```
% Intro to Communications
% Project Spring 2020

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clc
format compact

g1 = @(t) (1000*t - 2).^2;
g2 = @(t) (-5000*t + 22).^2;
g3 = @(t) (3000*t - 18).^2;

% Energy of g(t)
E_gt = integral(g1, .002, .004) + integral(g2, .004, .005) +
 integral(g3, .005, .006);

% g(t)^2
gt_sq = @(t) abs((2*tripuls(t - .004, .004) - 4*tripuls(t
 - .005, .002))).^2;

% Plot of g(t)
% t = 0:.0001:.04;
% gt = 2*tripuls(t - .004, .004) - 4*tripuls(t - .005, .002);
% plot(t, gt)

% Energy from triangular pulse waveform
E_tripuls = integral(gt_sq, 0, .006);

% G(f)^2
Gf_sq = @(f) abs((.004*sinc((.004*f)/2).^2 .* exp(-1i*pi*2*f*.004)
 - .004*sinc((.002*f)/2).^2 .* exp(-1i*pi*2*f*.005)).^2);

% Setup for while loop
E_ess = 0;
B_step = .1;
B_ess = B_step;

format long

% while E_ess < .99*E_gt
%     B_ess = B_ess + B_step;
%     E_ess = integral(Gf_sq, -B_ess, B_ess)
% end

% calculated from while loop
B_ess_cal = 694.2;

% oversample essential bandwidth
BW = 1400;
```
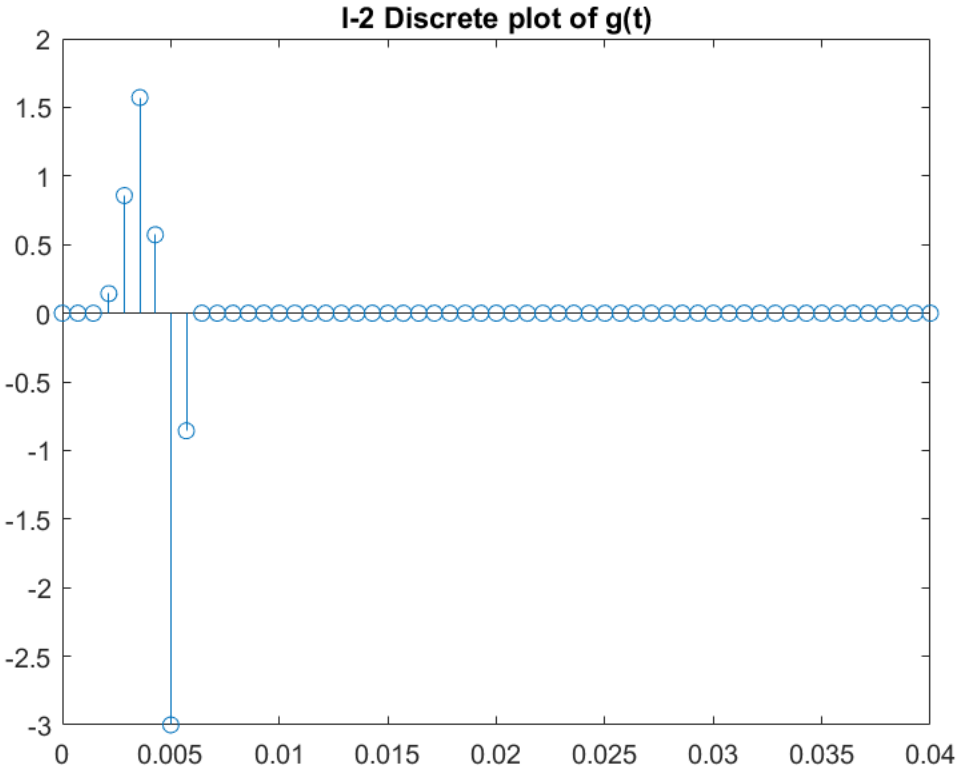

```
t = 0:1/BW:.04;
gt = 2*tripuls(t - .004, .004) - 4*tripuls(t - .005, .002);
stem(t, gt)
title('I-2 Discrete plot of g(t)')

n = 100000;
f = linspace(0, BW, n);
Gf_fft = fft(gt, n);
figure(1)
plot(f, abs(Gf_fft));
title('I-3 |G(f)| Fast Fourier Transform')

% subplot(2,1,1)

% Gf = .004*sinc((.004*f)/2).^2 .* exp(-1i*pi*2*f*.004)
 - .004*sinc((.002*f)/2).^2 .* exp(-1i*pi*2*.005*f);
% figure(2)
% plot(f, abs(Gf))
% title('?')

% I-4
gt_sq_int = @(t) abs(2*tripuls(t - .004, .004) - 4*tripuls(t
 - .005, .002)).^2;
E_gt = integral(gt_sq_int, 0, 1);

Gf_sq_int = @(f) abs((.004*sinc((.004*f)/2).^2 .* exp(-1i*pi*2*f*.004)
 - .004*sinc((.002*f)/2).^2 .* exp(-1i*pi*2*f*.005)).^2);
E_gf = integral(Gf_sq_int, -1000000, 1000000);

% I-5
G_xcorr = xcorr(gt);
figure(3)
plot(linspace(-1000, 1000, length(G_xcorr)), G_xcorr)
title('I-5 Autocorrelation Function')

G_ESD = abs(Gf).^2;
figure(4)
plot(f, G_ESD)
title('I-5 Energy Spectral Density |G(f)|^2')

% II-1
fc = 500;
fs = 2*(B_ess + fc);

BW = 1400;
Wc = 2*pi*fc;

t = 0:1/BW:.04;
gt_DSB = (2*tripuls(t - .004, .004) - 4*tripuls(t
 - .005, .002)).*cos(Wc*t);
figure(5)
plot(t, gt_DSB)
title('II-1 Double Sideband, Suppressed Carrier, time fc = 500Hz')
```

