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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

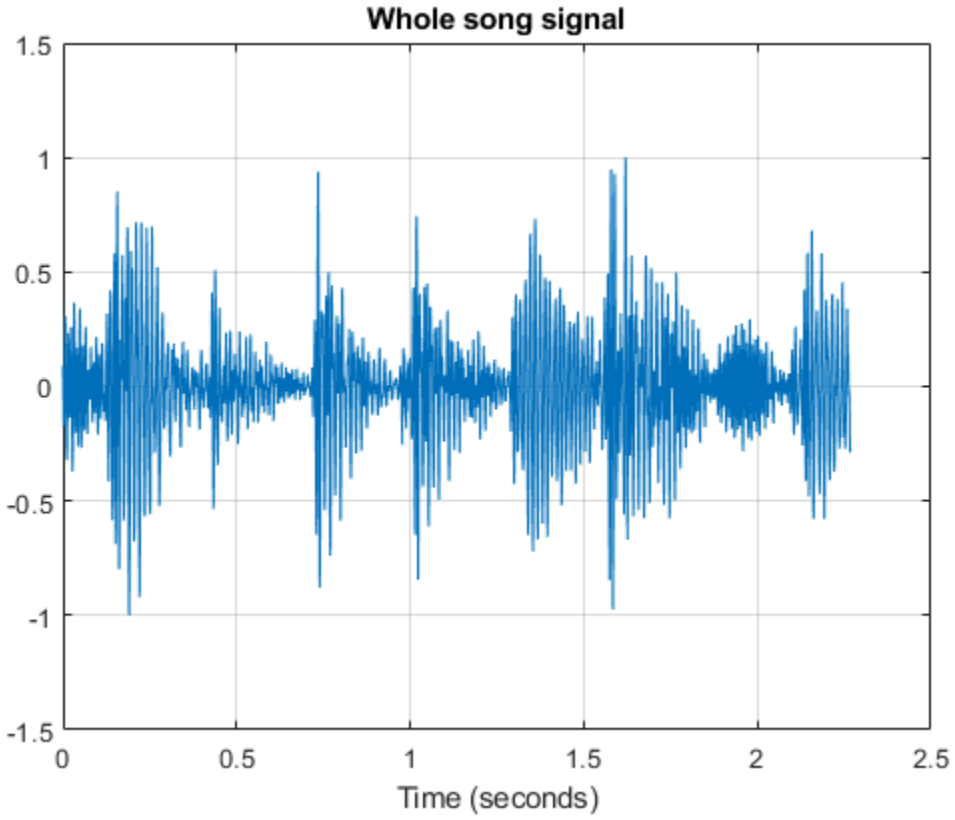
song.mat contains **song** variable containing Song samples and **Fs** which is the sampling frequency

```
% 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 Triangular Signal

Here we just create the triwave form.

```
triangle = @(t) 2*(abs(mod((2*t+1), 2)-1))-1;
twave = triangle(3e3*t);
```

Generate Modulated Signal

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

Carrier frequency:

$f_c = 60kHz$

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

% Additional frequency $f_c2=160kHz$
fc2 = 160e3;
```

