**Analogue Communication**

**Matlab Assignment**

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**Experiment 1**

**Matlab Code**

clc

clear

close all

% Read the audio file and get its sampling frequency

[y, F] = audioread('eric.wav');

ty = length(y)/F;

t = linspace(0, ty, length(y));

% Input signal conversion to frequency domain (to apply ideal LPF)

z = fftshift(fft(y));

f = linspace(-F/2, F/2, length(y));

figure

plot(f, abs(z));

title('Original Signal in Frequency Domain');

% Searching for indices where f = -4000 and f = 4000

for i = 1:length(f)

if (abs((f(i)+4.0000e+3)) < 0.01)

index1 = i;

end

if (abs((f(i)-4.0000e+3)) < 0.01)

index2 = i;

break;

end

end

% Generating a rect from index1 to index2

range = index2-index1;

step = [zeros(1, index1) ones(1, range) zeros(1, length(f)-index2)];

step = step.';

% Multiplying input signal by rect to eliminate frequencies other than 4k

yfilteredFreq = step.\*z;

yfilteredFreqAbs = abs(step.\*z);

figure

plot(f, yfilteredFreqAbs);

xlim([-15000 15000]);

title('Filtered Signal in Frequency Domain');

% Converting the filtered signal to time domain to be modulated

yfiltered = ifft(fftshift(yfilteredFreq));

figure

plot(t, yfiltered);

title('Filtered Signal in Time Domain');

% Signal after low pass filter

sound(yfiltered, F);

pause(9);

% Filtered signal resampling

maxAmplitude = max(yfiltered);

yfiltered = resample(yfiltered, 500000, F);

yfiltered = yfiltered.';

interval = length(yfiltered);

% DSB-SC Modulation and Demodulation

% Modulation

t = linspace(0, ty, interval);

dsbsc = 5\*cos(2\*pi\*100000\*t).\*yfiltered;

figure

plot(t, dsbsc);

title('Modulted DSB-SC Signal in Time Domain');

zmsc = abs(fftshift(fft(dsbsc)));

fmsc = linspace(-500000/2, 500000/2, length(dsbsc));

figure

plot(fmsc, zmsc);

xlim([-150000 150000]);

ylim([0 300]);

title('Modulated DSB-SC Signal in Frequency Domain');

% Demodulation

dsbscEnvelope = abs(hilbert(dsbsc));

dsbscEnvelope = resample(dsbscEnvelope, F, 500000);

t = 0:1/F:length(dsbscEnvelope)/(F);

t = t(1:end-1);

figure

plot(t, dsbscEnvelope);

title('Demodulted DSB-SC Signal in Time Domain');

zdsc = abs(fftshift(fft(dsbscEnvelope)));

fdsc = linspace(-F/2, F/2, length(dsbscEnvelope));

figure

plot(fdsc, zdsc);

xlim([-8000 8000]);

ylim([0 1500]);

title('Demodulated DSB-SC Signal in Frequency Domain');

sound(dsbscEnvelope, F);

pause(9);

% Coherent detection

dsbsc0 = awgn(dsbsc,0);

dsbsc10 = awgn(dsbsc,10);

dsbsc30 = awgn(dsbsc,30);

t = linspace(0, ty, length(dsbsc));

vpe = dsbsc.\*cos((2\*pi\*100000\*t) + deg2rad(20));

vfe = dsbsc.\*cos(2\*pi\*100100\*t);

v0 = dsbsc0.\*cos(2\*pi\*100000\*t);

v10 = dsbsc10.\*cos(2\*pi\*100000\*t);

v30 = dsbsc30.\*cos(2\*pi\*100000\*t);

v0 = resample(v0, F, 500000);

v10 = resample(v10, F, 500000);

v30 = resample(v30, F, 500000);

vpe = resample(vpe, F, 500000);

vfe = resample(vfe, F, 500000);

zsc0 = fftshift(fft(v0));

zsc10 = fftshift(fft(v10));

zsc30 = fftshift(fft(v30));

zscpe = fftshift(fft(vpe));

zscfe = fftshift(fft(vfe));

fsc = linspace(-F/2, F/2, length(v0));

for i = 1:length(fsc)

if (abs((fsc(i)+4.0000e+3)) < 0.01)

index1 = i;

end

if (abs((fsc(i)-4.0000e+3)) < 0.01)

index2 = i;

break;