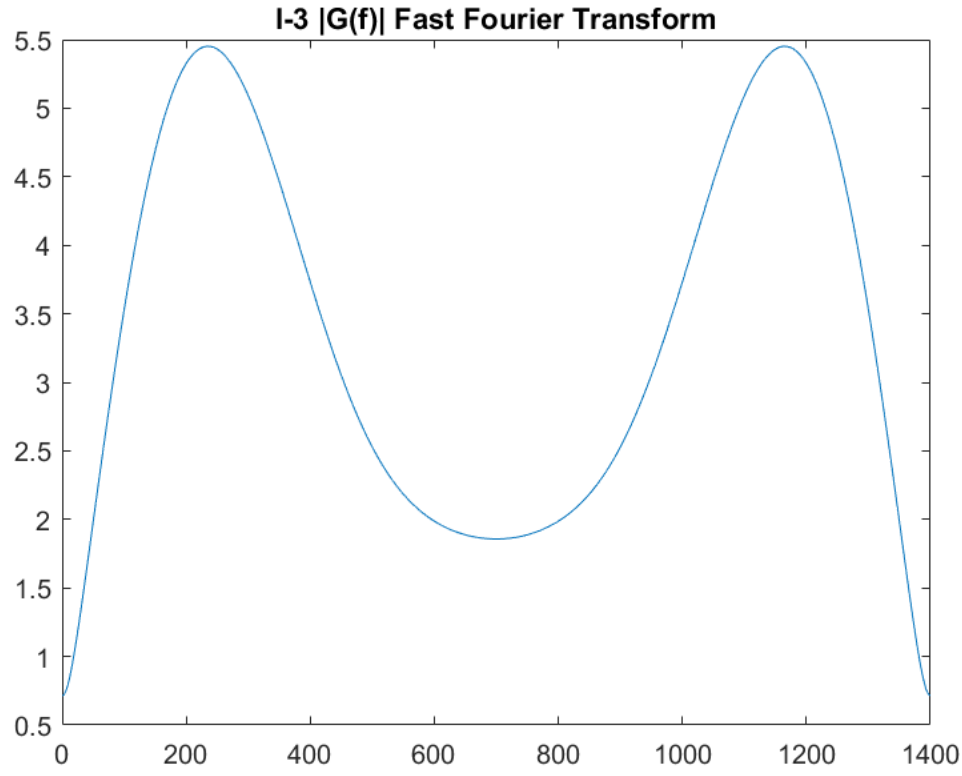
```
f = linspace(-2*BW, 2*BW, n);
f_1 = f - fc;
f_2 = f + fc;
Gf_1 = .004*sinc((.004*f_1)/2).^2 .* exp(-1i*pi*2*f_1*.004)
 - .004*sinc((.002*f_1)/2).^2 .* exp(-1i*pi*2*.005*f_1);
Gf_2 = .004*sinc((.004*f_2)/2).^2 .* exp(-1i*pi*2*f_2*.004)
 - .004*sinc((.002*f_2)/2).^2 .* exp(-1i*pi*2*.005*f_2);
Gf_DSB = abs(Gf_1) + abs(Gf_2);
figure(6)
plot(f, Gf_DSB)
title('II-1 DSB-SC Frequency fc = 500Hz')

lpf = fir1(20, B_ess/(fs/2), 'low');
demod = filter(lpf, 1, abs(Gf));
figure(7)
plot(linspace(-fs/2, fs/2, n), demod)
title('II-1 Coherent Demodulation f = 500Hz')

% gt_demod = ifft(demod);
% figure(16)
% plot(linspace(0, .04, length(gt_demod)), gt_demod)
% title('II-1 gt demodulated')

% II-2
fc = 1000;
fs = 2*(B_ess + fc);

BW = 1400;
Wc = 2*pi*fc;

t = 0:1/BW:.04;
gt_DSB = (2*tripuls(t - .004, .004) - 4*tripuls(t
 - .005, .002)).*cos(Wc*t);
figure(5)
plot(t, gt_DSB)
title('II-2 DSB-SC time fc = 1000Hz')

f = linspace(-2*BW, 2*BW, n);
f_1 = f - fc;
f_2 = f + fc;
Gf_1 = .004*sinc((.004*f_1)/2).^2 .* exp(-1i*pi*2*f_1*.004)
 - .004*sinc((.002*f_1)/2).^2 .* exp(-1i*pi*2*.005*f_1);
Gf_2 = .004*sinc((.004*f_2)/2).^2 .* exp(-1i*pi*2*f_2*.004)
 - .004*sinc((.002*f_2)/2).^2 .* exp(-1i*pi*2*.005*f_2);
Gf_DSB = abs(Gf_1) + abs(Gf_2);
figure(8)
plot(f, Gf_DSB)
title('II-2 DSB-SC Frequency fc = 1000Hz')

lpf = fir1(20, B_ess/(fs/2), 'low');
demod = filter(lpf, 1, abs(Gf));
figure(9)
plot(linspace(-fs/2, fs/2, n), demod)
title('II-2 Coherent Demodulation f = 1000Hz')
```

