Convolution Coding for Rate=1/3 and Kc=4

```
EbByNodb = 0:0.5:10;

R = 1/3;
k = 1;
n = 3;
kc = 4;

% Generating Practical_error and Theoratical_error matrices :
practical_error_Hard = zeros(1,length(EbByNodb));
practical_error_Soft = zeros(1, length(EbByNodb));
theoretical_error = zeros(1,length(EbByNodb));


Index = 1;
Index1 = 1;

N = 5000;
for j = EbByNodb
    EbByNo = 10^(j/10);
    std_dev = sqrt (1/(2*R*EbByNo));

    %BER = 0.5*erfc(1/((sqrt(2)*std_dev)) );
    %BER = 0.5*erfc( sqrt(EbByNo) );
    BER = 0.5 * erfc(sqrt(1 * EbByNo));

    No_of_errors_Hard = 0;
    No_of_errors_Soft = 0;

    i = 1;
    while i <= N

        %Generate Random msg
        message = randi ([0 1],1,10);
        message = [message zeros(1,kc-1)];
        %disp(msg);

        enc_array = Encoder(message);  % Encoding the msg
        %disp(enc_array);

        modulated_msg = Modulation(enc_array , std_dev);  %Modulating msg
through BPSK modulation
        %disp(modulated_msg);

        demodulated_msg = modulated_msg < 0;
        %disp(demodulated_msg);

        % Call Viterbi function
```

```
        decoded_msg_Hard = Hard_Decoder(demodulated_msg);
        decoded_msg_Soft = Soft_Decoder(modulated_msg);
        %disp(decoded_msg);

        No_of_errors_Hard = No_of_errors_Hard + sum(message ~=
decoded_msg_Hard);
        No_of_errors_Soft = No_of_errors_Soft + sum(message ~=
decoded_msg_Soft);
        i = i + 1;
    end

    practical_error_Hard(Index) = (No_of_errors_Hard /
(N*length(message)));  % Calculating the practical error through hard
decision decoding
    practical_error_Soft(Index) = (No_of_errors_Soft /
(N*length(message)));  % Calculating the practical error through soft
decision decoding
    theoretical_error(1,Index1) = BER;  % Theoretical error from the formula
of BER
    Index = Index + 1;
    Index1 = Index1 + 1;
end

practical_error_Soft
```

```
practical_error_Soft = 1×21
    0.1611    0.1244    0.0942    0.0626    0.0445    0.0260    0.0172    0.0094 ⋯
```

```
practical_error_Hard
```

```
practical_error_Hard = 1×21
    0.2157    0.1905    0.1494    0.1246    0.0988    0.0723    0.0500    0.0326 ⋯
```