end

end

range = index2-index1;

step = [zeros(1, index1) ones(1, range) zeros(1, length(fsc)-(index2))];

dsbscCoherent0 = step.\*zsc0;

dsbscCoherent10 = step.\*zsc10;

dsbscCoherent30 = step.\*zsc30;

dsbscCoherentpe = step.\*zscpe;

dsbscCoherentfe = step.\*zscfe;

figure

plot(fsc, abs(dsbscCoherent0));

title('Demodulated DSB-SC Signal using Coherent Detection with SNR = 0 in Frequency Domain');

xlim([-8000 8000]);

figure

plot(fsc, abs(dsbscCoherent10));

title('Demodulated DSB-SC Signal using Coherent Detection with SNR = 10 in Frequency Domain');

xlim([-8000 8000]);

figure

plot(fsc, abs(dsbscCoherent30));

title('Demodulated DSB-SC Signal using Coherent Detection with SNR = 30 in Frequency Domain');

xlim([-8000 8000]);

figure

plot(fsc, abs(dsbscCoherentpe));

title('Demodulated DSB-SC Signal using Coherent Detection with Phase Error = 20 in Frequency Domain');

xlim([-8000 8000]);

figure

plot(fsc, abs(dsbscCoherentfe));

title('Demodulated DSB-SC Signal using Coherent Detection with Frequency Error = 100 HZ in Frequency Domain');

xlim([-8000 8000]);

dsbscCoherentTime0 = ifft(fftshift(dsbscCoherent0));

dsbscCoherentTime10 = ifft(fftshift(dsbscCoherent10));

dsbscCoherentTime30 = ifft(fftshift(dsbscCoherent30));

dsbscCoherentTimepe = ifft(fftshift(dsbscCoherentpe));

dsbscCoherentTimefe = ifft(fftshift(dsbscCoherentfe));

t = linspace(0, ty, length(dsbscCoherentTime0));

figure

plot(t, abs(dsbscCoherentTime0));

title('Demodulated DSB-SC Signal using Coherent Detection with SNR = 0 in Time Domain');

sound(abs(dsbscCoherentTime0), F);

pause(9);

figure

plot(t, abs(dsbscCoherentTime10));

title('Demodulated DSB-SC Signal using Coherent Detection with SNR = 10 in Time Domain');

sound(abs(dsbscCoherentTime10), F);

pause(9);

figure

plot(t, abs(dsbscCoherentTime30));

title('Demodulated DSB-SC Signal using Coherent Detection with SNR = 30 in Time Domain');

sound(abs(dsbscCoherentTime30), F);

pause(9);

figure

plot(t, abs(dsbscCoherentTimepe));

title('Demodulated DSB-SC Signal using Coherent Detection with Phase Error = 20 in Time Domain');

sound(abs(dsbscCoherentTimepe), F);

pause(9);

figure

plot(t, abs(dsbscCoherentTimefe));

title('Demodulated DSB-SC Signal using Coherent Detection with Frequency Error = 100 HZ in Time Domain');

sound(abs(dsbscCoherentTimefe), F);

pause(9);

% DSB-TC Modulation and Demodulation

% Modulation

t = linspace(0, ty, interval);

dsbtc = 2.\*maxAmplitude.\*(1+(0.5/maxAmplitude).\*yfiltered).\*cos(2.\*pi.\*100000.\*t);

figure

plot(t, dsbtc);

title('Modulted DSB-TC Signal in Time Domain');

zmtc = abs(fftshift(fft(dsbtc)));

fmtc = linspace(-500000/2, 500000/2, length(dsbtc));

figure

plot(fmtc, zmtc);

xlim([-150000 150000]);

ylim([0 1000]);

title('Modulated DSB-TC Signal in Frequency Domain');

% Demodulation

dsbtcEnvelope = abs(hilbert(dsbtc));

dsbtcEnvelope = resample(dsbtcEnvelope, F, 500000);

dsbtcEnvelope=dsbtcEnvelope-mean(dsbtcEnvelope);

t = 0:1/F:length(dsbtcEnvelope)/(F);

t = t(1:end-1);

figure

plot(t, dsbtcEnvelope);

title('Demodulted DSB-TC Signal in Time Domain');

zdtc = abs(fftshift(fft(dsbtcEnvelope)));

fdtc = linspace(-F/2, F/2, length(dsbtcEnvelope));

figure

plot(fdtc, zdtc);

xlim([-8000 8000]);

ylim([0 1000]);

title('Demodulated DSB-TC Signal in Frequency Domain');

sound(dsbtcEnvelope, F);

**Experiment 1 Graphs**

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**Experiment Conclusions**

* By using Envelope Detector, we observe that there is more distortion in case of DSB-SC. DSB-SC should be demodulated by coherent detection. Envelope Detector can be used to demodulate DSB-TC.
* It is called Aliasing.