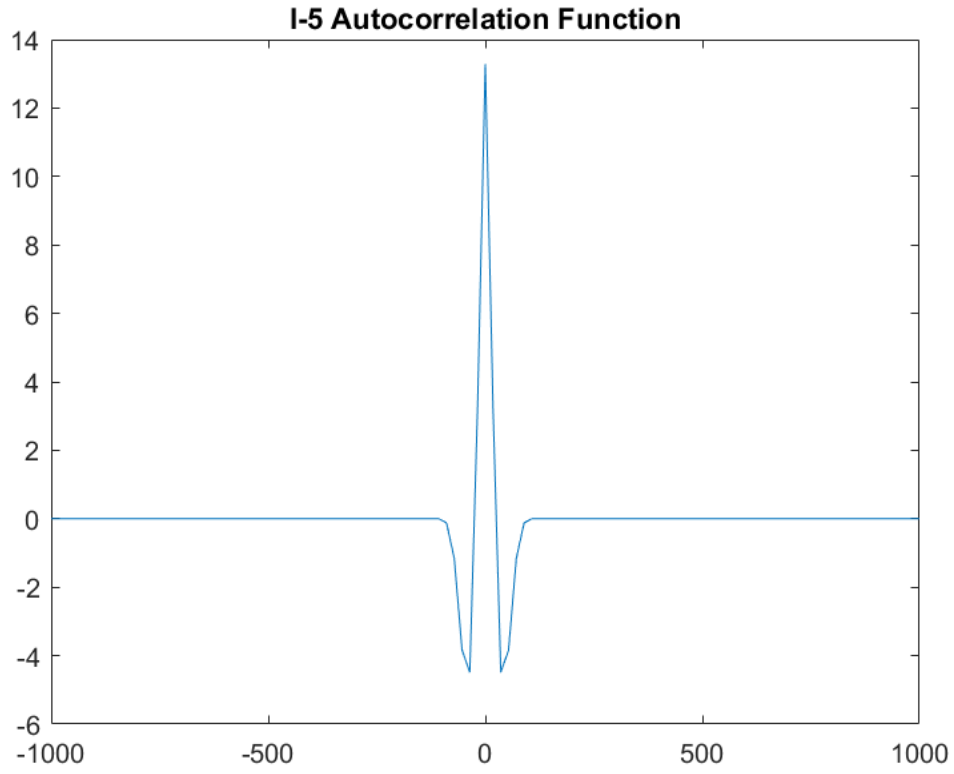
```
% II-3
A = 4;
mod_idx = (max(gt) - min(gt)) / (2*A + max(gt) + min(gt));
% fc = 1000;
% fs = 2*(B_ess + fc);
%
% BW = 1400;
% Wc = 2*pi*fc;
%
% t = 0:1/BW:.04;
% gt_DSB = (2*tripuls(t - .004, .004) - 4*tripuls(t
 - .005, .002)).*cos(Wc*t);
% figure(5)
% plot(t, gt_DSB)
%
% f = linspace(-2*BW, 2*BW, n);
% f_1 = f - fc;
% f_2 = f + fc;
% Gf_1 = .004*sinc((.004*f_1)/2).^2 .* exp(-1i*pi*2*f_1*.004)
 - .004*sinc((.002*f_1)/2).^2 .* exp(-1i*pi*2*.005*f_1);
% Gf_2 = .004*sinc((.004*f_2)/2).^2 .* exp(-1i*pi*2*f_2*.004)
 - .004*sinc((.002*f_2)/2).^2 .* exp(-1i*pi*2*.005*f_2);
% Gf_DSB = abs(Gf_1) + abs(Gf_2);
% figure(8)
% plot(f, Gf_DSB)

t = linspace(0, .04, n);
lpf = fir1(20, B_ess/(fs/2), 'low');
demod = filter(lpf, 1, abs(Gf));
figure(9)
plot(linspace(-fs/2, fs/2, n), demod)
title('II-2 Double Sideband, Suppressed Carrier, f = 500Hz')

% II-5
lpf = fir1(20, B_ess/(fs/2), 'low');
demod = filter(lpf, 1, abs(Gf_DSB));
figure
plot(linspace(-fs/2, fs/2, n), demod)
title('II-5 demodulated signal')

% III-1
fc = 1000;
BW = 1400;

f = linspace(-2*BW, 2*BW, n);
f_1 = f - fc;
f_2 = f + fc;
Gf_1 = .004*sinc((.004*f_1)/2).^2 .* exp(-1i*pi*2*f_1*.004)
 - .004*sinc((.002*f_1)/2).^2 .* exp(-1i*pi*2*.005*f_1);
Gf_2 = .004*sinc((.004*f_2)/2).^2 .* exp(-1i*pi*2*f_2*.004)
 - .004*sinc((.002*f_2)/2).^2 .* exp(-1i*pi*2*.005*f_2);
Gf_SSB = abs(Gf_1) + abs(Gf_2);
```

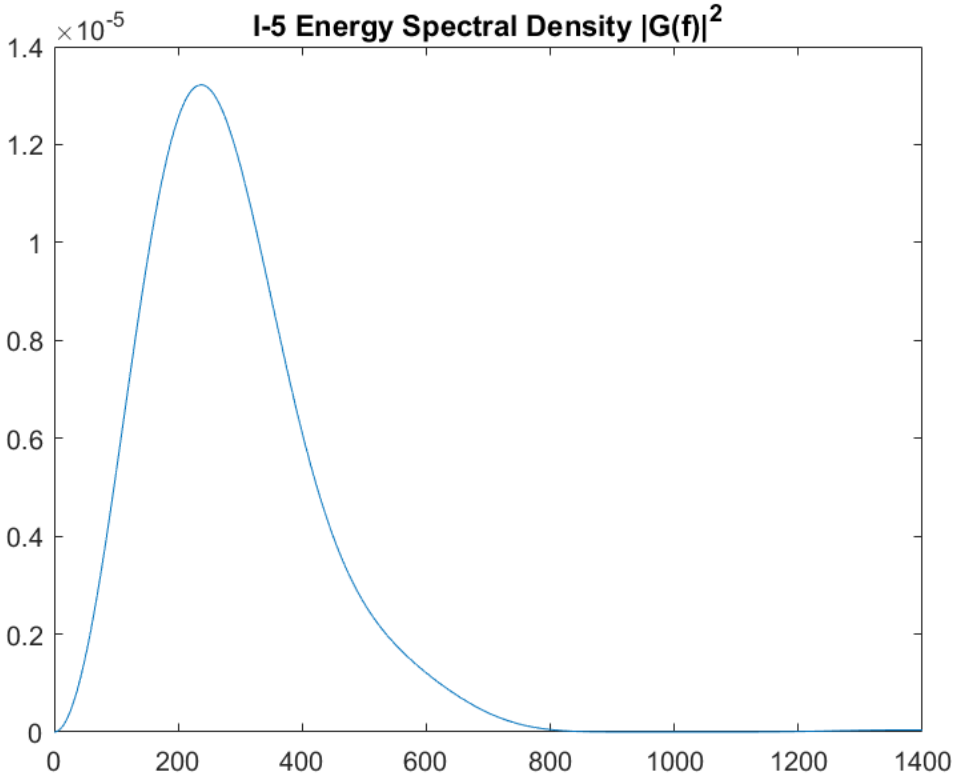
```
for i = 1:n
    if abs(f(i)) < fc
       Gf_SSB(i) = 0;
    end
end

figure(10)
plot(f, Gf_SSB)
title('III-1 USB-SC ideal filter')

offset = 17857;

Gf_SSB1 = [zeros(1, offset), Gf_SSB(1:n-offset)];
Gf_SSB2 = [Gf_SSB(offset:n-1), zeros(1, offset)];
Gf_SSB_mod = Gf_SSB1 + Gf_SSB2;
figure(15)
plot(f, Gf_SSB_mod)
title('III-1 demodulated signal')

% III-2
fc = 1000;
fs = 2*(B_ess + fc);

BW = 1400;

f = linspace(-2*BW, 2*BW, n);
f_1 = f - fc;
f_2 = f + fc;
Gf_1 = .004*sinc((.004*f_1)/2).^2 .* exp(-1i*pi*2*f_1*.004)
 - .004*sinc((.002*f_1)/2).^2 .* exp(-1i*pi*2*.005*f_1);
Gf_2 = .004*sinc((.004*f_2)/2).^2 .* exp(-1i*pi*2*f_2*.004)
 - .004*sinc((.002*f_2)/2).^2 .* exp(-1i*pi*2*.005*f_2);
Gf_SSB = abs(Gf_1) + abs(Gf_2);

lpf = fir1(20, [fc/(fs/2), .999999], 'low');
demod = filter(lpf, 1, abs(Gf_SSB));

figure(11)
plot(f, demod)
title('III-2 USB-SC band-pass FIR filter')

% III-3
fc = 1000;
fs = 2*(B_ess + fc);

BW = 1400;
Wc = 2*pi*fc;

f = linspace(-2*BW, 2*BW, n);
f_1 = f - fc;
f_2 = f + fc;
Gf_1 = .004*sinc((.004*f_1)/2).^2 .* exp(-1i*pi*2*f_1*.004)
 - .004*sinc((.002*f_1)/2).^2 .* exp(-1i*pi*2*.005*f_1);
```

