INEL 4301– COMMUNICATION THEORY I
MATLAB Class Assignment: DSB-SC Communications Systems
Prof. Domingo Antonio Rodríguez
MCA01 – DUE: FRIDAY, SEPT. 17, BEFORE 11:50 PM

DOUBLE SIDEBAND SUPPRESSED CARRIER

The objective of this simulation is to study the properties of a DSBSC system with **input signal** $x(t)$ and output $x_r(t)$.

Task 01.- 10 points: Learn about the **desired signal** $s(t)$ and modify its parameters (amplitude and frequency) to obtain a new signal. This new signal should have **three (3) cosine components** as the original input signal. Use this new desired signal to generate all your **new graphs** in a renamed script with name (**inel4301sxxxgpyyt1hw01**).

Task 02.- 10 points: Starting from results of **Task 01**, learn about interference signals in order to generate a new unwanted signal $g(t)$ to be added to the desired signal $s(t)$ (see ***Fig. 1***) resulting in a new modulating input signal $x_m(t)$. The unwanted signal should have two (2) **cosine signals** as components. Use this new signal to generate all your **new graphs** in a renamed script (**inel4301xxxgpyyt2hw01**).

Task 03.- 10 points: Starting from results of **Task 01**, learn about carrier signals in order to generate a new carrier signal by changing the carrier frequency (not the amplitude) in a renamed script with name (**inel4301sxxxgpyyt3hw01**).

Task 04.- 10 points: Starting from results of **Task 01**, learn about cutoff frequencies of ideal low-pass filters in order to design a new low-pass filter by changing the cutoff frequency in a renamed script (**inel4301xxxgpyyt4hw01**).

Task 05 to **Task 08.- (Each 15 points):** Repeat the **Task 01** to the **Task 04**, after designing and incorporating the band-pass filter at the transmitter for each of the tasks. The carrier frequency should be the center frequency of the filter. Provide new names (**inel4301xxxgpyytzhw01**), with (**z** from **5** to **8**).

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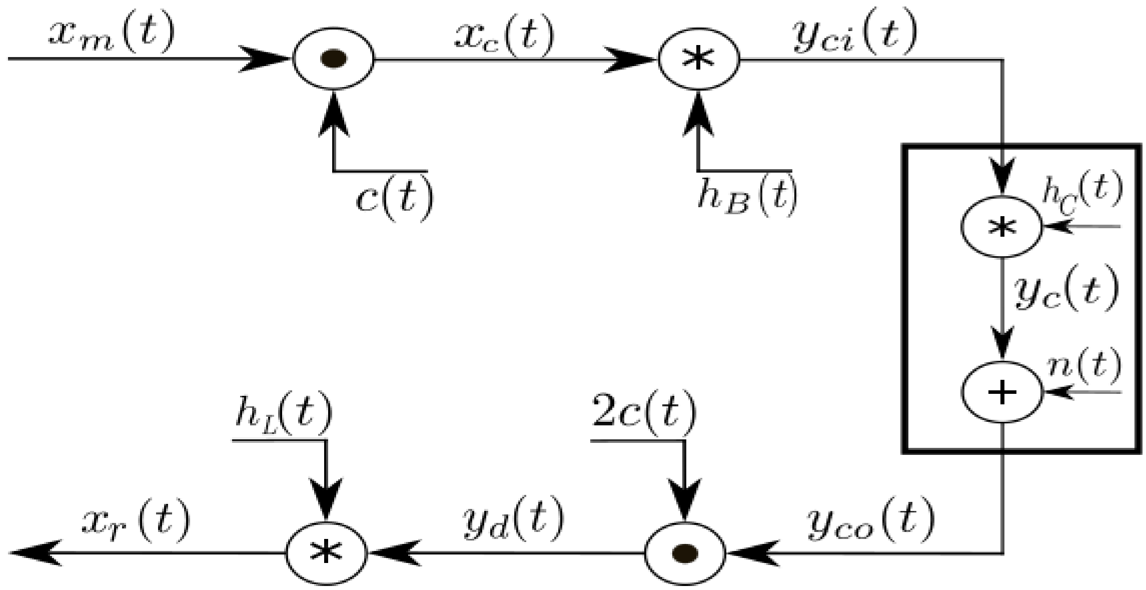

