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DSB-SC Modulator/Demodulator Example

This documents describes/implements the DSB-SC modulation and demodulation of a song signal.

Prepared for ELEC 301

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Program Initialization

```
%Clear Variables and Close All Figure Windows

% Clear all previous variables
clear
% Close all previous figure windows
close all
```

Read Song File

song.mat contains **song** variable containing Song samples and **Fs** which is the sampling frequency

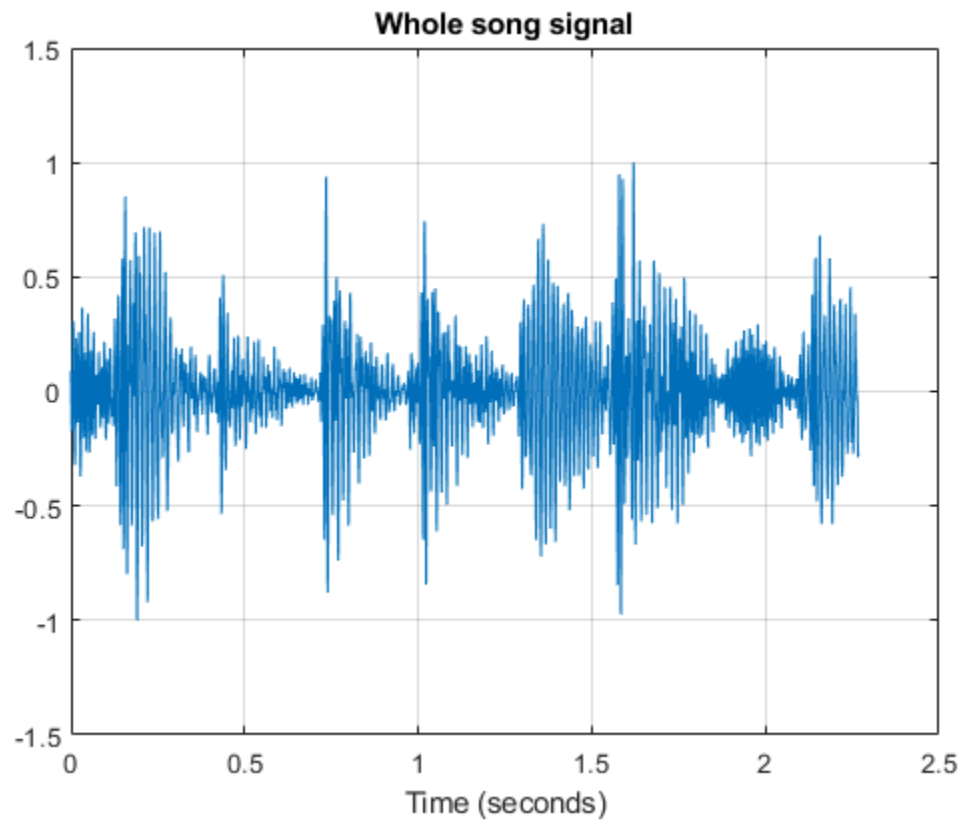
```
% Load the song file
load song.mat
% song is the song samples
% Fs is the sampling frequency

% Transform the song to low rate sampling for listening (sound command
% requires sampling rate to be less than 44K
songlowrate=downsample(song,10);
% Listen to
sound(songlowrate,Fs/10);
% convert it to row array
```

```
song=reshape(song,1,length(song));  
% Sampling Period  
Ts=1/Fs;  
% Sampling times  
t=(0:1:(length(song)-1))*Ts;
```

Display the whole song

```
% Display the whole song  
figure(1)  
plot(t,song);  
grid  
title('Whole song signal');  
xlabel('Time (seconds)');
```



Generate Modulated Signal

Generate carrier signal and multiply with the song signal to obtain DSB-SC modulated waveform

Carrier frequency:

