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% Divsalar_K1000_N5000_Q5_Simulate.m
% Simulate transmission and decoding of a regular RA code.
% Copyright Brendan J Frey, January 14, 2018.
% Software written and debugged from 8.00pm to 10.45pm on January
14, 2018.

% Parameters
K=1000; % Number of information bits
EbNo=[-.8:.1:.8]; % List of Gaussian noise levels (dB)
B=10000; % Number of blocks per noise level
I=100; % Number of iterations for decoding
q=5; % Number of times to repeat information bits
Pi=repmat([1:K],[q,1]); % Mapping from repeated bits to
information bits
Pi=Pi(:);
rng(0); % Seed random number generator

% Compute other parameters, allocate memory
N=length(Pi); % Number of transmitted bits
R=K/N; % Rate
P=randperm(N); % Random permuter
s=(2*R*10.^(EbNo/10)).^-.5; % Standard deviation of Gaussian
noise
Lf=zeros(1,N+1); % Forward messages (log-ratios)
Lb=zeros(1,N); % Backward messages (log-ratios)
Lx=zeros(1,K); % Combined messages at information bits (log-
ratios)
Lxd=zeros(1,N); % Messages sent from information bits down to
accumulator
Lxu=zeros(1,N); % Messages sent from accumulator up to
information bits
ber=zeros(1,length(EbNo)); % Bit error rate
wer=zeros(1,length(EbNo)); % Word error rate
fer=zeros(1,length(EbNo)); % Failure to decode rate
fprintf('Number of information bits = %d\n',K);
fprintf('Number of transmitted bits = %d\n',N);
fprintf('Rate = %f\n',R);

% Simulation
for j=1:length(s) % Loop over noise levels
    for b=1:B % Loop over transmitted blocks
        y=randn(1,N)*s(j)+1; % Generate channel output assuming +
1 sent
        Lc=-2*y/s(j)^2; % Channel log-likelihood ratio
        Lf(1)=-1e20; % Initialize forward state of Markov chain
to 0
        Lb(N)=Lc(N); % Initialize backward message to channel llr
        Lxd(:)=0; % Initialize messages from information bits to
0
        for i=1:I % Apply I iterations of decoding
            for n=1:N % Forward pass
                Lf(n+1)=Lc(n)+f(Lf(n),Lxd(n));
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            end;
            for n=N:-1:2 % Backward pass
                Lb(n-1)=Lc(n-1)+f(Lb(n),Lxd(n));
            end;
            Lx(:)=0;
            for n=1:N % Fuse messages at information bits
                Lxu(n)=f(Lf(n),Lb(n));
                Lx(Pi(P(n)))=Lx(Pi(P(n)))+Lxu(n);
            end;
            for n=1:N % Messages sent down to accumulator
                Lxd(n)=Lx(Pi(P(n)))-Lxu(n);
            end;
        end;
        xhat=1-(Lx<0); % Threhshold information bit llrs
        ber(j)=ber(j)+sum(xhat); % Update BER
        wer(j)=wer(j)+(sum(xhat)>0); % Udate WER
        fer(j)=fer(j)+(mean(xhat)>.1); % Update DER
    end;
    ber(j)=ber(j)/K/B; % Compute BER
    wer(j)=wer(j)/B; % Compute WER
    fer(j)=fer(j)/B; % Compute FER
    fprintf('  Eb/No=%f,  ber=%e,  wer=%e,  fer=%e\n', ...
        EbNo(j),ber(j),wer(j),fer(j));
end;