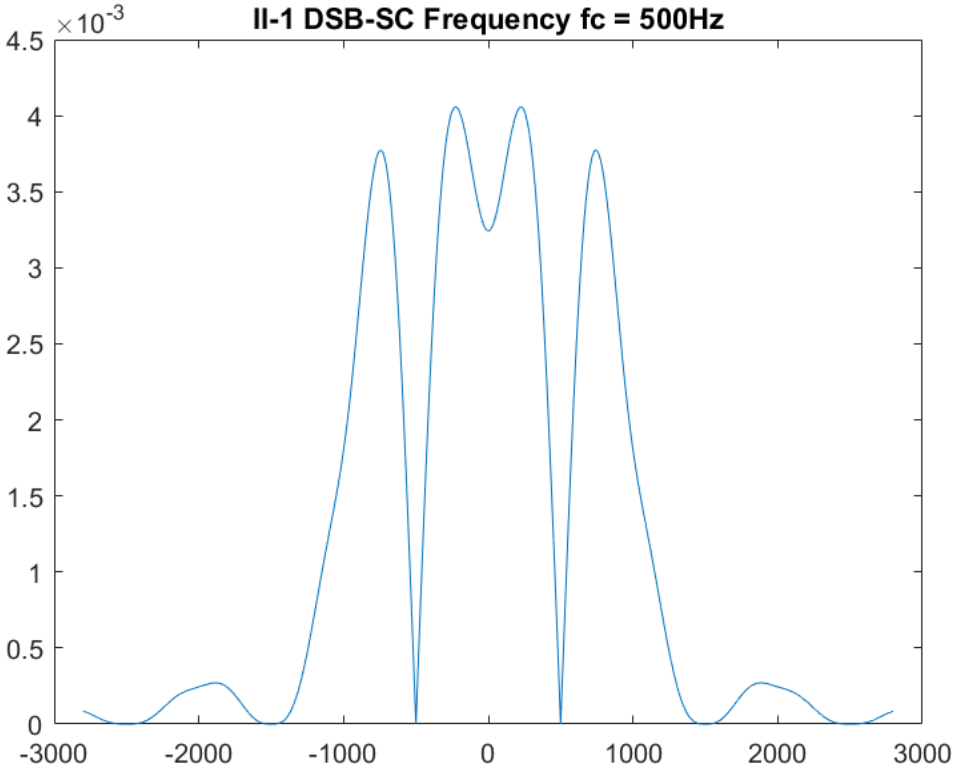
```
Gf_2 = .004*sinc((.004*f_2)/2).^2 .* exp(-1i*pi*2*f_2*.004)
 - .004*sinc((.002*f_2)/2).^2 .* exp(-1i*pi*2*.005*f_2);
Gf_SSB = abs(Gf_1) + abs(Gf_2);

for i = 1:n
    F = abs(f(i));
    if F > 970 && F < 1030
        mult = .01667*F - .01617;
        Gf_SSB(i) = Gf_SSB(i) * mult;
    elseif F > 1.03 && F < 2000
        % noop
    else
        Gf_SSB(i) = 0;
    end
end

figure(12)
plot(f, Gf_SSB)
title('III-3 VSB modulated signal')

% III-4
f = linspace(-2*BW, 2*BW, n);
Ho = zeros(1, n);

for i = 1:n
   if abs(f(i)) <= 1000
       Ho(i) = 1;
   end
end

figure(13)
plot(f, Ho)
title('III-4 equilizer filter response')

figure
plot(f, Gf_SSB_mod.*Ho)
title('III-4 coherent demod')
```

