QAM 16 Viterbi

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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
```

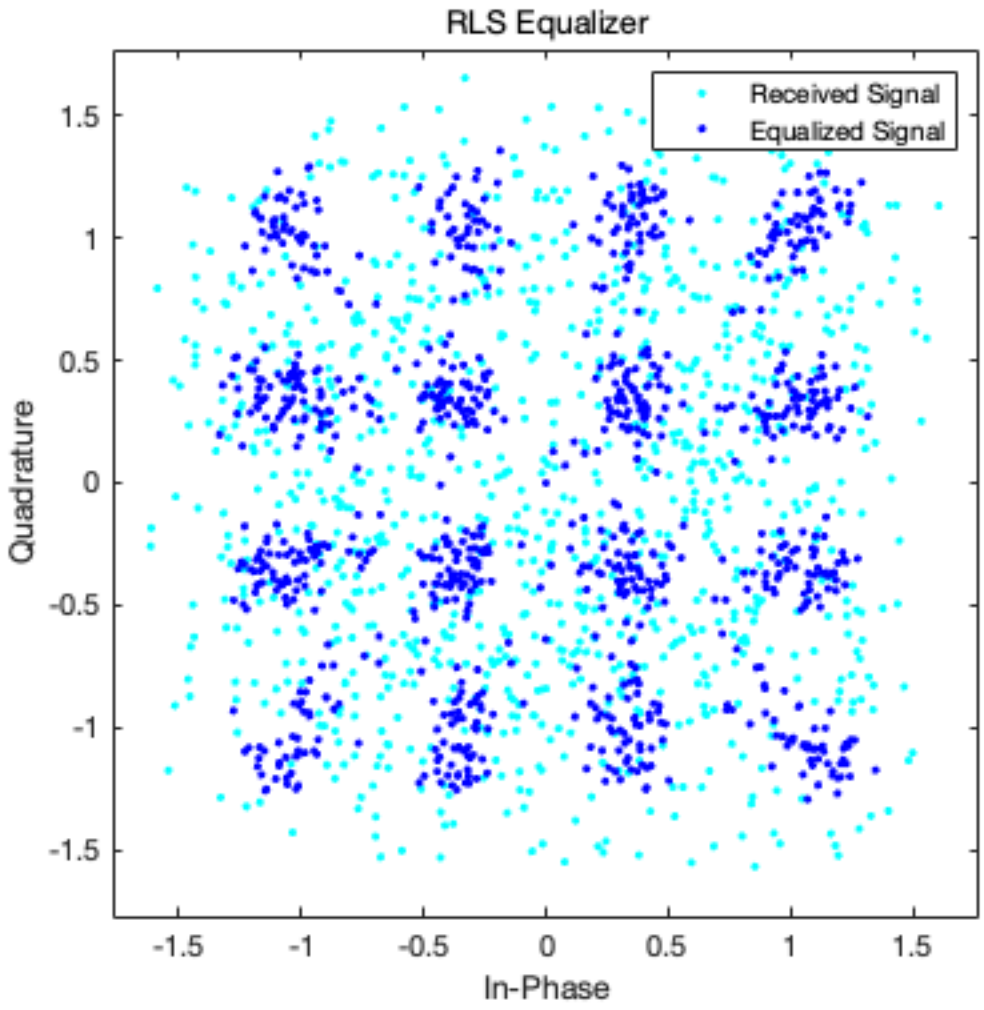
```
time =

    7.4328
```

Plots

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

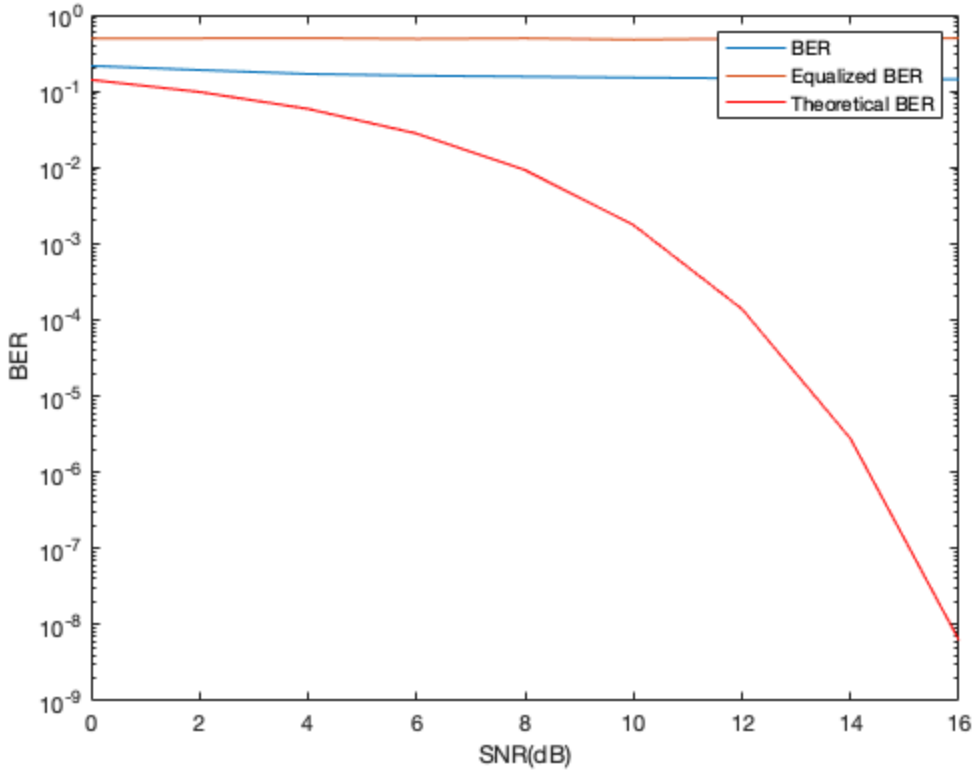
```
h = scatterplot(rx,1,0,'c.');
hold on
scatterplot(y,1,0,'b.',h)
legend('Received Signal','Equalized Signal')
title('RLS Equalizer')
hold off
%
```



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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