% Message passing for XOR function (check node, accumulator)
function c = f(a,b)
if a>b c=a+log(1+exp(b-a));
else c=b+log(1+exp(a-b));
end;
if a+b>0 c=c-(a+b+log(1+exp(-a-b)));
else c=c-log(1+exp(a+b));
end;
end
```

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% Divsalar_Plus_Frey_K1000_N5000_Q37_Simulate.m
% Simulate transmission and decoding of Divsalar RA code modified
using
% Frey's irregular construction.
% Copyright Brendan J Frey, January 21, 2018.
% Software written and debugged from 4.00pm to 4.30pm on January
21, 2018.
% Based on Divsalar_K4096_N16384_Q4_Simulate.m.

% Parameters
k=[0,0,500,0,0,0,500]; % Number of information bits with each
degree
K=sum(k); % Number of information bits
EbNo=[-.8:.1:.8]; % List of Gaussian noise levels (dB)
B=10000; % Number of blocks per noise level
I=100; % Number of iterations for decoding
rng(0); % Seed random number generator

% Compute other parameters
Pi=[]; j=0; % Mapping from repeated bits to information bits
for i=1:length(k) tmp=repmat([j+1:j+k(i)],[i,1]); Pi=[Pi;tmp(:)];
j=j+k(i); end;
N=length(Pi); % Number of transmitted bits
P=randperm(N); % Random permuter mapping from transmitted to
repeated bits
R=K/N; % Rate
s=(2*R*10.^(EbNo/10)).^-.5; % Standard deviation of Gaussian
noise
Lf=zeros(1,N+1); % Forward messages (log-ratios)
Lb=zeros(1,N); % Backward messages (log-ratios)
Lx=zeros(1,K); % Combined messages at information bits (log-
ratios)
Lxd=zeros(1,N); % Messages sent from information bits down to
accumulator
Lxu=zeros(1,N); % Messages sent from accumulator up to
information bits
ber=zeros(1,length(EbNo)); % Bit error rate
wer=zeros(1,length(EbNo)); % Word error rate
fer=zeros(1,length(EbNo)); % Failure to decode rate
fprintf('Number of information bits = %d\n',K);
fprintf('Number of transmitted bits = %d\n',N);
fprintf('Rate = %f\n',R);

% Simulation
for j=1:length(s) % Loop over noise levels
    for b=1:B % Loop over transmitted blocks
        y=randn(1,N)*s(j)+1; % Generate channel output assuming +
1 sent
        Lc=-2*y/s(j)^2; % Channel log-likelihood ratio
        Lf(1)=-1e20; % Initialize forward state of Markov chain
to 0
        Lb(N)=Lc(N); % Initialize backward message to channel llr
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        Lxd(:)=0; % Initialize messages from information bits to
0
        for i=1:I % Apply I iterations of decoding
            for n=1:N % Forward pass
                Lf(n+1)=Lc(n)+f(Lf(n),Lxd(n));
            end;
            for n=N:-1:2 % Backward pass
                Lb(n-1)=Lc(n-1)+f(Lb(n),Lxd(n));
            end;
            Lx(:)=0;
            for n=1:N % % Fuse messages at information bits
                Lxu(n)=f(Lf(n),Lb(n));
                Lx(Pi(P(n)))=Lx(Pi(P(n)))+Lxu(n);
            end;
            for n=1:N % Messages sent down to accumulator
                Lxd(n)=Lx(Pi(P(n)))-Lxu(n);
            end;
        end;
        xhat=1-(Lx<0);
        ber(j)=ber(j)+sum(xhat); % Update BER
        wer(j)=wer(j)+(sum(xhat)>0); % Udate WER
        fer(j)=fer(j)+(mean(xhat)>.1); % Update DER
    end;
    ber(j)=ber(j)/K/B; % Compute BER
    wer(j)=wer(j)/B; % Compute WER
    fer(j)=fer(j)/B; % Compute FER
    fprintf('  Eb/No=%f,  ber=%e,  wer=%e,  fer=%e\n', ...
        EbNo(j),ber(j),wer(j),fer(j));
end;

% Message passing for XOR function (check node, accumulator)
function c = f(a,b)
if a>b c=a+log(1+exp(b-a));
else c=b+log(1+exp(a-b));
end;
if a+b>0 c=c-(a+b+log(1+exp(-a-b)));
else c=c-log(1+exp(a+b));
end;
end
```

