ECE 300 Communication Theory Matlab Project 2 Using viterbi

Table of Contents

Zheng Liu, Jing Jiang, Tianshu Ren

Project Description

Our Goal in part 2 is to Achieve BER of 10^-6 at 12 dB SNR over moderate ISI channel using whatever means possible.

Algorithm Initialization

```
clear all;close all;clc

numIter = 5;  % The number of iterations of the simulation
nSym = 1000;    % The number of symbols per packet
SNR_Vec = 0:2:16;
lenSNR = length(SNR_Vec);

M = 8;        % The M-ary number, 2 corresponds to binary modulation

%chan = 1;          % No channel
chan = [1 .2 .4]; % Somewhat invertible channel impulse response,
 Moderate ISI
%chan = [0.227 0.460 0.688 0.460 0.227]';   % Not so invertible,
 severe ISI


% Create a vector to store the BER computed during each iteration
berVec = zeros(numIter, lenSNR);
eqlBerVec = zeros(numIter, lenSNR);
% Run the simulation numIter amount of times
```

Convolutional

```
%trel = poly2trellis([5 4],[23 35 0;0 5 13]); % Define trellis.
trel = poly2trellis(7,[171 133]);       %7 is the constraint length.
 171 173 define the system.
traceBack = 32;
```

```
codeRate = 1/2;
```

Below is the hard decision approach we tried. It worked worse than soft

```
    %decision. And soft decision is the more complicated case. So only
 soft
    %decision is shown.
    %enc = comm.ConvolutionalEncoder(trel);
    %dec =
 comm.ViterbiDecoder('TrellisStructure',trel,'InputFormat','Hard','TracebackDepth'
 'Continuous');       %Hard
```

iteration

```
tic
for i = 1:numIter

    %  bits = randint(1, nSym*M, [0 1]);     % Generate random bits
    bits = randi(2,[codeRate*nSym*log2(M), 1])-1;


    % If you increase the M-ary number, as you most likely will,
 you'll need to
    % convert the bits to integers. See the BIN2DE function
    % For binary, our MSG signal is simply the bits

    msg = bi2de(reshape(bits,log2(M),[]).');
    encodedMSG = convenc(bits,trel);            %Encoding using
 trellis generated above.

    for j = 1:lenSNR % one iteration of the simulation at each SNR
 Value

        noise_addition = 10*log10(log2(M)*codeRate);
  %To use soft decision, the variance of the noise is required for
 demodulation.
        noise_var = 10.^(-(SNR_Vec(j) + noise_addition)/10);

        tx =
 qammod(encodedMSG,M,'UnitAveragePower',true,'InputType','bit');  %
 BPSK modulate the signal
        tx2 =
 qammod(bits,M,'UnitAveragePower',true,'InputType','bit');

        if isequal(chan,1)
            txChan = tx;
            txChan2 = tx2;
        elseif isa(chan,'channel.rayleigh')
            reset(chan) % Draw a different channel each iteration
            txChan = filter(chan,tx);
        else
            txChan = filter(chan,1,tx);  % Apply the channel.
            txChan2 = filter(chan,1,tx2);
        end
```

```
        % Convert from EbNo to SNR.
        % Note: Because No = 2*noiseVariance^2, we must add ~3 dB
        % to get SNR (because 10*log10(2) ~= 3).
        txNoisy =
awgn(txChan,10*log10(log2(M))+SNR_Vec(j),'measured'); % Add AWGN
        txNoisy2 =
awgn(txChan2,10*log10(log2(M))+SNR_Vec(j),'measured');

        rx = txNoisy;
        rx2 = txNoisy2;

        % Again, if M was a larger number, I'd need to convert my
symbols
        % back to bits here.

        rxMSG =
qamdemod(rx2,M,'UnitAveragePower',true,'OutputType','bit');
        noEqlMSG =
qamdemod(rx,M,'UnitAveragePower',true,'OutputType','bit');

        %rxMSG = reshape(de2bi(rx,log2(M)),[],1);


        %Equilizer
        mu = 0.001; %step size
        trainlen = 200;
        n = 8; %number of weights
        const = qammod((0:1:M-1),M);
        trainSig=tx(1:trainlen);

        %LMS decision-feedback equalizer
        nfwd = 16;
        nfbk = 12;
        dfeLMS = dfe(nfwd,nfbk,lms(mu));
        dfeLMS.SigConst = const; % Set signal constellation.
        dfeLMS.ResetBeforeFiltering = 0;

        %RLS decision-feedback equalizer
        dfeRLS = dfe(nfwd,nfbk,rls(0.99,0.9));
        dfeRLS.SigConst = const; % Set signal constellation.
        dfeRLS.ResetBeforeFiltering = 0;

        %lms,linear
        %trainMSG = reshape(de2bi(tx(1:trainlen),log2(M)),[],1);
        linLMS = lineareq(n, lms(mu)); % Create an equalizer object.
        linLMS.SigConst = const; % Set signal constellation.
        linLMS.ResetBeforeFiltering = 0;

        %rls,linear
        linRLS = lineareq(n, rls(1,0.1)); % Create an equalizer
object.
        linRLS.SigConst = const; % Set signal constellation.
        linRLS.ResetBeforeFiltering = 0;
```

```
        %Again, linRLS is picked.

        %delay = (numRefTap-1)/eqobj.nSampPerSym;
        [y,eqlSig] = equalize(linRLS,rx,trainSig); % Equalize.
        eqlMSG =
 qamdemod(eqlSig,M,'UnitAveragePower',true,'OutputType','bit');
        eqlMSG_soft = qamdemod(eqlSig,M,'OutputType','approxllr', ...
            'UnitAveragePower',true,'NoiseVariance',noise_var);
        %decodedMSG = dec(eqlMSG_soft);
        decodedMSG =
 vitdec(eqlMSG_soft,trel,traceBack,'cont', 'unquant');

        % Compute and store the BER for this iteration

        rxMSG = bi2de(reshape(rxMSG,log2(M),[]).');
        %decodedMSG = bi2de(reshape(decodedMSG,log2(M),[]).');
        [zzz, berVec(i,j)] = biterr(msg, rxMSG);  % We're interested
 in the BER, which is the 2nd output of BITERR

        [zzz, eqlBerVec(i,j)] = biterr(bits(trainlen+1:end-traceBack),
 decodedMSG(trainlen+traceBack+1:end));        %For Conv Code
        [zzz, eqlBerVec(i,j)] = biterr(bits(trainlen+1:end-traceBack),
 decodedMSG(trainlen+traceBack+1:end));
```

Except for getting rid of the traning part, we also need to deal with delay between input and output caused by convolution, which is equal to traceback in this case because the rate is 1/2.