Carrier signal: _

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

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

% Additional Carrier Signal $c2(t)=cos(2/pi f_c2 t)$
c2 = cos(2*pi*fc2*t);
```

DSB-SC Modulated waveform

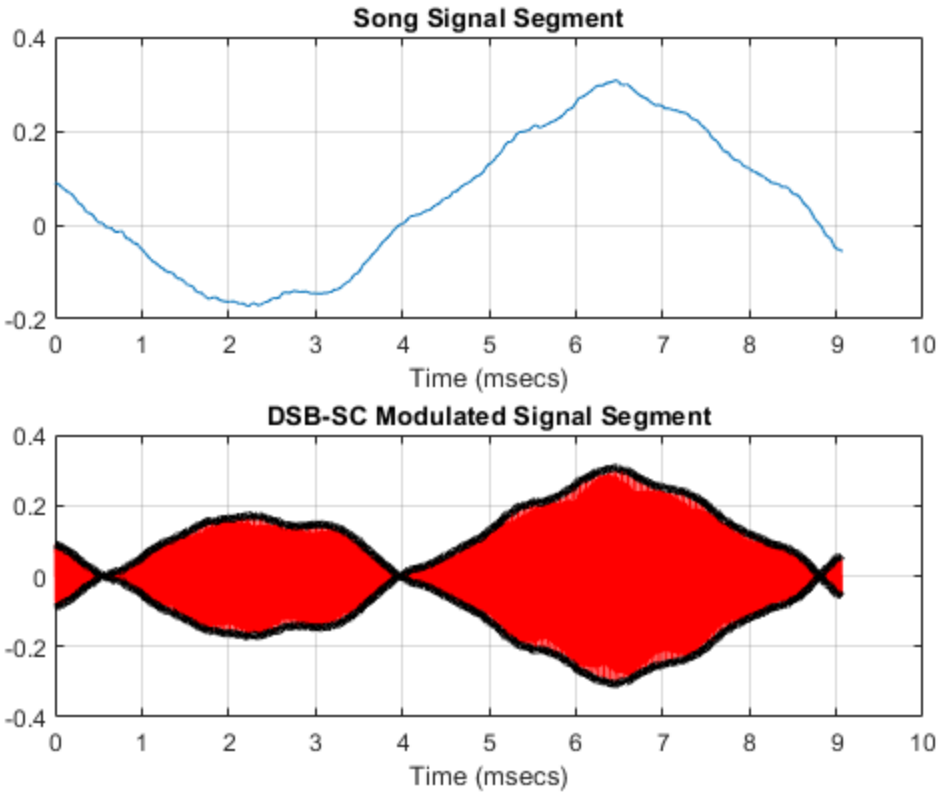
$x(t) = s(t)c(t)$

```
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 = 2*x.*c;

y_song =2*x.*c;
y_tri = 2*twave.*c2;

% Transmitter output (addition of two DSB-SC signals)

% $Y_add = 2*songSignal*c(t) + 2*triangularSignal+c_2(t)$
y_add = y_song + y_tri;
```

Then low pass filter this signal

Receiver output

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

z = lowpass(y_add,fc/2,Fs);
z2 = lowpass(y_add, fc2/2, 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);
```

Calculate FT of the addition of song signal and triangular wave

```
[FTadded, freqs] = fouriertransform(y_add,Fs);
```

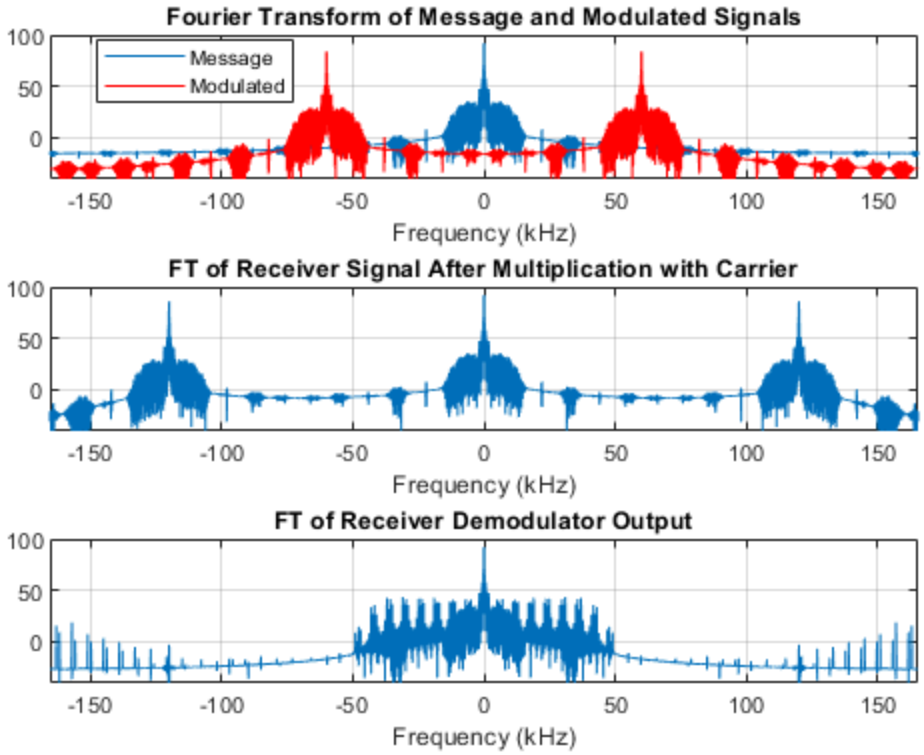
Calculate FT of Z2

```
[FTz2, freqs] = fouriertransform(z2,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])
```