**Experiment 2**

**Matlab Code**

clc

clear

close all

%Read the audio file and get its sampling frequency

[y, F] = audioread('eric.wav');

ty = length(y)/F;

t = linspace(0, ty, length(y));

T=linspace(0, ty, length(y));

plot(t,y);

title('Original Signal in Time Domain');

% Input signal conversion to frequency domain

z = fftshift(fft(y));

zf=abs(z);

f = linspace(-F/2, F/2, length(y));

plot(f,zf);

title('Original Signal in Frequency Domain');

%apply ideal LPF ,Searching for indices where f = -4000 and f = 4000

for i = 1:length(f)

if (abs((f(i)+4.0000e+3)) < 0.01)

index1 = i;

end

if (abs((f(i)-4.0000e+3)) < 0.01)

index2 = i;

break;

end

end

%Generating a rect from index1 to index2

range = index2-index1;

step = [zeros(1, index1) ones(1, range) zeros(1, length(f)-index2)];

step = step.';

%Multiplying input signal by rect to eliminate frequencies other than 4k

yfilteredFreq = step.\*z;

yfilteredFreqAbs = abs(step.\*z);

figure

plot(f, yfilteredFreqAbs);

xlim([-4.5 4.5].\*10^3)

title('Filtered Signal in Frequency Domain at 4KHZ (ideal filter)');

%Converting the filtered signal to time domain to be modulated DSB-SC

yfiltered= ifft(ifftshift(yfilteredFreq));

yfiltered=yfiltered.';

figure

plot(T,yfiltered);

title('Filtered Signal in Time Domain at 4KHZ (ideal filter)');

sound(yfiltered, F);

pause(9);

%Filtered signal resampling

maxAmplitude = max(yfiltered);

yfiltered = resample(yfiltered, 500000, F);

interval = length(yfiltered);

%DSB-SC Modulation

t = linspace(0, ty, interval);

carrier=cos(2\*pi\*100000\*t);

dsbsc =carrier.\*yfiltered;

figure

plot(t, dsbsc);

title('Modulted DSB-SC Signal in Time Domain');

zm\_sc=fftshift(fft(dsbsc));

zmsc = abs(fftshift(fft(dsbsc)));

fmsc = linspace(-500000/2, 500000/2, length(dsbsc));

figure

plot(fmsc, zmsc);

xlim([-150000 150000]);

ylim([0 1000]);

title('Modulated DSB-SC Signal in Frequency Domain');

xlim([-12 12].\*10^4)

%remove USB to get SSB using ideal filter

for i1 = 1:length(dsbsc)

if (abs((fmsc(i1)+1.0000e+5)) < 0.1)

idx1 = i1;

end

if (abs((fmsc(i1)-1.0000e+5)) < 0.1)

idx2 = i1;

break;

end

end

%Generating a rect from idx1 to idx2

range1 = idx2-idx1;

step1 = [zeros(1, idx1) ones(1, range1) zeros(1, length(fmsc)-idx2)];

LSB\_Frequency = step1.\*zm\_sc;

LSB\_FAbs = abs(step1.\*zm\_sc);

figure

plot(fmsc, LSB\_FAbs);

xlim([-150000 150000]);

ylim([0 1000]);

title('Obtain LSB in Frequency Domain using from DSB-SC (ideal filter)');

xlim([-12 12].\*10^4)

LSB\_time = ifft(ifftshift(LSB\_Frequency));

%demodulation of SSB using coherent detector ideal filter

SSB\_SC = LSB\_time.\*carrier;

SSB\_SC = resample(SSB\_SC,F,500000);

SSB\_SC\_ff= fftshift(fft(SSB\_SC)) ;

%ideal lpf to get signal in frequency domain

SSB\_SC\_ff=SSB\_SC\_ff(1:end-1);

SSB\_SC\_ff =SSB\_SC\_ff.\*step';