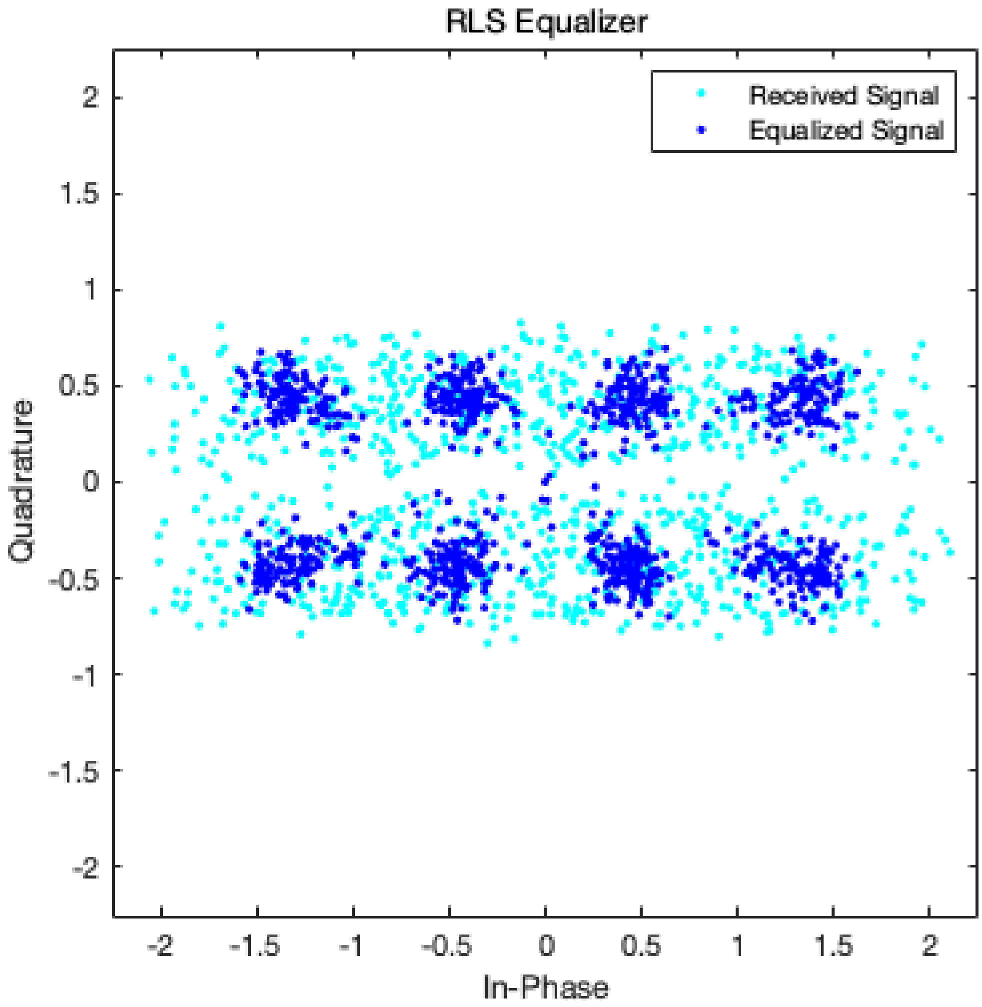
```
        % The best result we got is 8-QAM, the bit rate is improved
 while
        % keeping the BER below e-6.

        Bit_Rate = (log2(M)*nSym - trainlen) / 1000;

    end  % End SNR iteration
end      % End numIter iteration
time = toc;
time


time =

    5.9601
```

Plots

Played with M-ary QAM Scatter plot to see how equilizers work on

```
h = scatterplot(rx,1,0,'c.');
hold on
scatterplot(y,1,0,'b.',h)
legend('Received Signal','Equalized Signal')
title('RLS Equalizer')
```

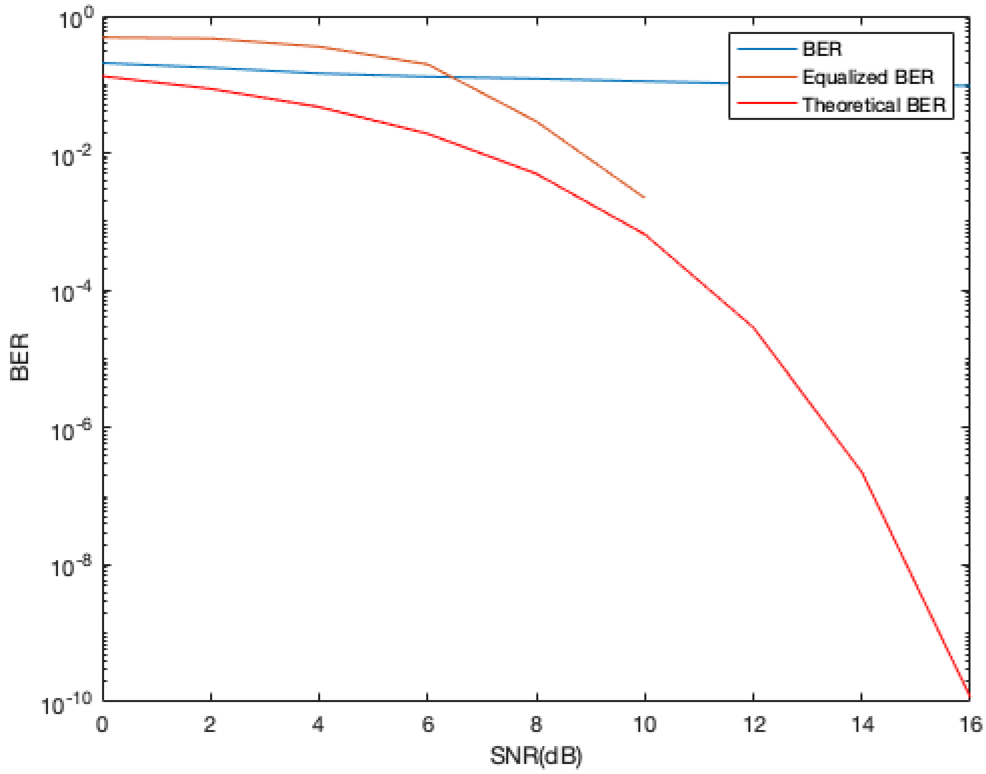
```
hold off
%
```



Compute and plot the mean BER. The result at 12dB is 0. Which fits the requirement.

```
figure;
ber = mean(berVec,1);
eqlBer = mean(eqlBerVec,1);
semilogy(SNR_Vec, ber);
hold on
semilogy(SNR_Vec, eqlBer);


berTheory = berawgn(SNR_Vec,'qam',M);
hold on
semilogy(SNR_Vec,berTheory,'r')
xlabel("SNR(dB)")
ylabel("BER")
```

```
legend('BER', 'Equalized BER','Theoretical BER')
```