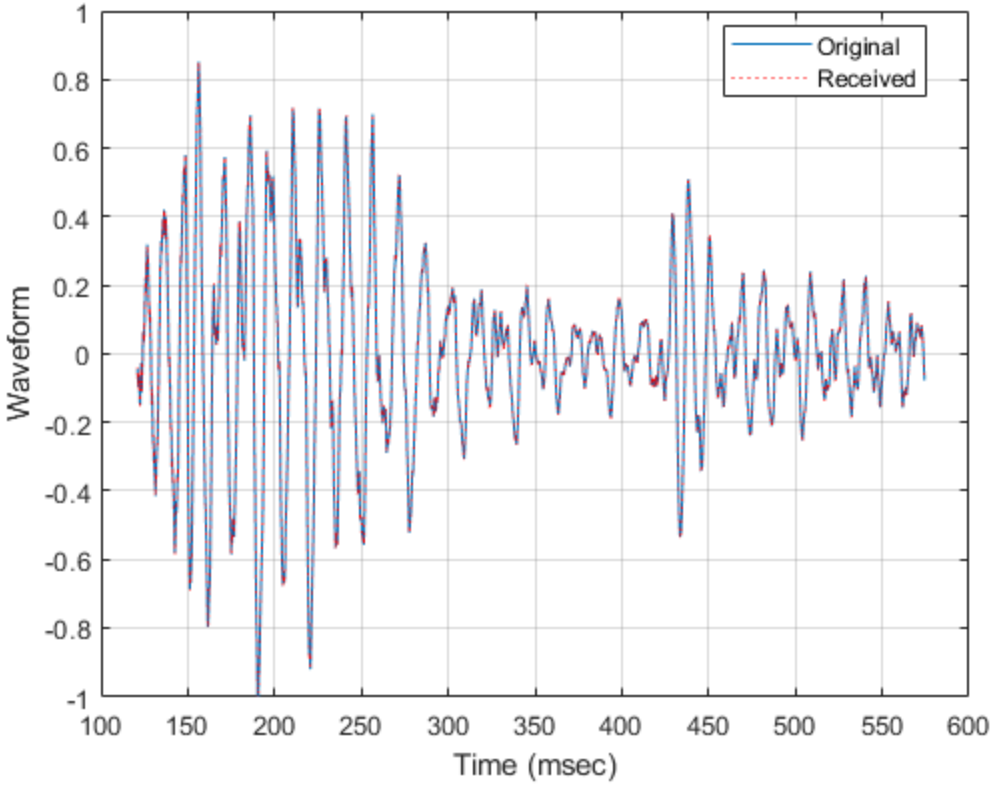
```
grid
xlabel('Frequency (kHz)')
title('FT of Receiver Demodulator Output')
```



Display the Original Song and the Receiver Output Segments

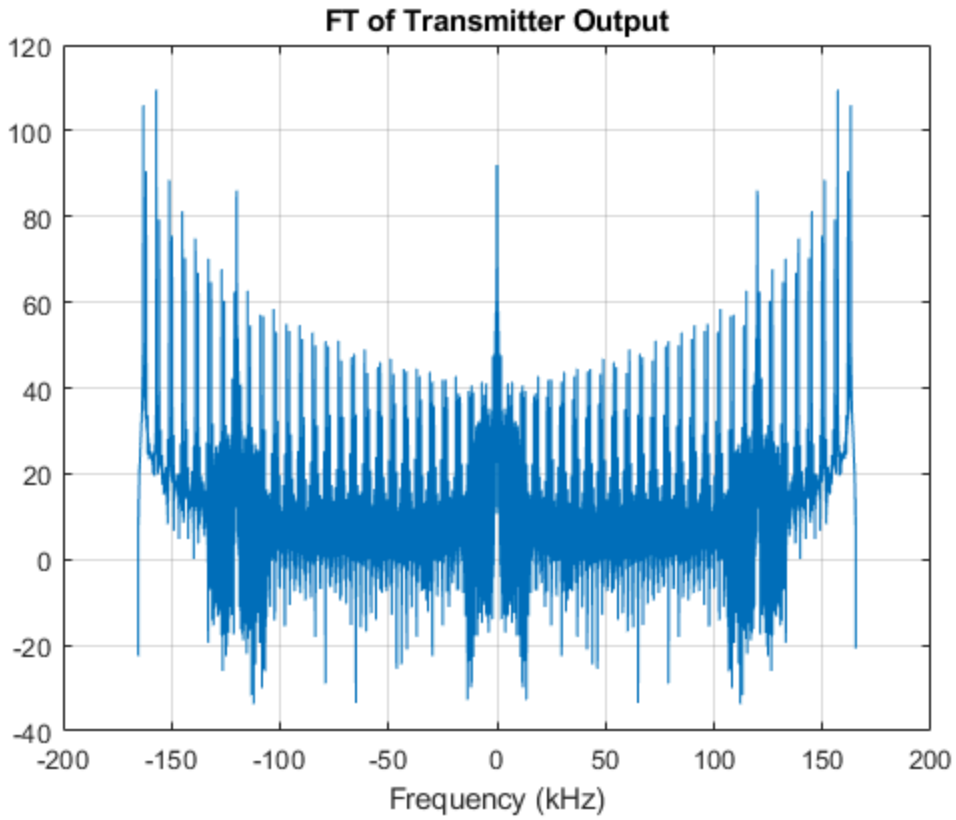
They are hardly distinguishable!

```
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');
```