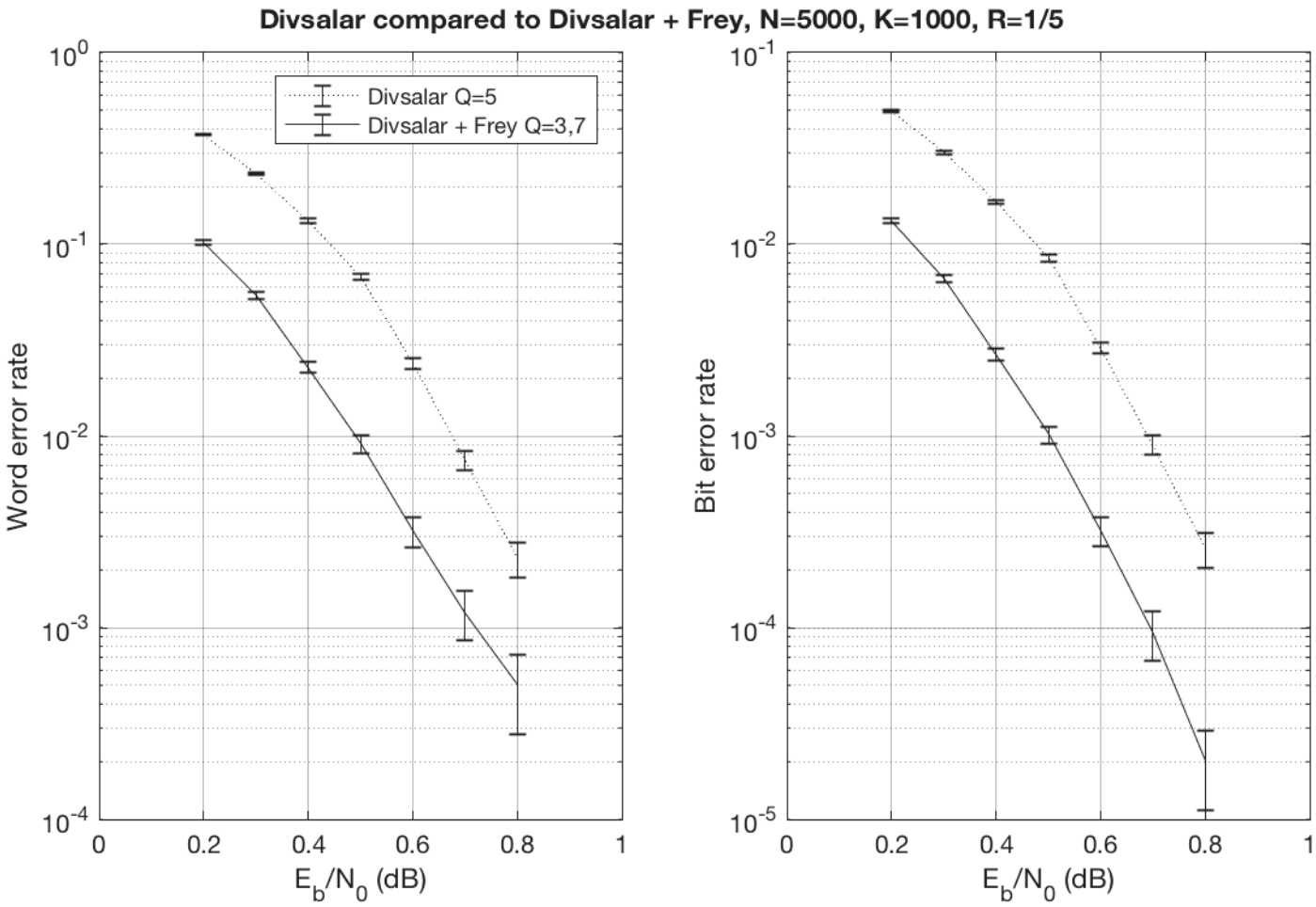

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