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QAM 32 Viterbi

Table of Contents

Algorithm Initialization

```
clear all;close all;clc

numIter = 5;  % The number of iterations of the simulation
nSym = 1000;    % The number of symbols per packet
SNR_Vec = 0:2:16;
lenSNR = length(SNR_Vec);

M = 16;        % The M-ary number, 2 corresponds to binary modulation

%chan = 1;          % No channel
chan = [1 .2 .4]; % Somewhat invertible channel impulse response,
 Moderate ISI
%chan = [0.227 0.460 0.688 0.460 0.227]';   % Not so invertible,
 severe ISI


% Create a vector to store the BER computed during each iteration
berVec = zeros(numIter, lenSNR);
eqlBerVec = zeros(numIter, lenSNR);
% Run the simulation numIter amount of times
```

Convolutional

```
%trel = poly2trellis([5 4],[23 35 0;0 5 13]); % Define trellis.
trel = poly2trellis(7,[171 133]);       %7 is the constraint length.
 171 173 define the system.
traceBack = 32;
codeRate = 1/2;
```

Below is the hard decision approach we tried. It worked worse than soft

```
    %decision. And soft decision is the more complicated case. So only
 soft
    %decision is shown.
    %enc = comm.ConvolutionalEncoder(trel);
    %dec =
 comm.ViterbiDecoder('TrellisStructure',trel,'InputFormat','Hard','TracebackDepth'
 'Continuous');       %Hard
```

iteration

```
tic
for i = 1:numIter

    %  bits = randint(1, nSym*M, [0 1]);      % Generate random bits
    bits = randi(2,[codeRate*nSym*log2(M), 1])-1;


    % If you increase the M-ary number, as you most likely will,
 you'll need to
    % convert the bits to integers. See the BIN2DE function
    % For binary, our MSG signal is simply the bits

    msg = bi2de(reshape(bits,log2(M),[]).');
    encodedMSG = convenc(bits,trel);            %Encoding using
 trellis generated above.

    for j = 1:lenSNR % one iteration of the simulation at each SNR
 Value

        noise_addition = 10*log10(log2(M)*codeRate);
  %To use soft decision, the variance of the noise is required for
 demodulation.
        noise_var = 10.^(-(SNR_Vec(j) + noise_addition)/10);

        tx =
 qammod(encodedMSG,M,'UnitAveragePower',true,'InputType','bit');  %
 BPSK modulate the signal
        tx2 =
 qammod(bits,M,'UnitAveragePower',true,'InputType','bit');

        if isequal(chan,1)
            txChan = tx;
            txChan2 = tx2;
        elseif isa(chan,'channel.rayleigh')
            reset(chan) % Draw a different channel each iteration
            txChan = filter(chan,tx);
        else
            txChan = filter(chan,1,tx);  % Apply the channel.
            txChan2 = filter(chan,1,tx2);
        end

        % Convert from EbNo to SNR.
        % Note: Because No = 2*noiseVariance^2, we must add ~3 dB
        % to get SNR (because 10*log10(2) ~= 3).
        txNoisy =
 awgn(txChan,10*log10(log2(M))+SNR_Vec(j),'measured'); % Add AWGN
        txNoisy2 =
 awgn(txChan2,10*log10(log2(M))+SNR_Vec(j),'measured');

        rx = txNoisy;
        rx2 = txNoisy2;
```

```
        % Again, if M was a larger number, I'd need to convert my
symbols
        % back to bits here.

        rxMSG =
qamdemod(rx2,M,'UnitAveragePower',true,'OutputType','bit');
        noEqlMSG =
qamdemod(rx,M,'UnitAveragePower',true,'OutputType','bit');

        %rxMSG = reshape(de2bi(rx,log2(M)),[],1);


        %Equilizer
        mu = 0.001; %step size
        trainlen = 200;
        n = 8; %number of weights
        const = qammod((0:1:M-1),M);
        trainSig=tx(1:trainlen);

        %LMS decision-feedback equalizer
        nfwd = 16;
        nfbk = 12;
        dfeLMS = dfe(nfwd,nfbk,lms(mu));
        dfeLMS.SigConst = const; % Set signal constellation.
        dfeLMS.ResetBeforeFiltering = 0;

        %RLS decision-feedback equalizer
        dfeRLS = dfe(nfwd,nfbk,rls(0.99,0.9));
        dfeRLS.SigConst = const; % Set signal constellation.
        dfeRLS.ResetBeforeFiltering = 0;

        %lms,linear
        %trainMSG = reshape(de2bi(tx(1:trainlen),log2(M)),[],1);
        linLMS = lineareq(n, lms(mu)); % Create an equalizer object.
        linLMS.SigConst = const; % Set signal constellation.
        linLMS.ResetBeforeFiltering = 0;

        %rls,linear
        linRLS = lineareq(n, rls(1,0.1)); % Create an equalizer
object.
        linRLS.SigConst = const; % Set signal constellation.
        linRLS.ResetBeforeFiltering = 0;

        %Again, linRLS is picked.

        %delay = (numRefTap-1)/eqobj.nSampPerSym;
        [y,eqlSig] = equalize(linRLS,rx,trainSig); % Equalize.
        eqlMSG =
qamdemod(eqlSig,M,'UnitAveragePower',true,'OutputType','bit');
        eqlMSG_soft = qamdemod(eqlSig,M,'OutputType','approxllr', ...
            'UnitAveragePower',true,'NoiseVariance',noise_var);
        %decodedMSG = dec(eqlMSG_soft);
```

```
        decodedMSG =
 vitdec(eqlMSG_soft,trel,traceBack,'cont', 'unquant');

        % Compute and store the BER for this iteration

        rxMSG = bi2de(reshape(rxMSG,log2(M),[]).');
        %decodedMSG = bi2de(reshape(decodedMSG,log2(M),[]).');
        [zzz, berVec(i,j)] = biterr(msg, rxMSG);  % We're interested
 in the BER, which is the 2nd output of BITERR

        [zzz, eqlBerVec(i,j)] = biterr(bits(trainlen+1:end-traceBack),
 decodedMSG(trainlen+traceBack+1:end));        %For Conv Code
        [zzz, eqlBerVec(i,j)] = biterr(bits(trainlen+1:end-traceBack),
 decodedMSG(trainlen+traceBack+1:end));
```