Display the Fourier Transform of the Transmitter Output

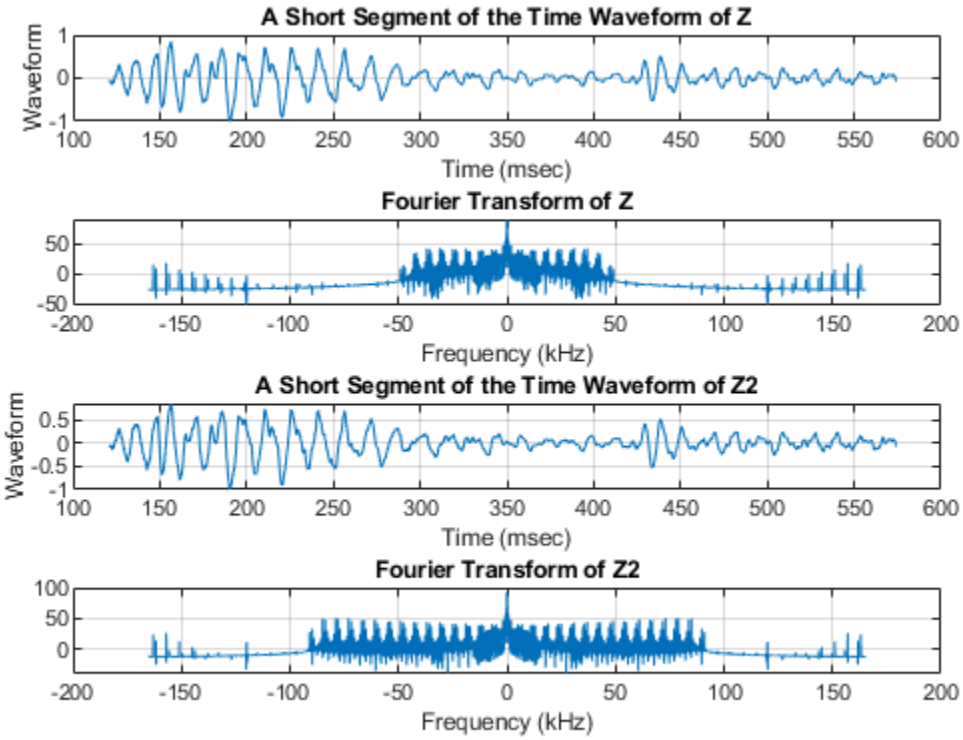
```
figure(5);
plot(freqs/1000, 20*log10(abs(FTadded)));
grid;
xlabel("Frequency (kHz)");
title("FT of Transmitter Output");
```



Display the Rest

```
figure(6);

% Short segment of time waveform of Z
subplot(4,1,1);
plot(t(40000:190000)*1000,z(40000:190000));
grid;
xlabel('Time (msec)');
ylabel('Waveform');
title("A Short Segment of the Time Waveform of Z");

% Fourier transform of Z
subplot(4,1,2);
plot(freqs/1000, 20*log10(abs(FTz)));
grid;
xlabel("Frequency (kHz)");
title("Fourier Transform of Z");

% Short segment of time waveform of Z2 (3 periods)
subplot(4,1,3);
plot(t(40000:190000)*1000,z2(40000:190000));
grid;
xlabel('Time (msec)');
ylabel('Waveform');
```

```
title("A Short Segment of the Time Waveform of Z2");

% Fourier transform of Z2
subplot(4,1,4);
plot(freqs/1000, 20*log10(abs(FTz2)));
grid;
xlabel("Frequency (kHz)");
title("Fourier Transform of Z2");
```



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