$$f_c = 60 \text{ kHz}$$

```
fc=60e3; % 60 kHz;
```

Carrier signal: _

$$c(t) = \cos(2\pi f_c t)$$

```
c=cos(2*pi*fc*t);
```

DSB-SC Modulated waveform

$$x(t) = s(t)c(t)$$

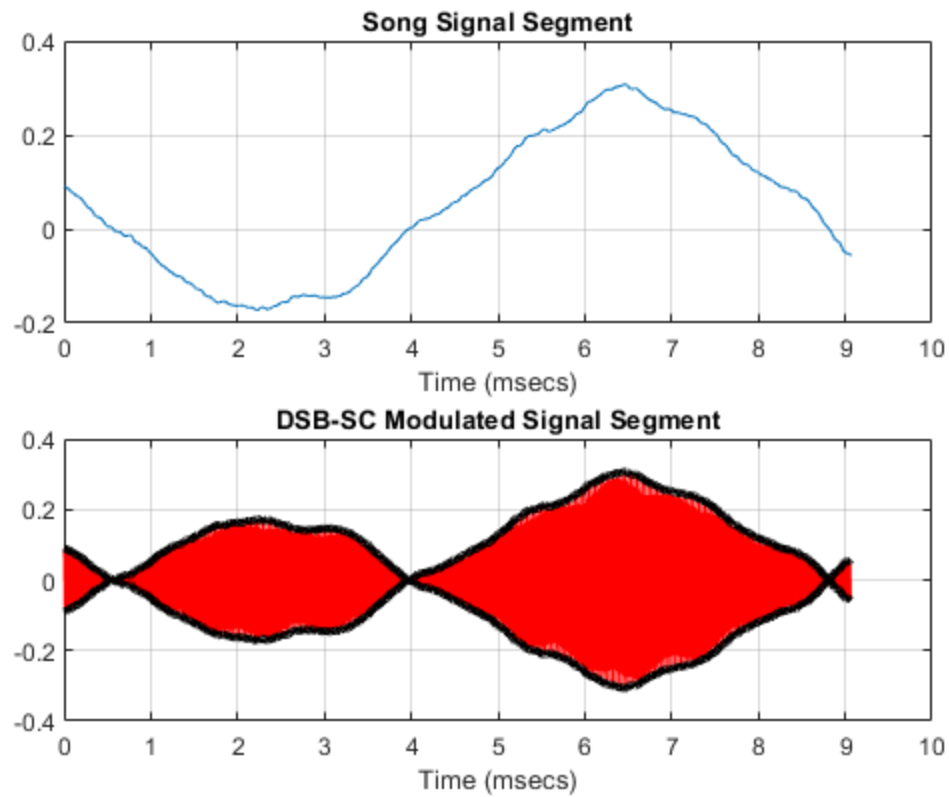
```
x=song.*c;
```

Display the Segments of Signal and Modulated Signal

Display small section of the original signal and then the DSB-SC modulated version

```
figure(2)
% plot the song segment (for about 3000 samples)
subplot(2,1,1)
plot(t(1:3000)*1000, song(1:3000));
xlabel('Time (msecs)')
title('Song Signal Segment')
grid

subplot(2,1,2)
% plot the modulated signal
plot(t(1:3000)*1000,x(1:3000),'r');
hold on
% plot also positive and negative envelopes
p1=plot(t(1:3000)*1000,song(1:3000),'k');
p2=plot(t(1:3000)*1000,-song(1:3000),'k');
xlabel('Time (msecs)')
set(p1,'LineWidth',3)
set(p2,'LineWidth',3)
grid
title('DSB-SC Modulated Signal Segment')
```



The DSB-SC Receiver Processing

Coherent DSB-SC Receiver operation

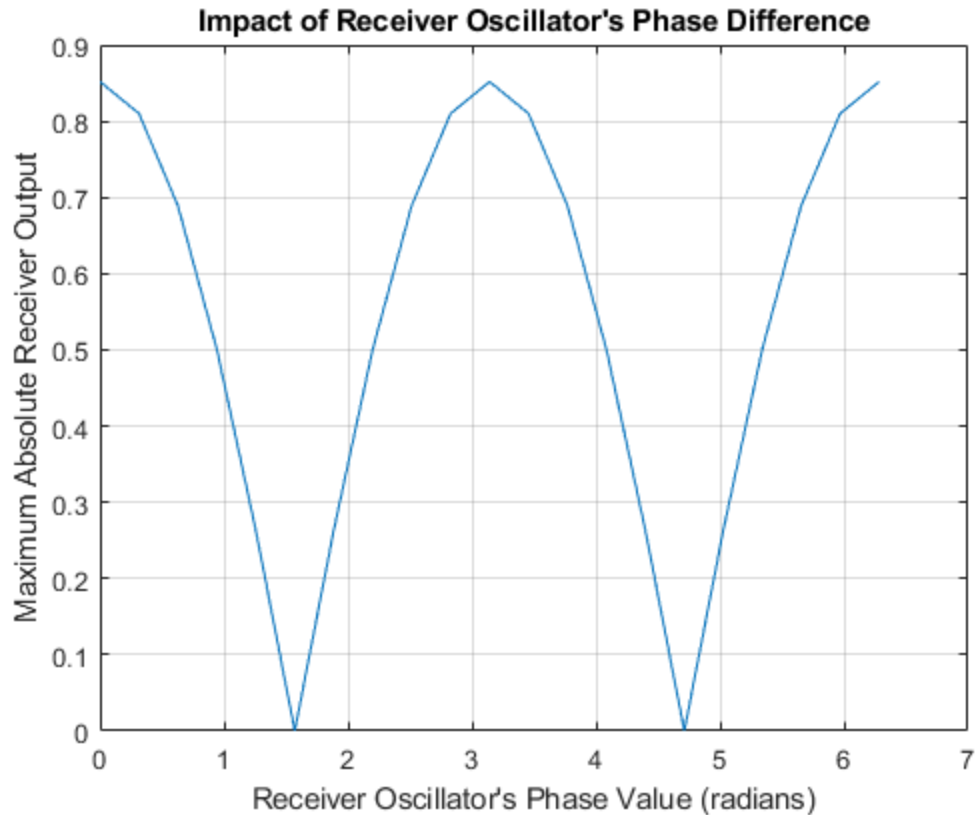
First multiply with the receiver carrier (which is assumed to be in phase)