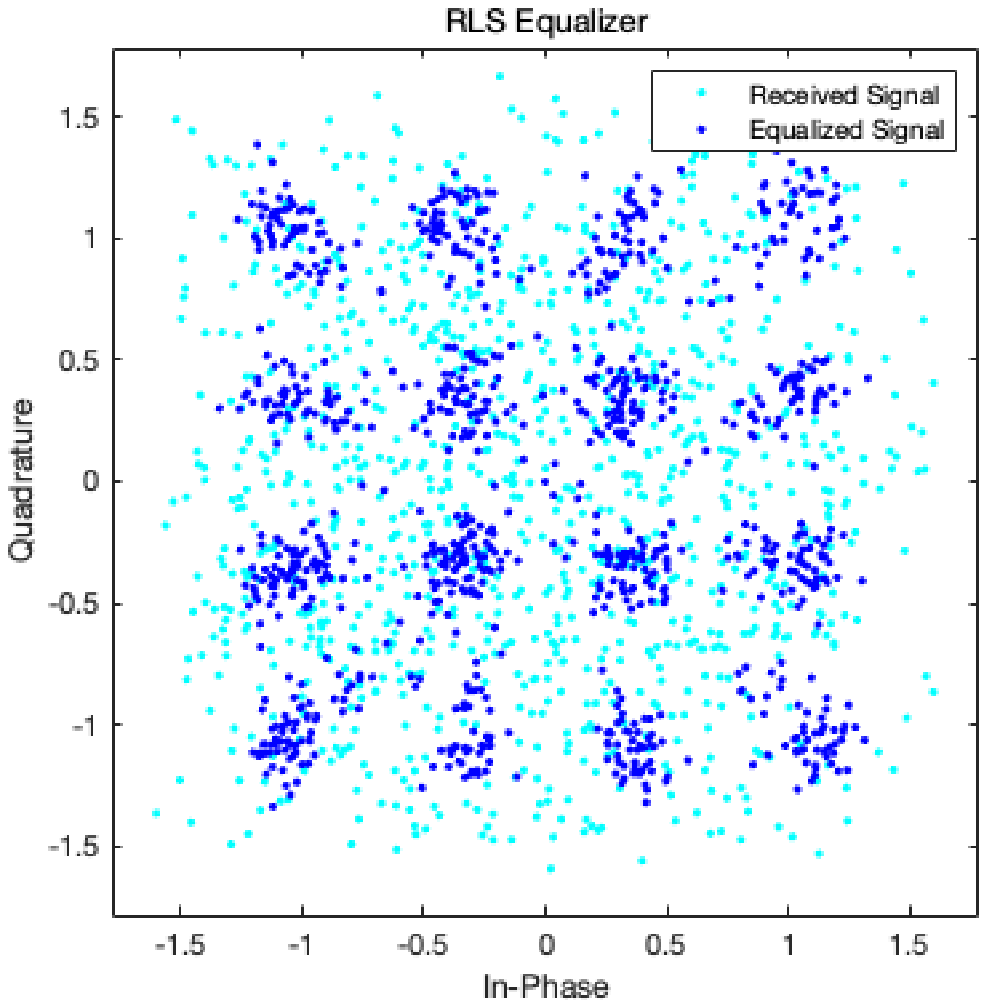
Except for getting rid of the traning part, we also need to deal with delay between input and output caused by convolution, which is equal to traceback in this case because the rate is 1/2.

```
        % The best result we got is 8-QAM, the bit rate is improved
 while
        % keeping the BER below e-6.

        Bit_Rate = (log2(M)*nSym - trainlen) / 1000;

    end  % End SNR iteration
end      % End numIter iteration
time = toc;
time


time =

    5.7438
```

Plots

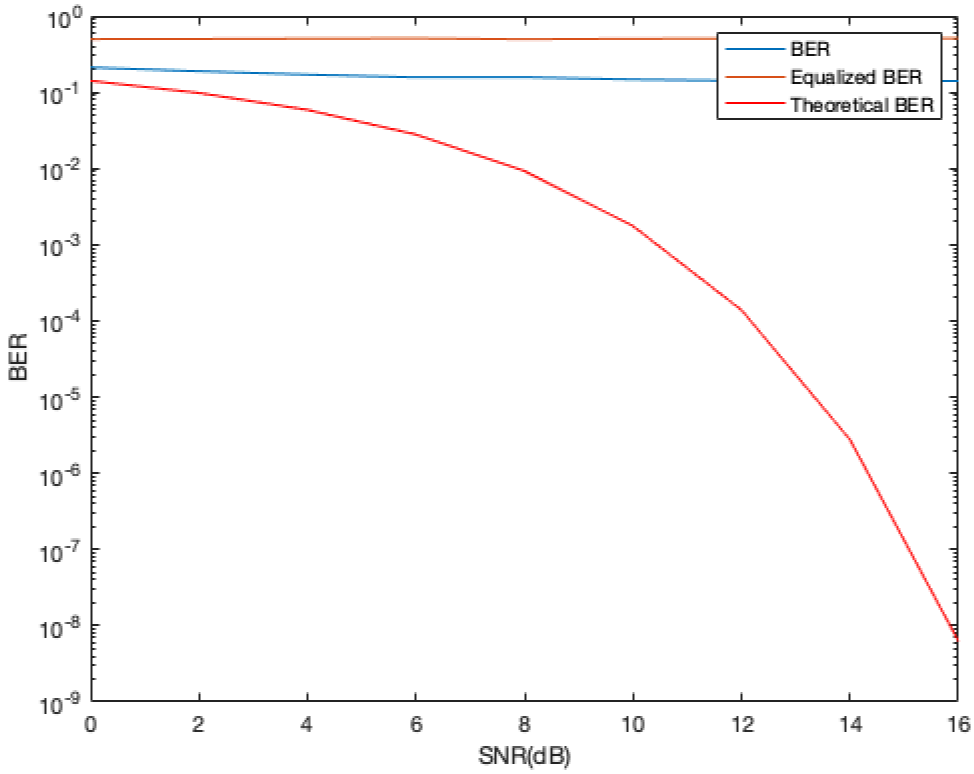
Played with M-ary QAM Scatter plot to see how equilizers work on

```
h = scatterplot(rx,1,0,'c.');
hold on
scatterplot(y,1,0,'b.',h)
legend('Received Signal','Equalized Signal')
title('RLS Equalizer')
hold off
%
```



Compute and plot the mean BER. The result at 12dB is 0. Which fits the requirement.

```
figure;
ber = mean(berVec,1);
eqlBer = mean(eqlBerVec,1);
semilogy(SNR_Vec, ber);
hold on
semilogy(SNR_Vec, eqlBer);


berTheory = berawgn(SNR_Vec,'qam',M);
hold on
semilogy(SNR_Vec,berTheory,'r')
xlabel("SNR(dB)")
ylabel("BER")
legend('BER', 'Equalized BER','Theoretical BER')
```



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ECE 300 Communication Theory Matlab Project 2 Using BCH

Table of Contents

Zheng Liu, Jing Jiang, Tianshu Ren

Project Description

Our Goal in part 2 is to Achieve BER of 10^-6 at 12 dB SNR over moderate ISI channel using whatever means possible.