SSB\_SC\_time =ifft(ifftshift(SSB\_SC\_ff)) ;

signal\_frequency\_domain= fftshift(fft(SSB\_SC\_time));

figure

plot(T,SSB\_SC\_time);

title('recieved LSB in Time Domain (ideal filter)');

figure;

plot(f,abs(signal\_frequency\_domain));

title('recieved LSB in Freqency Domain (ideal filter)');

xlim([-4.5 4.5].\*10^3)

sound(SSB\_SC\_time,F);

pause(9);

%remove USB to get SSB using butter filter

%Butterworth filter BPF to get LSB

fnorm = 500000/2;

BW\_fitler=(500000\*4000)/48000;

[numerator, denomenator] = butter(4,[100000 100000+BW\_fitler]/fnorm,'bandpass');

Filter\_DSB = filter(numerator, denomenator, dsbsc);

LSB\_Butter = Filter\_DSB.\*carrier;

plot(fmsc,abs(fftshift(fft(Filter\_DSB))));

title('Obtain LSB in Freqency Domain (Butter filter)');

%down sample butter filter

LSB\_down =resample(LSB\_Butter,F,500000);

LSB\_down =LSB\_down(1:end-1);

lsb\_freq=abs(fftshift(fft(LSB\_down)));

%Butterworth filter LPF to get LSB after demodulation

[numerator, denomenator] = butter(4,4000/(F/2));

LSB\_LPF\_Time = filter(numerator, denomenator, LSB\_down);

LSB\_LPF\_Freq = fftshift(fft(LSB\_LPF\_Time));

figure

plot(LSB\_LPF\_Time);

title('recieved LSB in Time Domain (butter filter)');

figure

plot(f,abs(LSB\_LPF\_Freq));

title('recieved LSB in Freqency Domain (butter filter)');

xlim([-4.5 4.5].\*10^3)

%NOISE is added to signal

noised\_signal\_0 = awgn(LSB\_time,0, 'measured');

noised\_signal\_10 = awgn(LSB\_time,10,'measured');

noised\_signal\_30 = awgn(LSB\_time,30,'measured');

noised\_signal\_0=noised\_signal\_0';

noised\_signal\_10=noised\_signal\_10';

noised\_signal\_30=noised\_signal\_30';

carrier=carrier.';

LSB0 = noised\_signal\_0.\*carrier;

coherent0 = resample(LSB0,F,500000);

coherent0 = coherent0(1:end-1);

coherentFreq0 = fftshift(fft(coherent0));

coherentFilter0 = step.\*coherentFreq0;

coherentTime0 = ifft(ifftshift(coherentFilter0)) ;

figure;

plot(T,coherentTime0);

title('recieved LSB in Time Domain (ideal filter) with noise SNR=0');

figure;

plot(f,abs(coherentFilter0));

title('recieved LSB in Freq Domain (ideal filter) with noise SNR=0');

xlim([-4.5 4.5].\*10^3)

sound(real(coherentTime0),F);

pause(9);

LSB10 = noised\_signal\_10.\*carrier;

coherent10 = resample(LSB10,F,500000);

coherent10 = coherent10(1:end-1);

coherentFreq10 = fftshift(fft(coherent10));

coherentFilter10 = step.\*coherentFreq10;

coherentTime10 = ifft(ifftshift(coherentFilter10)) ;

figure;

plot(T,coherentTime10);

title('recieved LSB in Time Domain (ideal filter) with noise SNR=10');

figure;

plot(f,abs(coherentFilter10));

title('recieved LSB in Freq Domain (ideal filter) with noise SNR=10');

xlim([-4.5 4.5].\*10^3)

sound(real(coherentTime10),F);

pause(9);

LSB30 = noised\_signal\_30.\*carrier;

coherent30 = resample(LSB30,F,500000);

coherent30 = coherent30(1:end-1);

coherentFreq30 = fftshift(fft(coherent30));

coherentFilter30 = step.\*coherentFreq30;

coherentTime30 = ifft(ifftshift(coherentFilter30)) ;

figure;

plot(T,coherentTime30);

title('recieved LSB in Time Domain (ideal filter) with noise SNR=30');

figure;

plot(f,abs(coherentFilter30));

title('recieved LSB in Freq Domain (ideal filter) with noise SNR=30');

xlim([-4.5 4.5].\*10^3)

sound(real(coherentTime30),F);

pause(9);