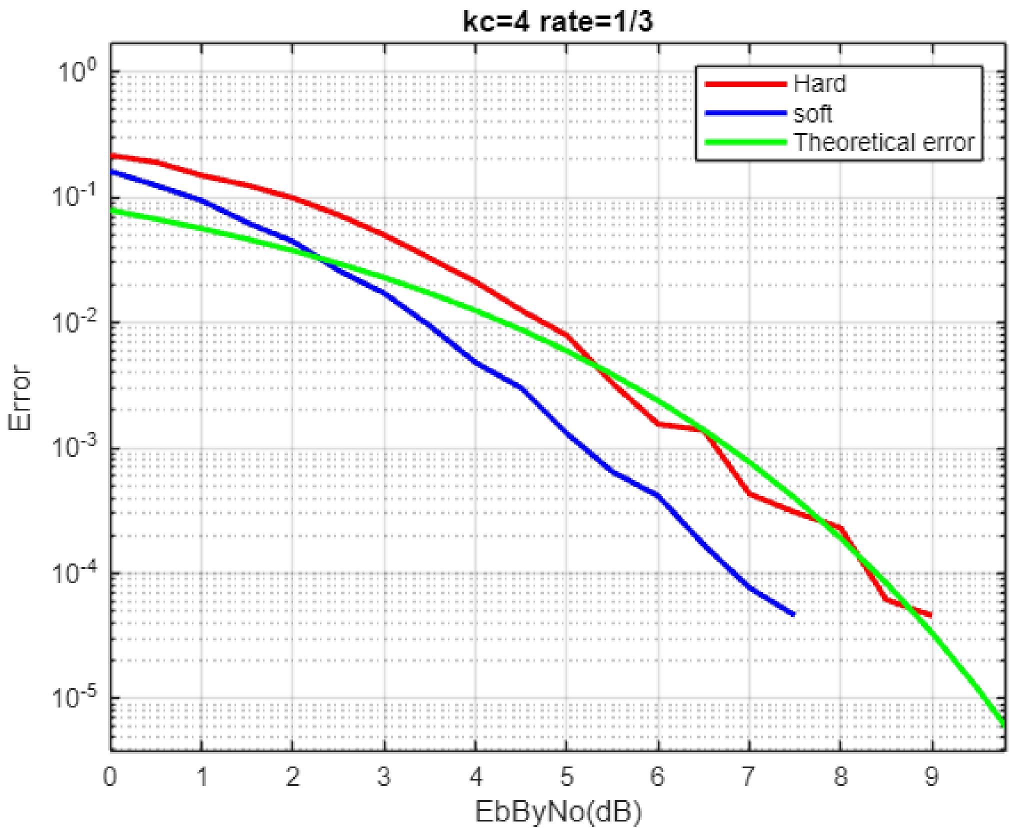
```
theoretical_error
```

```
theoretical_error = 1×21
    0.0786    0.0671    0.0563    0.0464    0.0375    0.0297    0.0229    0.0172 ⋯
```

```
% Ploting the Graph From our Results
semilogy(EbByNodb, practical_error_Hard, 'r-', 'LineWidth', 2.0);
hold on;
semilogy(EbByNodb, practical_error_Soft, 'b-', 'LineWidth', 2.0);
semilogy(EbByNodb, theoretical_error, 'g-', 'LineWidth', 2.0);
legend('Hard','soft', 'Theoretical error');
title('kc=4 rate=1/3');
grid on
xlabel('EbByNo(dB)');
ylabel('Error');
hold off;

xlim([0.1 9.9])
ylim([0.00 0.90])
```

```
xlim([-0.0 9.8])
ylim([0.00 1.67])
```



Encoding Function

```
function observe = Encoder(input)

    % Initialize shift register
    g1 = [1 0 1 1]; % Generator polynomial for output bit 1
    g2 = [1 1 0 1]; % Generator polynomial for output bit 2
    g3 = [1 1 1 1]; % Generator polynomial for output bit 3

    observe = zeros(1, length(input) * 3);
    state = [0 0 0];
    observe_index = 1;
    %disp(observe);

    % Iterate over input sequence
    for i = 1:length(input)

        % Update the state of the encoder
```

```
        reg = [input(i) state];
        state = [input(i) state(1:2)];

        % Encode the input message using the generator polynomials

        output1 = mod(reg*g1', 2);
        output2 = mod(reg*g2', 2);
        output3 = mod(reg*g3', 2);

        % Store encoded bits in 1D array

        observe(observe_index) = output1;
        observe(observe_index + 1) = output2;
        observe(observe_index + 2) = output3;
        observe_index = observe_index + 3;
    end

end
```

Modulation Function

```
function modulated_opeartion = Modulation(encoded_msg,std_dev)
     % BPSK modulation
     s = 1 - 2 * encoded_msg;
     modulated_opeartion = s + std_dev * randn(1, length(encoded_msg));
end
```

Hamming Distance calculator Function

```
function dist = Hamming_Distance(x,y,w,z,p,q)
    dist = xor(x,z)+xor(y,p)+xor(w,q);
end
```

Euclidean distance calculator function

```
function dist = Euclidean_Distance(x,y,w,z,p,q)
    dist = sqrt((x-z)^2+(y-p)^2+(w-q)^2);
end
```