Algorithm Initialization

```
clear all;close all;clc
numIter = 5;  % The number of iterations of the simulation
nSym = 1000;    % The number of symbols per packet
SNR_Vec = 0:2:16;
lenSNR = length(SNR_Vec);

M = 4;        % The M-ary number, 2 corresponds to binary modulation

%chan = 1;          % No channel
chan = [1 .2 .4]; % Somewhat invertible channel impulse response,
 Moderate ISI
%chan = [0.227 0.460 0.688 0.460 0.227]';   % Not so invertible,
 severe ISI


% Create a vector to store the BER computed during each iteration
berVec = zeros(numIter, lenSNR);
eqlBerVec = zeros(numIter, lenSNR);
% Run the simulation numIter amount of times
```

Block code

```
N = 63;  % Codeword length
K = 24;  % Message length
S = K;  % Shortened message length

   % N and K have to be paired up. All valid pairs are shown by
 bchnumerr.
   % Small K can deal with more bits of error but low efficiency. BCH
 works
```

```
    % only if N and K are picked so that many parity bits are used.
 Therefore,
    % it is not ideal for maximizing bit rate. Demo of it working uses
 4-QAM.
```

BCH

```
bchnumerr(63)        %determine K given N. ie. N and K has to be a
 valid pair in the result
%gp = bchgenpoly(N,K);  %Tried but did not improve performance. Just
 go with default.
enc = comm.BCHEncoder(N,K);
dec = comm.BCHDecoder(N,K);


ans =

    63    57     1
    63    51     2
    63    45     3
    63    39     4
    63    36     5
    63    30     6
    63    24     7
    63    18    10
    63    16    11
    63    10    13
    63     7    15
```

Iteration

```
tic
for i = 1:numIter

    %  bits = randint(1, nSym*M, [0 1]);     % Generate random bits
    bits = randi(2,[K*nSym*log2(M), 1])-1;
    % New bits must be generated at every
    % iteration

    % If you increase the M-ary number, as you most likely will,
 you'll need to
    % convert the bits to integers. See the BIN2DE function
    % For binary, our MSG signal is simply the bits
    encodedMSG = enc(bits);

    for j = 1:lenSNR % one iteration of the simulation at each SNR
 Value

        tx =
 qammod(encodedMSG,M,'UnitAveragePower',true,'InputType','bit');
  %Input has to be bits.
```

```
        tx2 =
qammod(bits,M,'UnitAveragePower',true,'InputType','bit');
 %This signal does not go through coding or equalizer. (Control for
comparison and debugging )

        if isequal(chan,1)
            txChan = tx;
            txChan2 = tx2;
        elseif isa(chan,'channel.rayleigh')
            reset(chan) % Draw a different channel each iteration
            txChan = filter(chan,tx);
        else
            txChan = filter(chan,1,tx);  % Apply the channel.
            txChan2 = filter(chan,1,tx2);
        end

        % Convert from EbNo to SNR.
        % Note: Because No = 2*noiseVariance^2, we must add ~3 dB
        % to get SNR (because 10*log10(2) ~= 3).
        txNoisy =
awgn(txChan,10*log10(log2(M))+SNR_Vec(j),'measured'); % Add AWGN
        txNoisy2 =
awgn(txChan2,10*log10(log2(M))+SNR_Vec(j),'measured');
        %txNoisy = awgn(txChan,3+SNR_Vec(j),'measured'); % Add AWGN
        rx = txNoisy;
        rx2 = txNoisy2;
        %rx_demod = qamdemod(txNoisy,M); % Demodulate

        % Again, if M was a larger number, I'd need to convert my
symbols
        % back to bits here.

        rxMSG =
qamdemod(rx2,M,'UnitAveragePower',true,'OutputType','bit');
        noEqlMSG =
qamdemod(rx,M,'UnitAveragePower',true,'OutputType','bit');   %Encoded
but will not be equalized (for tuning and debugging)


        %Equilizer
        mu = 0.001; %step size
        trainlen = 200;
        n = 8; %number of weights
        const = qammod((0:1:M-1),M);
        trainSig=tx(1:trainlen);

        %LMS decision-feedback equalizer
        nfwd = 16;
        nfbk = 12;
        dfeLMS = dfe(nfwd,nfbk,lms(mu));
        dfeLMS.SigConst = const; % Set signal constellation.
        dfeLMS.ResetBeforeFiltering = 0;

        %RLS decision-feedback equalizer
```

```
        dfeRLS = dfe(nfwd,nfbk,rls(0.99,0.9));
        dfeRLS.SigConst = const; % Set signal constellation.
        dfeRLS.ResetBeforeFiltering = 0;

        %lms,linear
        %trainMSG = reshape(de2bi(tx(1:trainlen),log2(M)),[],1);
        linLMS = lineareq(n, lms(mu)); % Create an equalizer object.
        linLMS.SigConst = const; % Set signal constellation.
        linLMS.ResetBeforeFiltering = 0;

        %rls,linear
        linRLS = lineareq(n, rls(1,0.1)); % Create an equalizer
 object.
        linRLS.SigConst = const; % Set signal constellation.
        linRLS.ResetBeforeFiltering = 0;

        %Decide to use linear RLS after many trials because of its
 good
        %performance.


        [y,eqlSig] = equalize(linRLS,rx,trainSig); % Equalize.
        eqlMSG =
 qamdemod(eqlSig,M,'UnitAveragePower',true,'OutputType','bit');
        decodedMSG = dec(eqlMSG);
```

Compute and store the BER for this iteration

```
        %decodedMSG = bi2de(reshape(decodedMSG,log2(M),[]).');
        [zzz, berVec(i,j)] = biterr(bits, rxMSG);  % We're interested
 in the BER, which is the 2nd output of BITERR

        [zzz, eqlBerVec(i,j)] = biterr(bits(trainlen+1:end),
 decodedMSG(trainlen+1:end));        %For Block Code
        [zzz, eqlBerVec(i,j)] = biterr(bits(trainlen+1:end),
 decodedMSG(trainlen+1:end));

    end  % End SNR iteration
end      % End numIter iteration
time = toc;
time
```