***Fig. 1: DSB-SC** Comm. System with* $\boldsymbol{h_c(t) = \delta(t)}$ *and* $\boldsymbol{n(t) = \mathrm{AWGN}}$.

The **spectrum** or Fourier transform of the output of the modulator is:

$$\boldsymbol{X_c(f) = X_m(f) * C(f) = X_m(f) * \left[\tfrac{1}{2}\delta(f-f_c) + \tfrac{1}{2}\delta(f+f_c)\right]}$$

$$\boldsymbol{X_c(f) = \tfrac{1}{2}X_m(f) * \delta(f-f_c) + \tfrac{1}{2}X_m(f) * \delta(f+f_c)}$$

$$\boldsymbol{X_c(f) = \tfrac{1}{2}X_m(f-f_c) + \tfrac{1}{2}X_m(f+f_c)}$$

The spectrum of the channel input signal is the product of the spectrum of the output of the modulation times the frequency response of the bandpass filter:

$$\boldsymbol{Y_{ci}(f) = X_c(f) \cdot H_B(f) = \left[\tfrac{1}{2}X_m(f-f_c) + \tfrac{1}{2}X_m(f+f_c)\right] \cdot H_B(f)}$$

For tasks **Task 01** to **Task 04** the frequency response function of the bandpass filter is assumed to be fixed and given in the MATLAB script. This results in the spectrum of the channel input signal is being equal to the filtered version of the modulator output signal:

$$\boldsymbol{Y_{ci}(f) = X_c(f) \cdot H_B(f) \cdot}$$

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```
%inel4301s000gp00t0hw01
%Inel 4301 - Communication Theory I
%MATLAB CLASS ASSIGNAMENT 01(MCA01)
%Double Sideband Suppressed Carrier Systems
%Prof. Domingo Antonio Rodríguez
%
%%
%%PARAMETER SETTINGS******************************
%%
clear all
close all
Fs=16800;              %Sampling frequency
Ts=1/Fs;               %Sampling time or temporal resolution
f1=220;                %First frequency component (A3) of s(t)
f2=329;                %Second frequency component (E4) of s(t)
f3=440;                %Third frequency component of (A4) s(t)
fc=2000;               %Frequency of carrier signal > 2*fm
fm=500;                %Bandwidth of desired signal s(t)
Ns=1200;                %Number of samples of s(t)
Tw=Ns*Ts;              %Time observation window for s(t)
t=0:Ts:Tw-Ts;          %Time axis for desired signal s(t)
%%
%%TRANSMITTER SYSTEM******************************
%%
s=(3*cos(2*pi*f1*t)-2*cos(2*pi*f2*t)+2*cos(2*pi*f3*t))/8;
g=1*cos(2*pi*800*t);       %Interference signal g(t)
max_sg=max(s+g);           %Absolute value of signal s(t)+g(t)
xm=(s+g)/max_sg;           %Normalized Modulating signal xm(t)
ct=cos(2*pi*fc*t);         %Transmitter carrier signal ct(t)
xc=xm.*ct;                 %Modulated signal xc(t)
%%
%%Transmitter's Band-Pass Filter Design
%%
fu=fc+fm;              %Upper cut-off frequency
fl=fc-fm;              %Lower cut-off frequency
wu=(2*fu)/Fs;          %Normalized upper frequency
wl=(2*fl)/Fs;          %Normalized lower frequency
wb=[wl wu];            %Bandwidth of band-pass filter
Mb=101;                %Order of band-pass filter
thB=0:Ts:Mb*Ts-Ts;     %Time axis of impulse response signal hB(t)
hB=fir1(Mb-1,wb,'bandpass');       %Filter design function
yci=conv(xc,hB);           %Discrete-time convolution operation
lyci=length(yci);          %Length of yci=Ns+Mb-1;
tyci=0:Ts:(lyci-1)*Ts;     %Time axis of signal yci(t)
%%
%% COMMUNICATION CHANNEL**************************
%%
nn=randn(lyci,1);              %AWGN with mean=0 and variance=1.
```