Hard Decision Decoding Function

```
function decoded_msg_Hard = Hard_Decoder(observed)

 st_metric = struct('zero', 0, 'one', 0, 'two', 0, 'three', 0 , 'four', 0 ,
'five', 0 , 'six', 0 , 'seven', 0);
 state_machine = struct( ...
            'zero',...
            struct('b1', struct('out_b', [1 1 1], 'prev_st', 'one',
'input_b',0), ...
                      'b2', struct('out_b', [0 0 0], 'prev_st', 'zero',
'input_b',0)), ...
            'one',...
            struct('b1', struct('out_b', [0 1 0], 'prev_st', 'three',
'input_b',0), ...
                      'b2', struct('out_b', [1 0 1], 'prev_st', 'two',
'input_b',0)), ...
            'two', ...
            struct('b1', struct('out_b', [0 1 1], 'prev_st', 'four',
'input_b',0), ...
                      'b2', struct('out_b', [1 0 0], 'prev_st', 'five',
'input_b',0)), ...
            'three', ...
            struct('b1', struct('out_b', [1 1 0], 'prev_st', 'six',
'input_b',0), ...
                      'b2', struct('out_b', [0 0 1], 'prev_st', 'seven',
'input_b',0)), ...
            'four',...
            struct('b1', struct('out_b', [1 1 1], 'prev_st', 'zero',
'input_b',1), ...
                      'b2', struct('out_b', [0 0 0], 'prev_st', 'one',
'input_b',1)), ...
            'five',...
            struct('b1', struct('out_b', [1 0 1], 'prev_st',
'three','input_b', 1), ...
                      'b2', struct('out_b', [0 1 0], 'prev_st', 'two',
'input_b',1)), ...
            'six',...
            struct('b1', struct('out_b', [1 0 0], 'prev_st', 'four',
'input_b',1), ...
                      'b2', struct('out_b', [0 1 1], 'prev_st', 'five',
'input_b',1)), ...
            'seven',...
            struct('b1', struct('out_b', [0 0 1], 'prev_st',
'six','input_b', 1), ...
                      'b2', struct('out_b',[1 1 0], 'prev_st', 'seven',
'input_b',1)));
```

```
  % Trellis structure
  decoded_msg_Hard = [];
  mp = cell(1, length(observed)/3 + 1);
  mp{1} = containers.Map();

  for i = fieldnames(state_machine)'
    mp{1}(i{1}) = struct('metric', st_metric.(i{1}));
  end

  for j = 1:length(observed)/3
     mp{j + 1} = containers.Map();

      for i = fieldnames(state_machine)'
          % Check for smallest bit difference from possible previous paths,
adding with previous metric

          previous_state_1 = state_machine.(i{1}).b1.prev_st;
          first_branch_metric = mp{j}
(previous_state_1).metric + (Hamming_Distance(state_machine.
(i{1}).b1.out_b(1),state_machine.(i{1}).b1.out_b(2),state_machine.
(i{1}).b1.out_b(3),observed(3*j-2),observed(3*j-1),observed(3*j)));

          previous_state_2 = state_machine.(i{1}).b2.prev_st;
          second_branch_metric = mp{j}
(previous_state_2).metric + (Hamming_Distance(state_machine.
(i{1}).b2.out_b(1),state_machine.(i{1}).b2.out_b(2),state_machine.
(i{1}).b2.out_b(3),observed(3*j-2),observed(3*j-1),observed(3*j)));

          if first_branch_metric > second_branch_metric
              mp{j + 1}(i{1}) = struct('metric',
second_branch_metric,'branch', 'b2');

          else
              mp{j + 1}(i{1}) = struct('metric', first_branch_metric,
'branch','b1');
          end
      end
  end


  % Traceback the path on smaller metric on last trellis column

  smaller = min(cellfun(@(x) x.metric, mp{end}.values));
  for i = fieldnames(state_machine)'

      if mp{end}(i{1}).metric == smaller
          source_state = i{1};

          for t = length(observed)/3:-1:1
```

```
              branch = mp{t + 1}(source_state).branch;
              % Correcting the index
              decoded_msg_Hard = [state_machine.(source_state).
(branch).input_b,decoded_msg_Hard];
              source_state = state_machine.(source_state).(branch).prev_st;

          end
          %decoded_msg_Hard
          break;
      end
  end
end
```