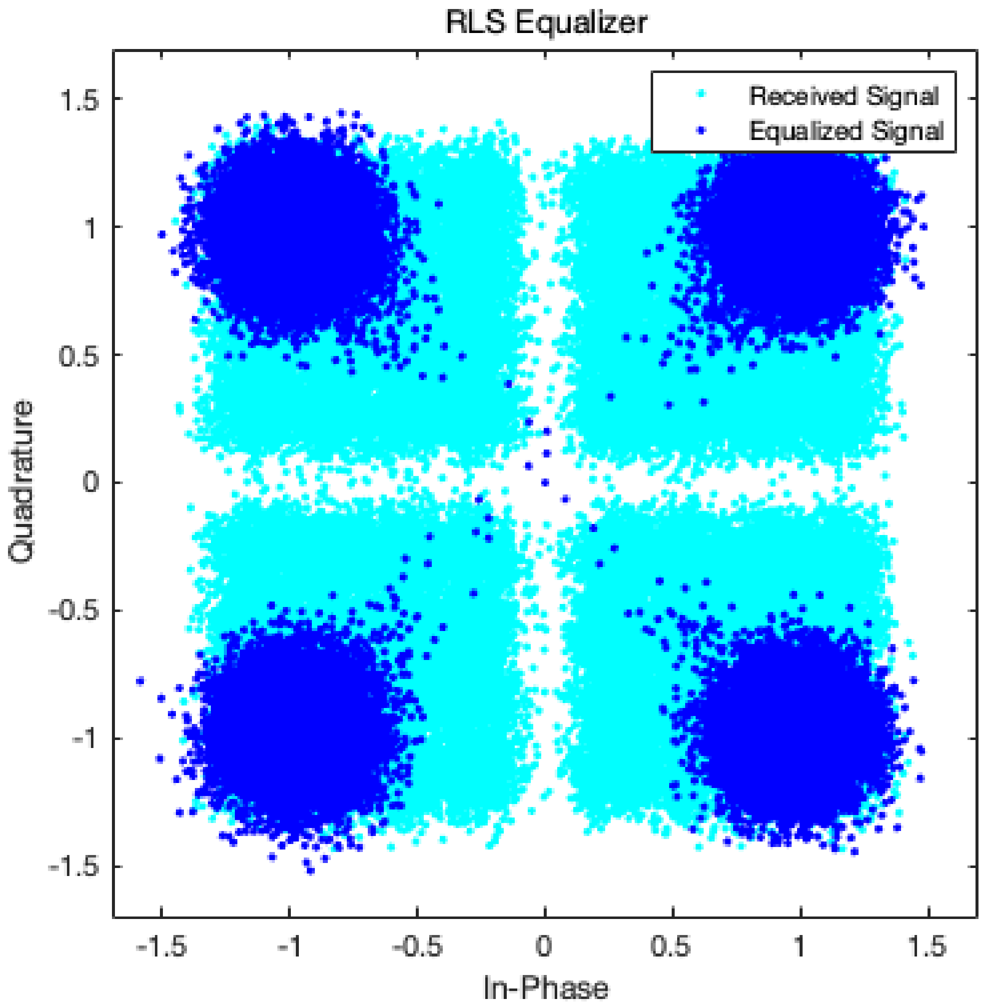
```
time =

  174.2056
```

Plots

```
    %Played with M-ary QAM Scatter plot to see how equilizers work on
%
h = scatterplot(rx,1,0,'c.');
hold on
```

```
scatterplot(y,1,0,'b.',h)
legend('Received Signal','Equalized Signal')
title('RLS Equalizer')
hold off
%
```

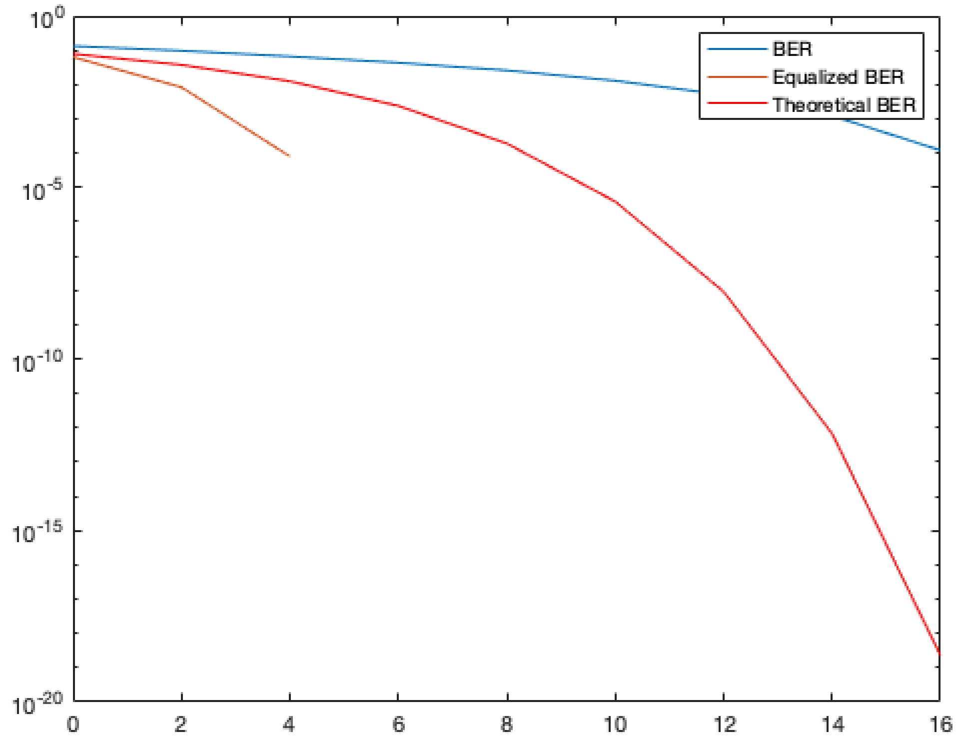


Compute and plot the mean BER. The result at 12dB is 0. Which fits the requirement.

```
figure;
ber = mean(berVec,1);
eqlBer = mean(eqlBerVec,1);
semilogy(SNR_Vec, ber);
hold on
semilogy(SNR_Vec, eqlBer);

berTheory = berawgn(SNR_Vec,'qam',M);
hold on
semilogy(SNR_Vec,berTheory,'r')
```

```
legend('BER', 'Equalized BER','Theoretical BER')
```



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ECE 300 Communication Theory Matlab Project 2 Using Reed-Solomon

Table of Contents

Zheng Liu, Jing Jiang, Tianshu Ren

Project Description

Our Goal in part 2 is to Achieve BER of 10^-6 at 12 dB SNR over moderate ISI channel using whatever means possible.