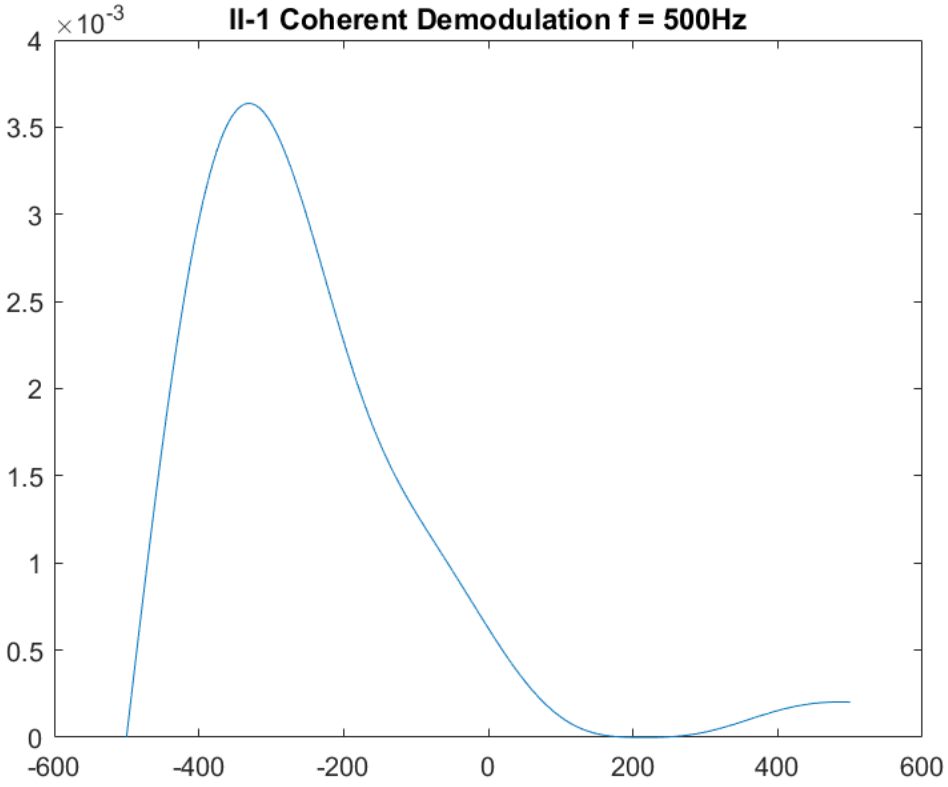

I-2 Discrete plot of g(t)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04

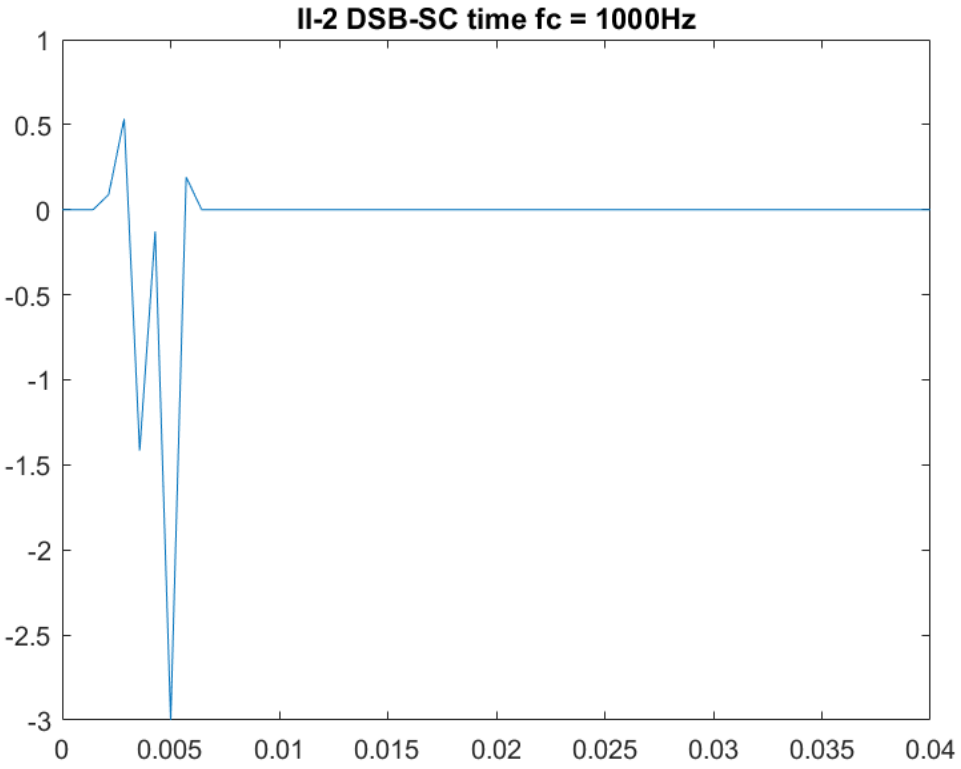

I-3 |G(f)| Fast Fourier Transform
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
200
400
600
800
1000
1200
1400

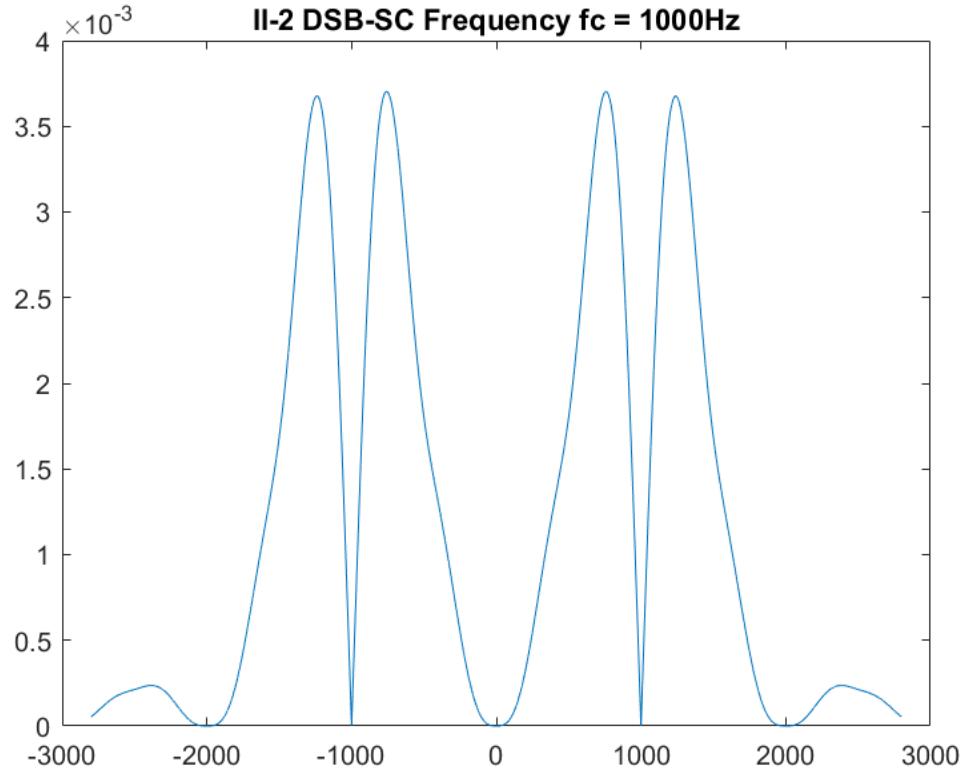

I-5 Autocorrelation Function
14
12
10
8
6
4
2
0
-2
-4
-6
-1000
-500
0
500
1000

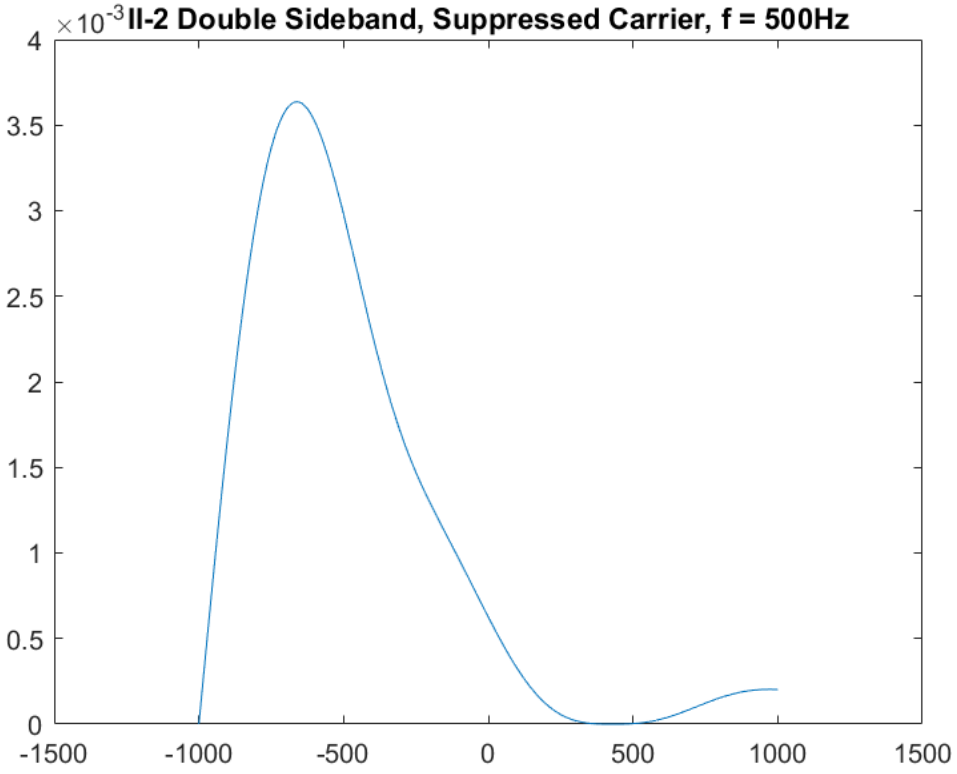

I-5 Energy Spectral Density |G(f)|2
×10-5
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
200
400
600
800
1000
1200
1400