$$y(t) = 2x(t)c(t)$$

```
theta = 0:pi/10:2*pi;
max_z = theta;
for zi = 1:length(theta)
    c_shifted = cos(2*pi*fc*t + theta(zi));
    y=2*x.*c_shifted;
    z = lowpass(y,30e3,Fs);

    max_z(zi) = max(abs(z(40000:60000)));
end

% GRAPH
figure(5);
plot(theta, max_z);
xlabel("Receiver Oscillator's Phase Value (radians)");
ylabel("Maximum Absolute Receiver Output");
grid;
title("Impact of Receiver Oscillator's Phase Difference");
```



Then low pass filter this signal

`% STUDENT NOTE: Lowpassed the signal inside the previous for loop`

$$z(t) = y(t) * h_{LP}(t)$$

`%z = lowpass(y,30e3,Fs);`

Fourier Transforms of Song, Modulated and Demodulated Signals

Calculate and Display the Fourier Transforms of the song,modulated and demodulated signals

Calculate the Fourier Transform of the song signal

`[ftsong,freqs]=fouriertransform(song, Fs);`

Calculate the Fourier Transform of the DSB-SC signal

`[ftx,freqs]=fouriertransform(x,Fs);`

Calculate Fourier Transform after receiver carrier multiplication

`[fty,freqs]=fouriertransform(y,Fs);`

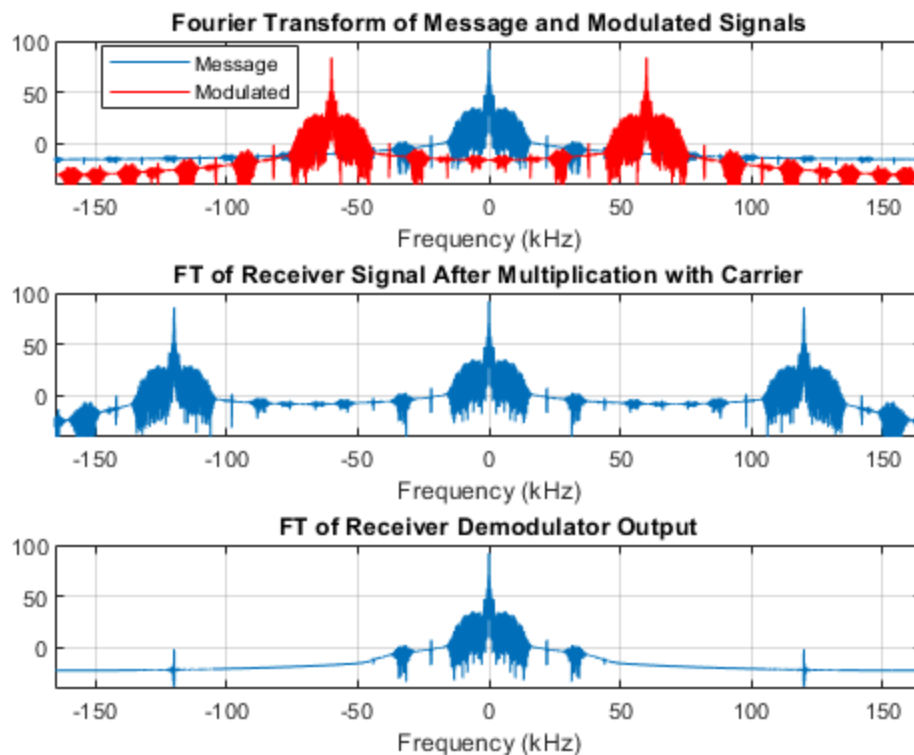
Calculate Fourier Transform of the receiver output