%OBTAIN SSB-TC using ideal filter

A=2\*max(LSB\_time);

carrier=carrier.';

SSB\_TC=(A+LSB\_time).\*carrier;

SSB\_TC\_freq = fftshift(fft(SSB\_TC));

step=step.';

step=resample(step,500000,F);

SSB\_SCinFreqIdeal = SSB\_TC\_freq.\*step;

SSB\_TC\_time = ifft(ifftshift(SSB\_SCinFreqIdeal));

envelopeSSBTC=abs(hilbert(real(SSB\_TC\_time)));

%down sample envelop detector

envelopeSSBTC=resample(envelopeSSBTC,F,500000);

envelopeSSBTC=envelopeSSBTC-mean(envelopeSSBTC);

figure;

plot(T,envelopeSSBTC(1:end-1));

title('Demodulated SSB-TC Signal in Time Domain');

zdtc = abs(fftshift(fft(envelopeSSBTC)));

fdtc = linspace(-F/2, F/2, length(envelopeSSBTC));

figure

plot(fdtc, zdtc);

xlim([-5000 5000]);

ylim([0 300]);

title('Demodulated SSB-TC Signal in Frequency Domain');

sound(real(envelopeSSBTC),F);

**Experiment 2 Graphs**

Chart, histogram

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A picture containing text, writing implement, stationary, pencil

Description automatically generated

Chart, histogram

Description automatically generated

Chart, bar chart, histogram

Description automatically generated

Chart, histogram

Description automatically generated

**Experiment 3**

**Matlab Code**

clc

clear

close all

% Read the audio file and get its sampling frequency

[y, F] = audioread('eric.wav');

ty = length(y)/F;

t = linspace(0, ty, length(y));

% Input signal conversion to frequency domain (to apply ideal LPF)

z = fftshift(fft(y));

f = linspace(-F/2, F/2, length(y));

figure

plot(f, abs(z));

title('Original Signal in Frequency Domain');

% Searching for indices where f = -4000 and f = 4000

for i = 1:length(f)

if (abs((f(i)+4.0000e+3)) < 0.01)

index1 = i;

end

if (abs((f(i)-4.0000e+3)) < 0.01)

index2 = i;

break;

end

end

% Generating a rect from index1 to index2

range = index2-index1;

step = [zeros(1, index1) ones(1, range) zeros(1, length(f)-index2)];

step = step.';

% Multiplying input signal by rect to eliminate frequencies other than 4k

yfilteredFreq = step.\*z;

yfilteredFreqAbs = abs(step.\*z);

figure

plot(f, yfilteredFreqAbs);

xlim([-15000 15000]);

title('Filtered Signal in Frequency Domain');

% Converting the filtered signal to time domain to be modulated

yfiltered = ifft(fftshift(yfilteredFreq));

figure

plot(t, yfiltered);

title('Filtered Signal in Time Domain');

% Signal after low pass filter

sound(yfiltered, F);

pause(9);

% Filtered signal resampling

maxAmplitude = max(yfiltered);

yfiltered = resample(yfiltered, 500000, F);

yfiltered = yfiltered.';

interval = length(yfiltered);

% Frequency Modulation

% NBFM Signal

kf = 1e+1\*pi;

t = linspace(0, ty, interval);

deltaF = abs(kf\*max(yfiltered));

m\_int = kf.\*cumsum(yfiltered);

nbfm = 2\*10.\*cos(2.\*pi.\*100000.\*t + m\_int);

figure

plot(t, nbfm);

title('Modulted NBFM Signal in Time Domain');

zmnbfm = abs(fftshift(fft(nbfm)));

fmnbfm = linspace(-500000/2, 500000/2, length(nbfm));

figure

plot(fmnbfm, zmnbfm);

title('Modulated NBFM Signal in Frequency Domain');

% Frequency Demodulation

nbfm = diff(nbfm);

nbfmEnvelope = abs(hilbert(nbfm));

nbfmEnvelope = resample(nbfmEnvelope, F, 500000);

sound(nbfmEnvelope , F);

**Experiment 3 Graphs**

Chart, histogram

Description automatically generated

Chart, histogram

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Chart

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Chart

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Chart, histogram

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**Experiment 3 Conclusions**

* When the instantaneous frequency increases the value of the phase deviation increases.
* To achieve NBFM modulation index, frequency deviation, phase deviation and frequency deviation constant are very small.