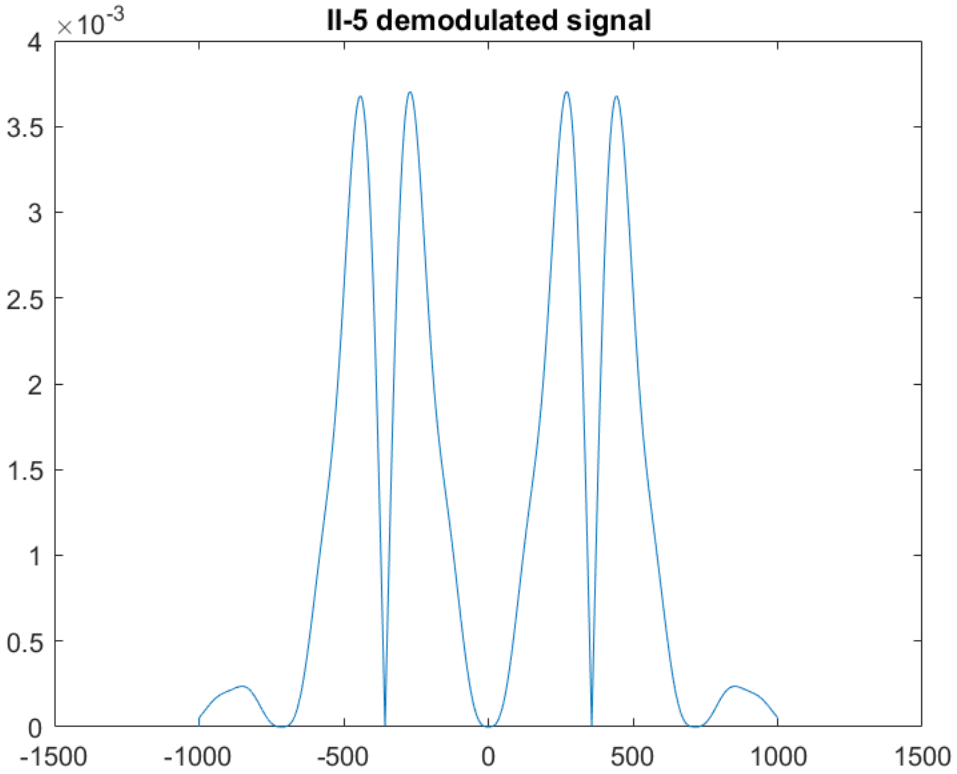

II-1 DSB-SC Frequency fc = 500Hz
×10^-3
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-3000
-2000
-1000
0
1000
2000
3000

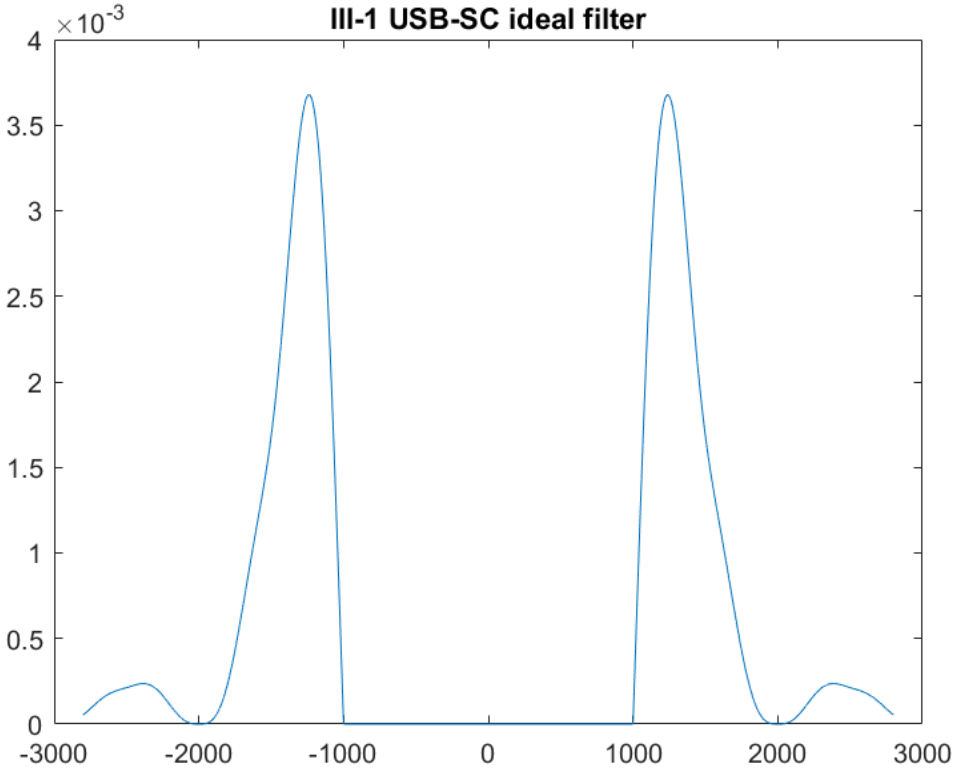

II-1 Coherent Demodulation f = 500Hz
×10^-3
4
3.5
3
2.5
2
1.5
1
0.5
0
-600
-400
-200
0
200
400
600