`[FTz,freqs]=fouriertransform(z,Fs);`

Display these Fourier Transforms

```
figure(3)
subplot(3,1,1);
plot(freqs/1000, 20*log10(abs(ftsong)));
hold on
plot(freqs/1000, 20*log10(abs(ftx)), 'r');
grid
legend('Message', 'Modulated', 'Location', 'Best')
xlabel('Frequency (kHz)');
title('Fourier Transform of Message and Modulated Signals')
axis([-Fs/2000 Fs/2000 -40 100])
subplot(3,1,2);
plot(freqs/1000, 20*log10(abs(fty)));
axis([-Fs/2000 Fs/2000 -40 100])
grid
xlabel('Frequency (kHz)');
title('FT of Receiver Signal After Multiplication with Carrier')
subplot(3,1,3)

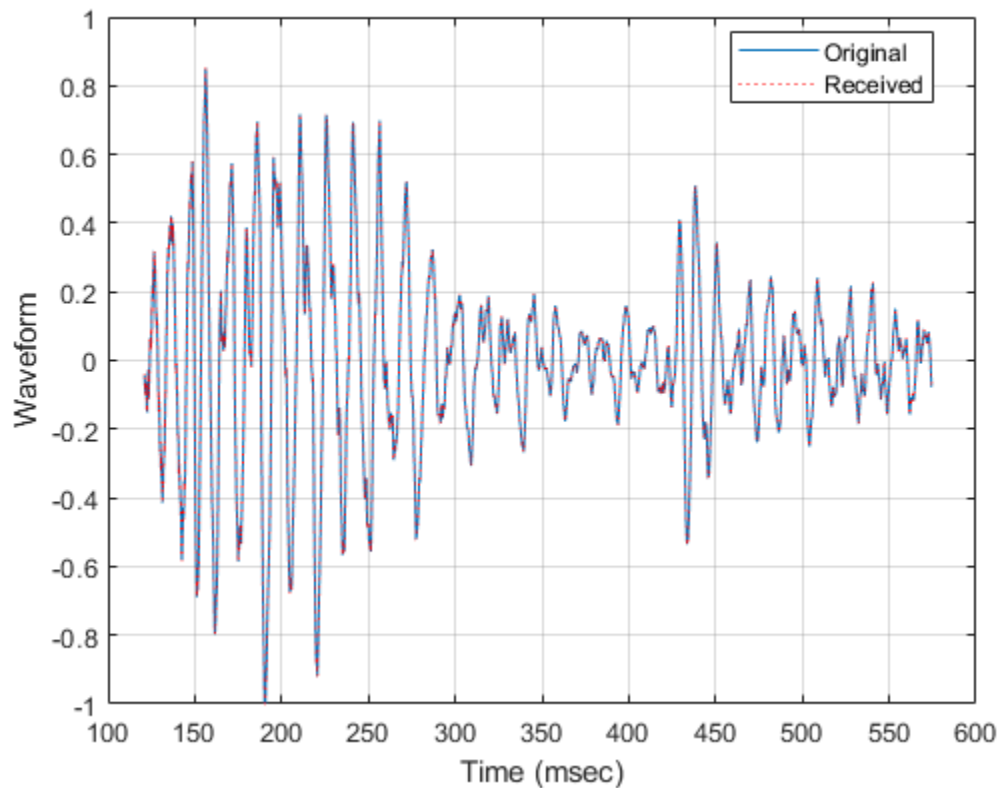
plot(freqs/1000, 20*log10(abs(FTz)));
axis([-Fs/2000 Fs/2000 -40 100])
grid
xlabel('Frequency (kHz)')
title('FT of Receiver Demodulator Output')
```



Display the Original Song and the Receiver Output Segments

They are hardly distinguishable!

```
figure(4)
plot(t(40000:190000)*1000,song(40000:190000))
hold on
plot(t(40000:190000)*1000,z(40000:190000),'r:')
grid
xlabel('Time (msec)');
ylabel('Waveform');
legend('Original','Received','Location','Best');
```



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