```
n=(1/1000)*transpose(nn);   %Attenuated noise signal n(t)
yco=yci+0*n;
%%
%% RECEIVER SYSTEM********************************
%%
cr=cos(2*pi*fc*tyci);
yd=2*yco.*cr;        %Demodulated signal
%
%Low-Pass Filter Design**************************
%
Wn=2*fm/Fs;          %Normalized cut-off frequency
M=091;               %Order of the impulse response signal hL(t)
thL=0:Ts:M*Ts-Ts;    %Time axis to plot impulse response signal
hL=fir1(M-1,Wn);     %Impulse response signal
%
%Signal Filtering at the Receiver*****************
%
tr=0:Ts:(lyci+M-1)*Ts-Ts;    %Time axis for received signal
xr=conv(yd,hL);              %Convolution operation for filtering
Af=1;                        %Signal amplification factor
xr=Af*xr;
%%
%%SIGNALS SPECTRA*********************************
%%
fres_s=1/(length(s)*Ts);
faxis_s=-(Fs/2):fres_s:(Fs/2)-fres_s;
Fss=fft(s);
sFss=fftshift(Fss);
asFss=abs(sFss);
%
fres_g=1/(length(g)*Ts);
faxis_g=-(Fs/2):fres_g:(Fs/2)-fres_g;
Fg=fft(g);
sFg=fftshift(Fg);
asFg=abs(sFg);
%
fres_xm=1/(length(xm)*Ts);
faxis_xm=-(Fs/2):fres_xm:(Fs/2)-fres_xm;
Fxm=fft(xm);
sFxm=fftshift(Fxm);
asFxm=abs(sFxm);
%
fres_ct=1/(length(ct)*Ts);
faxis_ct=-(Fs/2):fres_ct:(Fs/2)-fres_ct;
Fct=fft(ct);
sFct=fftshift(Fct);
asFct=abs(sFct);
%
fres_xc=1/(length(xc)*Ts);
```

```
faxis_xc=-(Fs/2):fres_xc:(Fs/2)-fres_xc;
Fxc=fft(xc);
sFxc=fftshift(Fxc);
asFxc=abs(sFxc);
%
fres_hB=1/(length(hB)*Ts);
faxis_hB=-(Fs/2):fres_hB:(Fs/2)-fres_hB;
FhB=fft(hB);
sFhB=fftshift(FhB);
asFhB=abs(sFhB);
%
fres_yci=1/(length(yci)*Ts);
faxis_yci=-(Fs/2):fres_yci:(Fs/2)-fres_yci;
Fyci=fft(yci);
sFyci=fftshift(Fyci);
asFyci=abs(sFyci);
%
fres_n=1/(length(n)*Ts);
faxis_n=-(Fs/2):fres_n:(Fs/2)-fres_n;
Fn=fft(n);
sFn=fftshift(Fn);
asFn=abs(sFn);
%
fres_yco=1/(length(yco)*Ts);
faxis_yco=-(Fs/2):fres_yco:(Fs/2)-fres_yco;
Fyco=fft(yco);
sFyco=fftshift(Fyco);
asFyco=abs(sFyco);
%
fres_cr=1/(length(cr)*Ts);
faxis_cr=-(Fs/2):fres_cr:(Fs/2)-fres_cr;
Fcr=fft(cr);
sFcr=fftshift(Fcr);
asFcr=abs(sFcr);
%
fres_yd=1/(length(yd)*Ts);
faxis_yd=-(Fs/2):fres_yd:(Fs/2)-fres_yd;
Fyd=fft(yd);
sFyd=fftshift(Fyd);
asFyd=abs(sFyd);
%
fres_hL=1/(length(hL)*Ts);
faxis_hL=-(Fs/2):fres_hL:(Fs/2)-fres_hL;
FhL=fft(hL);
sFhL=fftshift(FhL);
asFhL=abs(sFhL);
%
fres_xr=1/(length(xr)*Ts);
faxis_xr=-(Fs/2):fres_xr:(Fs/2)-fres_xr;
```