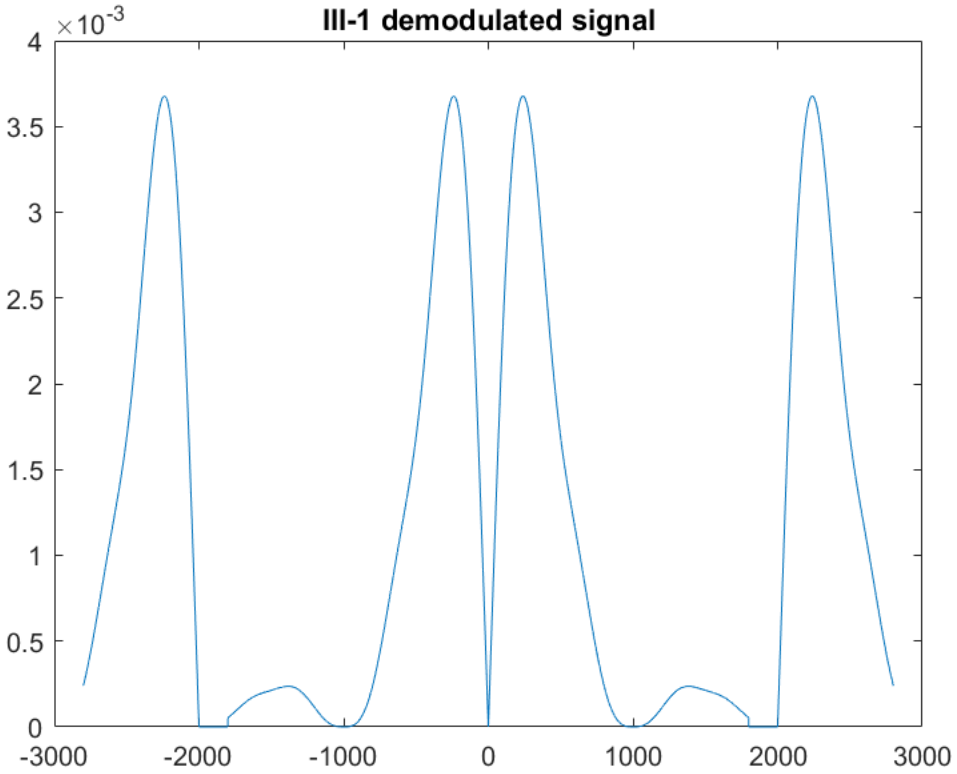

II-2 DSB-SC time fc = 1000Hz
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04

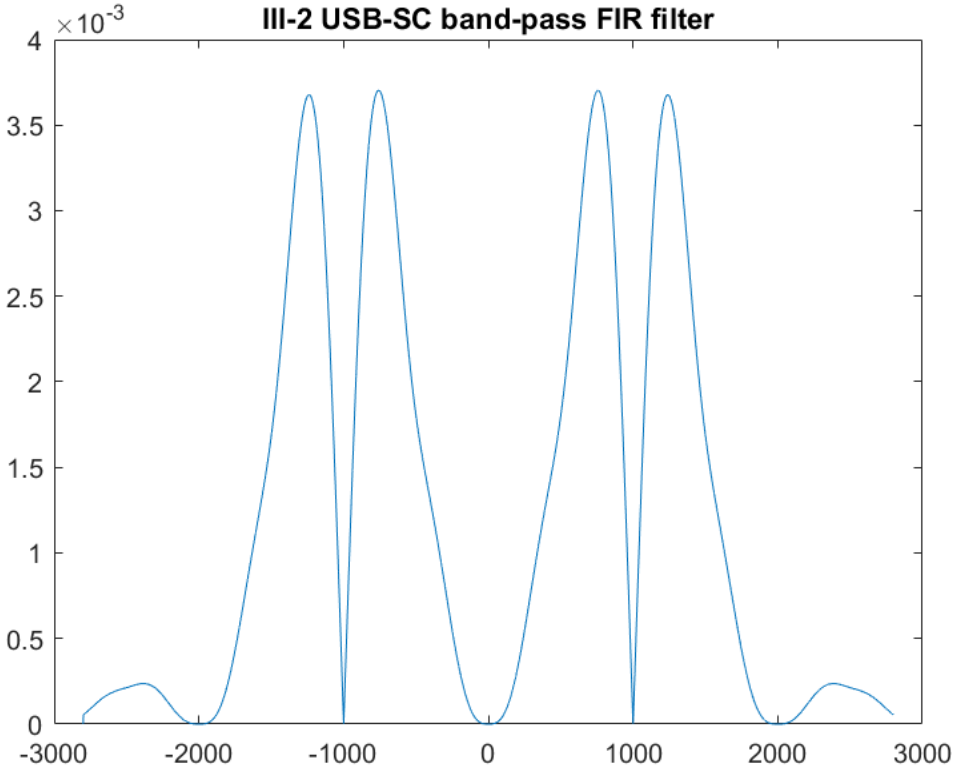

II-2 DSB-SC Frequency fc = 1000Hz
×10-3
4
3.5
3
2.5
2
1.5
1
0.5
0
-3000
-2000
-1000
0
1000
2000
3000

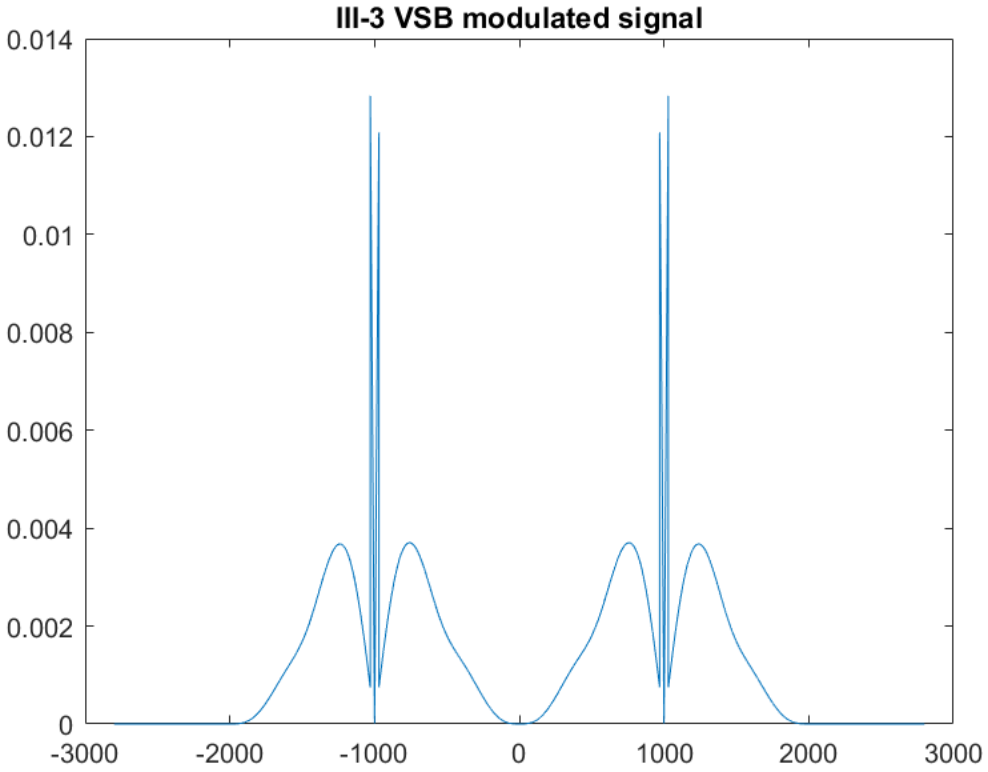

×10^-3
II-2 Double Sideband, Suppressed Carrier, f = 500Hz
4
3.5
3
2.5
2
1.5
1
0.5
0
-1500
-1000
-500
0
500
1000
1500