Algorithm Initialization

```
clear all;close all;clc
numIter = 5;  % The number of iterations of the simulation
nSym = 1000;    % Real symbol number needs to be scaled because of
 encoding. See bit generation code.
SNR_Vec = 0:2:16;
lenSNR = length(SNR_Vec);

M = 4;        % The M-ary number, 2 corresponds to binary modulation

%chan = 1;          % No channel
chan = [1 .2 .4]; % Somewhat invertible channel impulse response,
 Moderate ISI
%chan = [0.227 0.460 0.688 0.460 0.227]';   % Not so invertible,
 severe ISI


% Create a vector to store the BER computed during each iteration
berVec = zeros(numIter, lenSNR);
eqlBerVec = zeros(numIter, lenSNR);
% Run the simulation numIter amount of times
```

Block code

```
N = 15;  % Codeword length
K = 2;  % Message length
S = K;  % Shortened message length
```

```
   % N and K have to be paired up. All valid pairs are shown by
 bchnumerr.
   % Small K can deal with more bits of error but low efficiency. BCH
 works
   % only if N and K are picked so that many parity bits are used.
 Therefore,
   % it is not ideal for maximizing bit rate. Demo of it working uses
 4-QAM.
```

Reed Solomon

```
enc = comm.RSEncoder(N,K,'BitInput',true);
dec = comm.RSDecoder(N,K,'BitInput',true);


%numPuncs = N - K;
%m = log2(N + 1);
%enc.PuncturePatternSource = 'Property';
%enc.PuncturePattern = [ones(N-K-numPuncs,1); zeros(numPuncs,1)];
% Set the shortened message length values
%enc.ShortMessageLength = S;
% Specify the field of GF(2^6) in the RS encoder/decoder System
 objects, by setting the PrimitivePolynomialSource property ...
% to 'Property' and the PrimitivePolynomial property to a 6th degree
 primitive polynomial.
%enc.PrimitivePolynomialSource = 'Property';
%enc.PrimitivePolynomial = de2bi(primpoly(m, 'nodisplay'), 'left-
msb');

%dec.PuncturePatternSource = 'Property';
%dec.PuncturePattern = [ones(N-K-numPuncs,1); zeros(numPuncs,1)];
% Set the shortened message length values
%dec.ShortMessageLength = S;
% Specify the field of GF(2^6) in the RS encoder/decoder System
 objects, by setting the PrimitivePolynomialSource property ...
% to 'Property' and the PrimitivePolynomial property to a 6th degree
 primitive polynomial.
%dec.PrimitivePolynomialSource = 'Property';
%dec.PrimitivePolynomial = de2bi(primpoly(m, 'nodisplay'), 'left-
msb');


%Tried user-defined parameters above but did not get improvement.
%Researched puncture but did not know how to use it.
```

Iteration

```
tic
for i = 1:numIter

    %  bits = randint(1, nSym*M, [0 1]);     % Generate random bits
    bits = randi(2,[K*nSym*log2(M), 1])-1;
```

```
   % New bits must be generated at every
   % iteration

   %msg = bits;
   msg = bi2de(reshape(bits,log2(M),[]).');
   encodedMSG = enc(bits);


   for j = 1:lenSNR % one iteration of the simulation at each SNR
Value

       tx =
qammod(encodedMSG,M,'UnitAveragePower',true,'InputType','bit');  %
BPSK modulate the signal
       tx2 =
qammod(bits,M,'UnitAveragePower',true,'InputType','bit');

       if isequal(chan,1)
           txChan = tx;
           txChan2 = tx2;
       elseif isa(chan,'channel.rayleigh')
           reset(chan) % Draw a different channel each iteration
           txChan = filter(chan,tx);
       else
           txChan = filter(chan,1,tx);  % Apply the channel.
           txChan2 = filter(chan,1,tx2);
       end

       % Convert from EbNo to SNR.
       % Note: Because No = 2*noiseVariance^2, we must add ~3 dB
       % to get SNR (because 10*log10(2) ~= 3).
       txNoisy =
awgn(txChan,10*log10(log2(M))+SNR_Vec(j),'measured'); % Add AWGN
       txNoisy2 =
awgn(txChan2,10*log10(log2(M))+SNR_Vec(j),'measured');
       %txNoisy = awgn(txChan,3+SNR_Vec(j),'measured'); % Add AWGN
       rx = txNoisy;
       rx2 = txNoisy2;
       %rx_demod = qamdemod(txNoisy,M); % Demodulate

       % Again, if M was a larger number, I'd need to convert my
symbols
       % back to bits here.

       rxMSG =
qamdemod(rx2,M,'UnitAveragePower',true,'OutputType','bit');
       noEqlMSG =
qamdemod(rx,M,'UnitAveragePower',true,'OutputType','bit');

       %rxMSG = reshape(de2bi(rx,log2(M)),[],1);



       %Equilizer
```

```
        mu = 0.001; %step size
        trainlen = 200;
        n = 8; %number of weights
        const = qammod((0:1:M-1),M);
        trainSig=tx(1:trainlen);

        %LMS decision-feedback equalizer
        nfwd = 16;
        nfbk = 12;
        dfeLMS = dfe(nfwd,nfbk,lms(mu));
        dfeLMS.SigConst = const; % Set signal constellation.
        dfeLMS.ResetBeforeFiltering = 0;

        %RLS decision-feedback equalizer
        dfeRLS = dfe(nfwd,nfbk,rls(0.99,0.9));
        dfeRLS.SigConst = const; % Set signal constellation.
        dfeRLS.ResetBeforeFiltering = 0;

        %lms,linear
        %trainMSG = reshape(de2bi(tx(1:trainlen),log2(M)),[],1);
        linLMS = lineareq(n, lms(mu)); % Create an equalizer object.
        linLMS.SigConst = const; % Set signal constellation.
        linLMS.ResetBeforeFiltering = 0;

        %rls,linear
        linRLS = lineareq(n, rls(1,0.1)); % Create an equalizer
 object.
        linRLS.SigConst = const; % Set signal constellation.
        linRLS.ResetBeforeFiltering = 0;

        %lms,decision feedback

        %delay = (numRefTap-1)/eqobj.nSampPerSym;
        [y,eqlSig] = equalize(linRLS,rx,trainSig); % Equalize.
        eqlMSG =
 qamdemod(eqlSig,M,'UnitAveragePower',true,'OutputType','bit');
        decodedMSG = dec(eqlMSG);


        % Compute and store the BER for this iteration

        rxMSG = bi2de(reshape(rxMSG,log2(M),[]).');
        %decodedMSG = bi2de(reshape(decodedMSG,log2(M),[]).');
        [zzz, berVec(i,j)] = biterr(msg, rxMSG);  % We're interested
 in the BER, which is the 2nd output of BITERR

        [zzz, eqlBerVec(i,j)] = biterr(bits(trainlen+1:end),
 decodedMSG(trainlen+1:end));        %For Block Code
        [zzz, eqlBerVec(i,j)] = biterr(bits(trainlen+1:end),
 decodedMSG(trainlen+1:end));
    end  % End SNR iteration
end      % End numIter iteration
time = toc;
time
```