```
Fxr=fft(xr);
sFxr=fftshift(Fxr);
asFxr=abs(sFxr);
%
%%
%%PLOTS****************************************
%%
%
figure
plot(t,s)
grid
xlabel('Time in Seconds')
ylabel('Amplitude')
title('Desired Signal s(t)')
%
figure
plot(t,g)
grid
xlabel('Time in Seconds')
ylabel('Amplitude')
title('Interference Signal g(t)')
%
figure
plot(t,xm)
grid
xlabel('Time in Seconds')
ylabel('Amplitude')
title('Modulating Signal xm(t)')
%
figure
plot(t,ct)
grid
xlabel('Time in Seconds')
ylabel('Amplitude')
title('Transmitter Carrier Signal ct(t)')
%
figure
plot(t,xc)
grid
xlabel('Time in Seconds')
ylabel('Amplitude')
title('Modulated Signal xc(t)')
%
figure
plot(thB,hB,thB,hB,'o')
grid
xlabel('Time in Seconds')
ylabel('Amplitude')
title('Impulse Response Signal hB(t)')
```

```
%
figure
plot(tyci,yci)
grid
xlabel('Time in Seconds')
ylabel('Amplitude')
title('Channel Input Signal yci(t)')
%
figure
plot(tyci,n)
grid
xlabel('Time in Seconds')
ylabel('Amplitude')
title('Channel Noise Signal n(t)')
%
figure
plot(tyci,yco)
grid
xlabel('Time in Seconds')
ylabel('Amplitude')
title('Channel Output Signal yco(t)')
%
figure
plot(tyci,cr)
grid
xlabel('Time in Seconds')
ylabel('Amplitude')
title('Receiver Carrier Signal cr(t)')
%
figure
plot(tyci,yd)
grid
xlabel('Time in Seconds')
ylabel('Amplitude')
title('Demodulated Signal yd(t)')
%
figure
plot(thL,hL,thL,hL,'o')
grid
xlabel('Time in Seconds')
ylabel('Amplitude')
title('Impulse Response Signal hL(t)')
%
figure
plot(tr,xr)
grid
xlabel('Time in Seconds')
ylabel('Amplitude')
title('Receiver Output Signal Signal xr')
```

```
%
figure
plot(tr,xr)
grid
xlabel('Time in Seconds')
ylabel('Amplitude')
title('Signals s(t) vs. xr(t)')
hold on
plot(t,s)
hold off
%
figure
plot(faxis_s,asFss)
grid
xlabel('Frequency in Hertz')
ylabel('Magnitude')
title('Spectrum of Desired Signal s(t)')
%
figure
plot(faxis_g,asFg)
grid
xlabel('Frequency in Hertz')
ylabel('Magnitude')
title('Spectrum of Interference Signa g(t)')
%
figure
plot(faxis_xm,asFxm)
grid
xlabel('Frequency in Hertz')
ylabel('Magnitude')
title('Spectrum of Modulating Signal xm(t)')
%
figure
plot(faxis_ct,asFct)
grid
xlabel('Frequency in Hertz')
ylabel('Magnitude')
title('Spectrum of Carrier Signal ct(t)')
%
figure
plot(faxis_xc,asFxc)
grid
xlabel('Frequency in Hertz')
ylabel('Magnitude')
title('Spectrum of Modulated Signal xc(t)')
%
figure
plot(faxis_hB,asFhB,faxis_hB,asFhB,'o')
grid
```