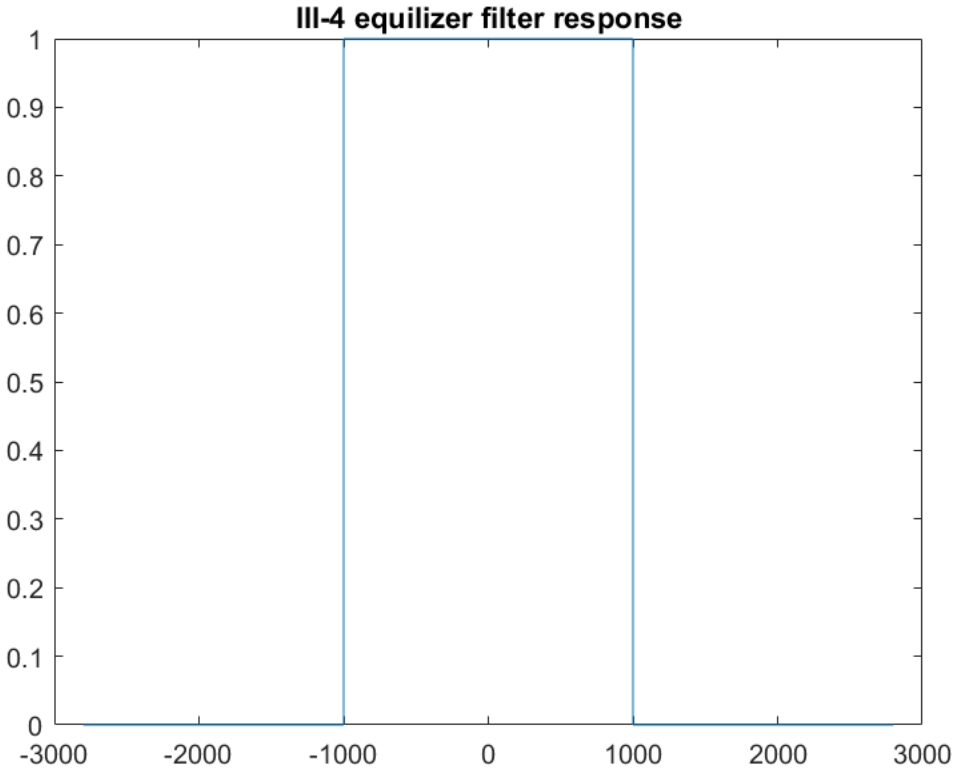

×10^-3
II-5 demodulated signal
4
3.5
3
2.5
2
1.5
1
0.5
0
-1500
-1000
-500
0
500
1000
1500

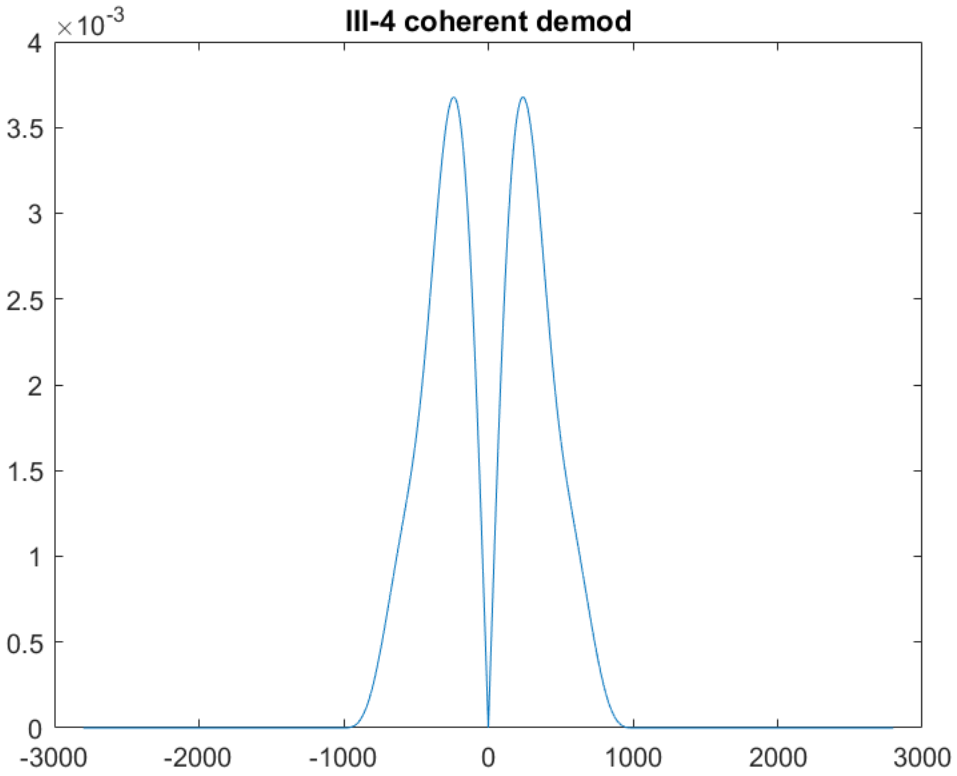

III-1 USB-SC ideal filter
×10^-3
4
3.5
3
2.5
2
1.5
1
0.5
0
-3000
-2000
-1000
0
1000
2000
3000


III-1 demodulated signal
×10^-3
4
3.5
3
2.5
2
1.5
1
0.5
0
-3000
-2000
-1000
0
1000
2000
3000


III-2 USB-SC band-pass FIR filter
×10^-3
4
3.5
3
2.5
2
1.5
1
0.5
0
-3000
-2000
-1000
0
1000
2000
3000


III-3 VSB modulated signal
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
-3000
-2000
-1000
0
1000
2000
3000


III-4 equilizer filter response
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-3000
-2000
-1000
0
1000
2000
3000


III-4 coherent demod
×10-3
4
3.5
3
2.5
2
1.5
1
0.5
0
-3000
-2000
-1000
0
1000
2000
3000

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