[**DOUBLE SIDEBAND SUPPRESSED CARRIER**](https://www.tutorialspoint.com/analog_communication/analog_communication_dsbsc_modulation.htm)

The objective of this simulation is to study the properties of a DSBSC system with [**input signal**](https://electronicspost.com/introduction-to-double-sideband-suppressed-carrier-dsb-sc-system-explain-the-generation-of-dsb-sc-signal/) and output .

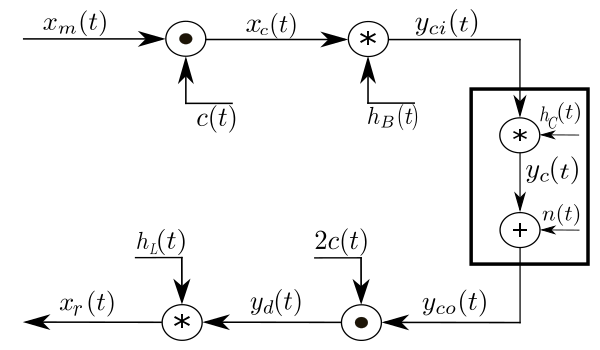
**Task 01.- 10 points:** Learn about the **desired signal** and modify its parameters (amplitude and frequency) to obtain a new signal. This new signal should have **three (3)** [**cosine components**](https://www.sciencedirect.com/topics/engineering/cosine-wave) as the original input signal. Use this 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 to be added to the desired signal (see ***Fig. 1***) resulting in a new [modulating input signal](https://education.ni.com/teach/resources/1189/double-sideband-modulation-and-demodulation-dsbsc) . The unwanted signal should have two (2)[**cosine signals**](https://en.wikipedia.org/wiki/Beat_%28acoustics%29)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](https://en.wikipedia.org/wiki/Double-sideband_suppressed-carrier_transmission) 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](https://www.mathworks.com/help/signal/ref/lowpass.html) 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](https://www.mathworks.com/help/signal/ref/fir1.html) 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**).



***Fig. 1:******DSB-SC*** *Comm. System with and .*

The [**spectrum**](https://en.wikipedia.org/wiki/Fourier_transform) or Fourier transform of the output of the modulator is:

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:

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:

**%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('\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*')**

**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**](mailto: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**](https://www.youtube.com/watch?v=Z1Uwmxdshqc) **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.** |