```
xlabel('Frequency in Hertz')
ylabel('Magnitude')
title('Spectrum of Band-Pass Filter Signal hB(t)')
%
figure
plot(faxis_yci,asFyci)
grid
xlabel('Frequency in Hertz')
ylabel('Magnitude')
title('Spectrum of Channel Input Signal yci(t)')
%
figure
plot(faxis_n,asFn)
grid
xlabel('Frequency in Hertz')
ylabel('Magnitude')
title('Spectrum of AWGN Signal n(t)')
%
figure
plot(faxis_yco,asFyco)
grid
xlabel('Frequency in Hertz')
ylabel('Magnitude')
title('Spectrum of Channel Output Signal yco(t)')
%
figure
plot(faxis_cr,asFcr)
grid
xlabel('Frequency in Hertz')
ylabel('Magnitude')
title('Spectrum of Receiver Carrier cr(t)')
%
figure
plot(faxis_yd,asFyd)
grid
xlabel('Frequency in Hertz')
ylabel('Magnitude')
title('Spectrum of Demodulated Signal yd(t)')
%
figure
plot(faxis_hL,asFhL,faxis_hL,asFhL,'o')
grid
xlabel('Frequency in Hertz')
ylabel('Magnitude')
title('Spectrum of Low-Pass Filter Signal hL(t)')
%
figure
plot(faxis_xr,asFxr)
grid
```

```
xlabel('Frequency in Hertz')
ylabel('Magnitude')
title('Spectrum of Receiver Output Signal xr(t)')
%
figure
plot(faxis_xr,asFxr)
grid
xlabel('Frequency in Hertz')
ylabel('Magnitude')
title('Spectra of Signals s(t) vs. xr(t)')
hold on
plot(faxis_s,asFss)
hold off
%
sound(s,Fs)
pause(2)
sound(xm,Fs)
pause(2)
sound(xr,Fs)
%
clc
disp('******************************')
disp('Simulation ended succesfully')
disp('******************************')
```

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CLASS ASSIGNMENT GUIDELINES:

A.- This MCA01 **does not require** a written report. It requires for each student group to send a **.zip** folder with the following items provided in the list below. There should be **NOTHING else** inside the requested **.zip** folder:

i.- Original, unaltered, INEL4301_MCW01_SXXX_GPYY.docx
ii.- Original, unaltered, INEL4301_MCW01_SXXX_GPYY.pdf
iii.- Copy of original **inel4301s000gp00t0hw01.m**
iv.- Task assignment table **sxxxgpyymcw01_tat.pdf**
v.- One **inel4301s000gp00t0hw01.m** per task.

Refers to the class section number: **sxxx**
Refers to the student's group number: **gpyy**
Refers to the script or program number: **pgzz**

B.- Name of **.zip** folder and the name of the **e-mail subject**:

INEL4301_MCW01_SXXX_GPYY

C.- Send e-mail, with the correct **e-mail subject** and **.zip** file with appropriate name, to the following e-mail address:

domingo.rodriguez1@upr.edu

STANDARD TABLE FOR DEMERITS

01.- Script file does NOT execute well	**-05 pts.**
02.- Correct script file NOT included	**-05 pts.**
03.- Task assignment table NOT included	**-05 pts.**
04.- Unzipped folder does NOT have same name	**-05 pts.**
05.- Missing INEL4095_MCW01_SXXX_GPYY.docx	**-03 pts.**
06.- Missing INEL4095_MCW01_SXXX_GPYY.pdf	**-03 pts.**
07.- Missing class section number sxxx	**-03 pts.**
08.- Missing student's group number gpyy	**-03 pts.**
09.- Missing script or program number pgzz	**-03 pts.**
10.- Missing or incorrect e-mail subject name	**-03 pts.**