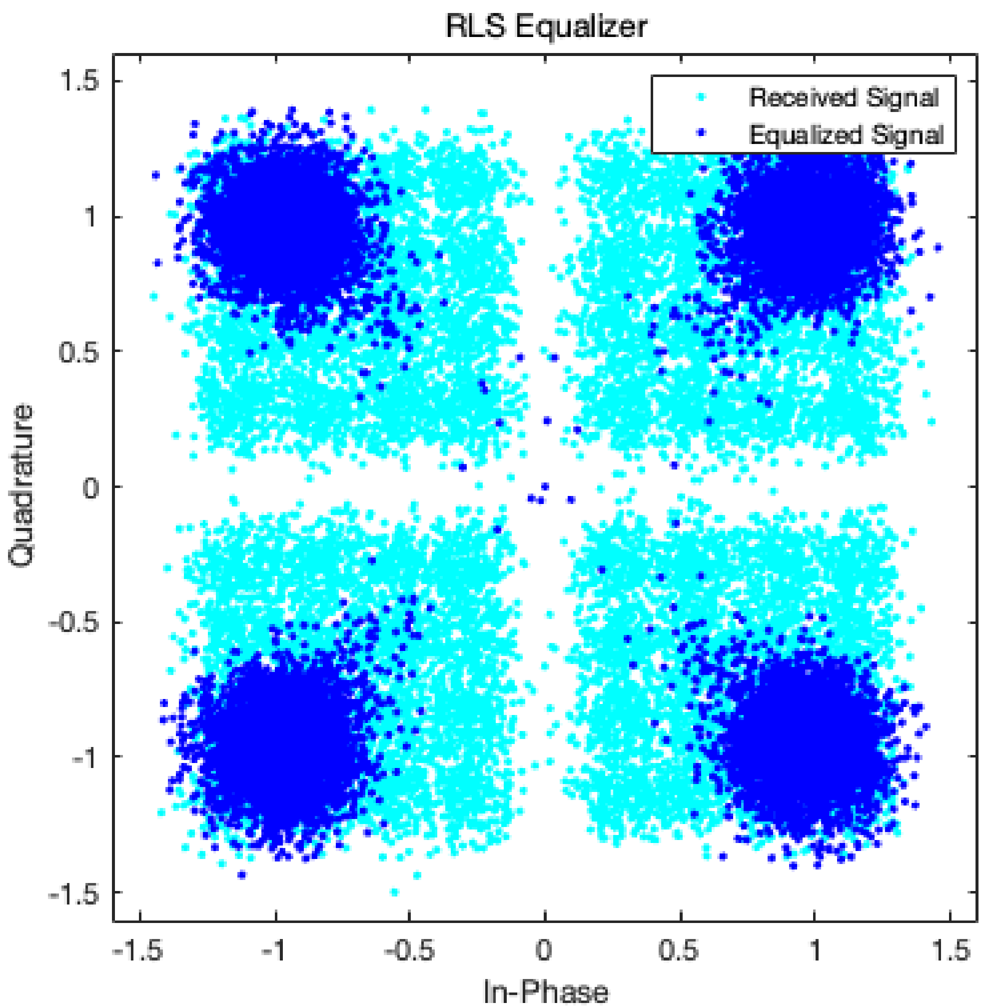
```
time =

   42.3645
```

Plots

Played with M-ary QAM Scatter plot to see how equilizers work on

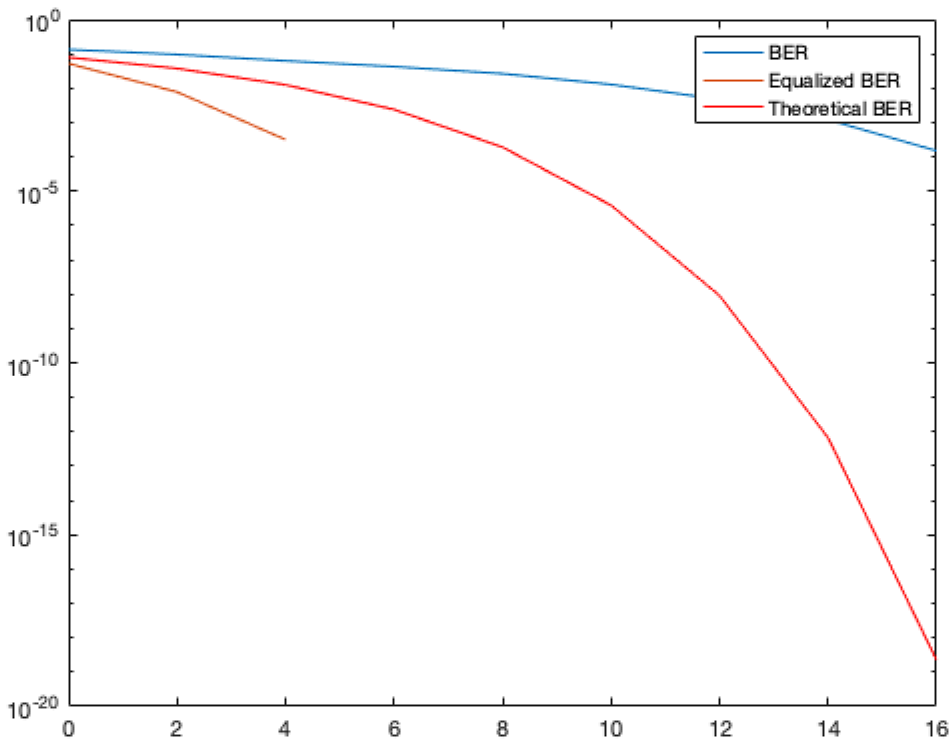
```
h = scatterplot(rx,1,0,'c.');
hold on
scatterplot(y,1,0,'b.',h)
legend('Received Signal','Equalized Signal')
title('RLS Equalizer')
hold off
%
```



Compute and plot the mean BER. The result at 12dB is 0. Which fits the requirement.

```
figure;
ber = mean(berVec,1);
eqlBer = mean(eqlBerVec,1);
semilogy(SNR_Vec, ber);
hold on
semilogy(SNR_Vec, eqlBer);

berTheory = berawgn(SNR_Vec,'qam',M);
hold on
semilogy(SNR_Vec,berTheory,'r')
legend('BER', 'Equalized BER','Theoretical BER')
```



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