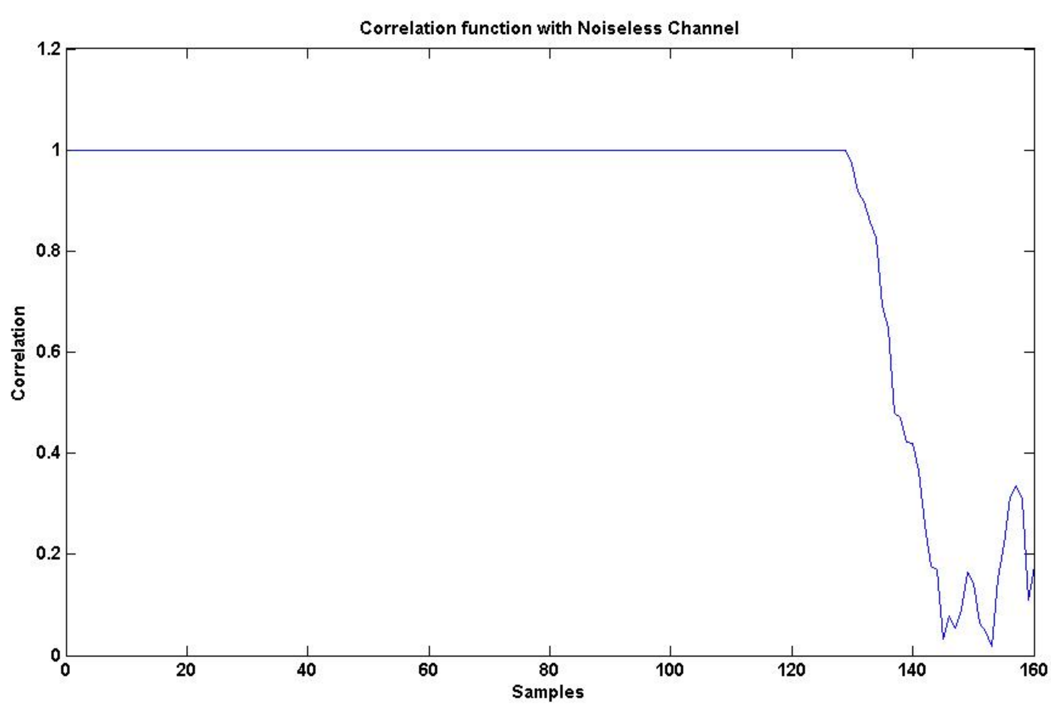
```
A(d)=sum(P(d:d+15).*conj(P(d+16:d+31)));
B(d)=sum((abs(P(d:d+15))).*abs(P(d+16:d+31)));
M(d)=A(d)/B(d);
```

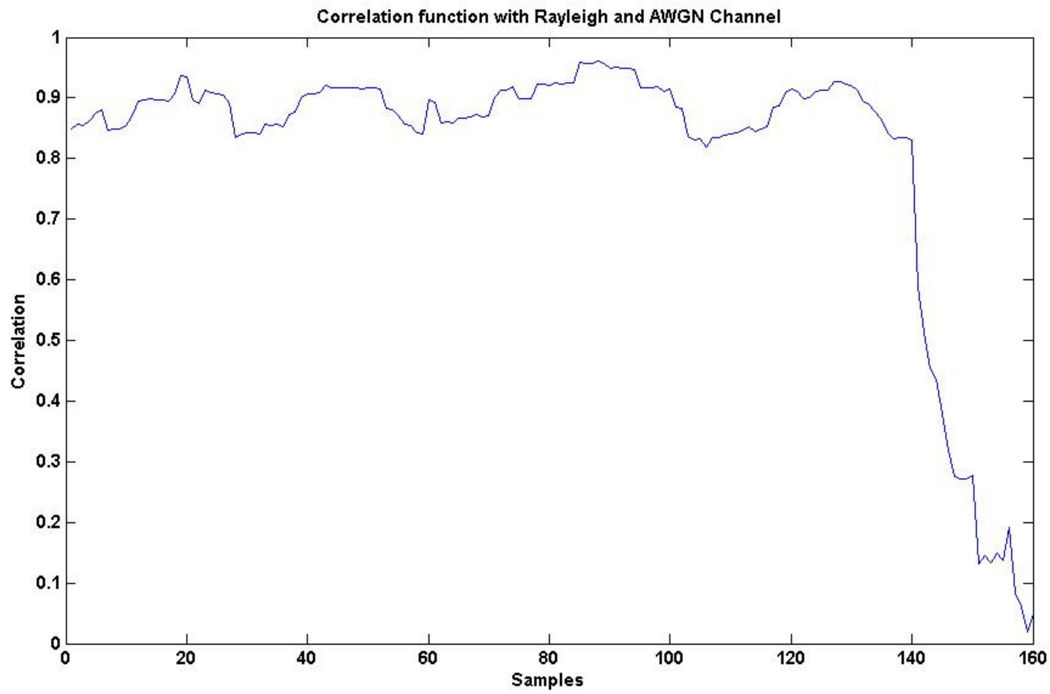
Where,

d=Sample in received preamble
P=Received Preamble

After M is found over samples in preamble. A threshold is set and the value where M goes zero indicates the ending of STS and starting of guard interval

Simulation Results:




Correlation function with Rayleigh and AWGN Channel
Correlation
Samples
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
20
40
60
80
100
120
140
160