Soft Decision Decoding

```
function decoded_msg_Soft = Soft_Decoder(observed)


st_metric = struct('zero', 0, 'one', 0, 'two', 0, 'three', 0 , 'four', 0 ,
'five', 0 , 'six', 0 , 'seven', 0);
state_machine = struct( ...
            'zero',...
            struct('b1', struct('out_b', [-1 -1 -1], 'prev_st', 'one',
'input_b',0), ...
                      'b2', struct('out_b', [1 1 1], 'prev_st', 'zero',
'input_b',0)), ...
            'one',...
            struct('b1', struct('out_b', [1 -1 1], 'prev_st', 'three',
'input_b',0), ...
                      'b2', struct('out_b', [-1 1 -1], 'prev_st', 'two',
'input_b',0)), ...
            'two', ...
            struct('b1', struct('out_b', [1 -1 -1], 'prev_st', 'four',
'input_b',0), ...
                      'b2', struct('out_b', [-1 1 1], 'prev_st', 'five',
'input_b',0)), ...
            'three', ...
            struct('b1', struct('out_b', [-1 -1 1], 'prev_st', 'six',
'input_b',0), ...
                      'b2', struct('out_b', [1 1 -1], 'prev_st', 'seven',
'input_b',0)), ...
            'four',...
            struct('b1', struct('out_b', [-1 -1 -1], 'prev_st', 'zero',
'input_b',1), ...
```

```
                      'b2', struct('out_b', [1 1 1], 'prev_st', 'one',
'input_b',1)), ...
            'five',...
            struct('b1', struct('out_b', [-1 1 -1], 'prev_st',
'three','input_b', 1), ...
                      'b2', struct('out_b', [1 -1 1], 'prev_st', 'two',
'input_b',1)), ...
            'six',...
            struct('b1', struct('out_b', [-1 1 1], 'prev_st', 'four',
'input_b',1), ...
                      'b2', struct('out_b', [1 -1 -1], 'prev_st', 'five',
'input_b',1)), ...
            'seven',...
            struct('b1', struct('out_b', [1 1 -1], 'prev_st',
'six','input_b', 1), ...
                      'b2', struct('out_b', [-1 -1 1], 'prev_st', 'seven',
'input_b',1)));

 % Trellis structure
 decoded_msg_Soft = [];
 mp = cell(1, length(observed)/3 + 1);
 mp{1} = containers.Map();

 for i = fieldnames(state_machine)'
   mp{1}(i{1}) = struct('metric', st_metric.(i{1}));
 end

 for j = 1:length(observed)/3
    mp{j + 1} = containers.Map();

     for i = fieldnames(state_machine)'
         % Check for smallest bit difference from possible previous paths,
adding with previous metric

         previous_state_1 = state_machine.(i{1}).b1.prev_st;
         first_branch_metric = mp{j}
(previous_state_1).metric + (Euclidean_Distance(state_machine.
(i{1}).b1.out_b(1),state_machine.(i{1}).b1.out_b(2),state_machine.
(i{1}).b1.out_b(3),observed(3*j-2),observed(3*j-1),observed(3*j)));

         previous_state_2 = state_machine.(i{1}).b2.prev_st;
         second_branch_metric = mp{j}
(previous_state_2).metric + (Euclidean_Distance(state_machine.
(i{1}).b2.out_b(1),state_machine.(i{1}).b2.out_b(2),state_machine.
(i{1}).b2.out_b(3),observed(3*j-2),observed(3*j-1),observed(3*j)));

         if first_branch_metric > second_branch_metric
             mp{j + 1}(i{1}) = struct('metric',
second_branch_metric,'branch', 'b2');
```

```
        else
            mp{j + 1}(i{1}) = struct('metric', first_branch_metric,
'branch','b1');
        end
    end
end


% Traceback the path on smaller metric on last trellis column

smaller = min(cellfun(@(x) x.metric, mp{end}.values));
for i = fieldnames(state_machine)'

    if mp{end}(i{1}).metric == smaller
        source_state = i{1};

        for t = length(observed)/3:-1:1

            branch = mp{t + 1}(source_state).branch;
            % Correcting the index
            decoded_msg_Soft = [state_machine.(source_state).
(branch).input_b,decoded_msg_Soft];
            source_state = state_machine.(source_state).(branch).prev_st;

        end
        %decoded_msg_Soft
        break;
    end
end
end
```