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Conventional AM Example

This documents describes/implements the AM modulation with carrier and demodulation of a song signal.

```
Prepared for ELEC 301

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*01.04.2020*
```

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

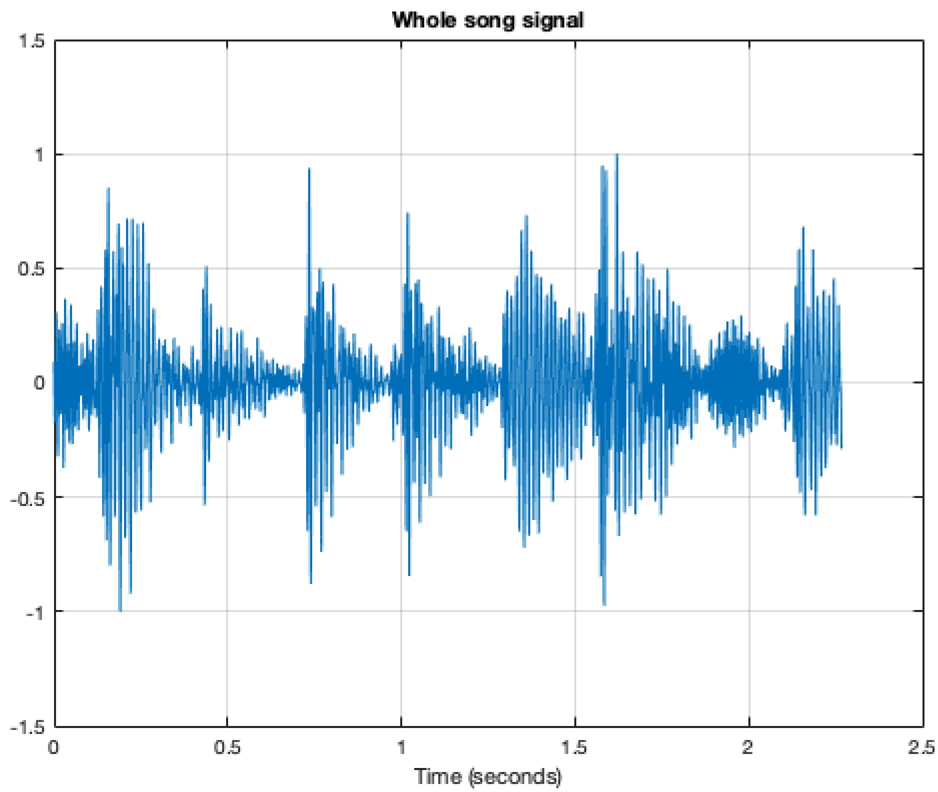
```
% Load the song file
load song.mat
% song is the song samples
% Fs is the sampling frequency

% 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-S modulated waveform

Carrier frequency:

$f_c = 60kHz$

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

Carrier signal: _

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

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

Ac should be bigger than the minimum value of the signal to make the whole signal positive

Find Ac for envelope detector

```
Ac = abs(min(song));
```

DSB-C Modulated waveform

$x(t) = s(t)c(t)$ + Ac*c(t)

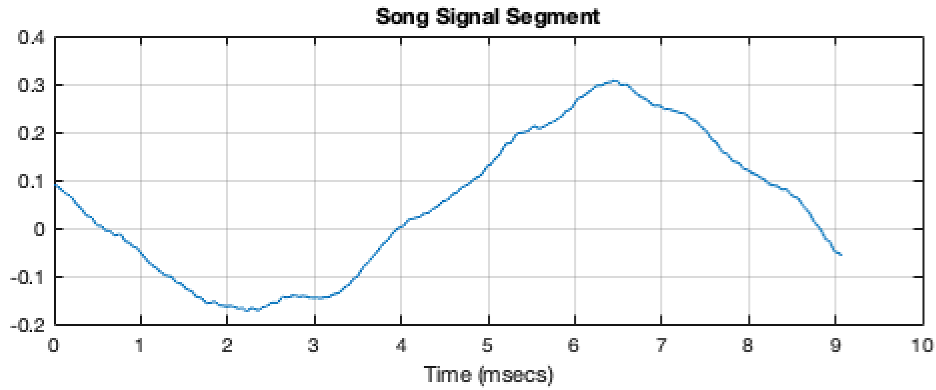
```
x=(song.*c) + (Ac.*c);
```

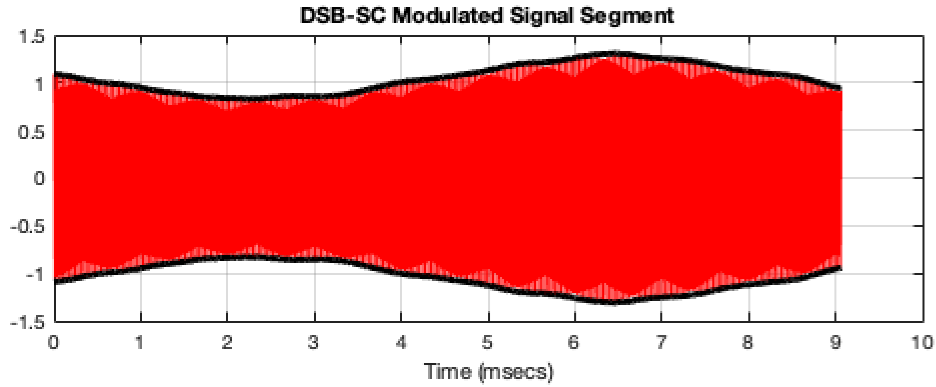
Display the Segments of Signal and Modulated Signal

Display small section of the original signal and then the DSB-C 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)+Ac,'k');
p2=plot(t(1:3000)*1000,-song(1:3000)-Ac,'k');
xlabel('Time (msecs)')
set(p1,'LineWidth',3)
set(p2,'LineWidth',3)
grid
title('DSB-SC Modulated Signal Segment')
```





The DSB-C Receiver Processing (Question 3)

Coherent DSB-C Receiver operation,

Deciding RC constant

```
%RC = 1/(2*pi*fc);
fm = 15e3; % signal bandwidth
```

```
% 1/fc < RC < 1/fm
RC = ((1/fc) + (1/fm))/2;
```

Constant

```
a = exp(-Ts/(RC));
```

Defining Vin

```
Vin = x;
```

Defining Vout

```
Vout=(1:750000);
```

The operation of the envelope detector at sample n

```
for n = 2:750000
```

```
    if Vout(n-1)*a > Vin(n)
        Vout(n) = a*Vout(n-1);
    else
        Vout(n) = Vin(n);
    end

end
```

Then, apply DC blocker to this signal

```
z = Vout - Ac;
```

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(Vout,Fs);
```

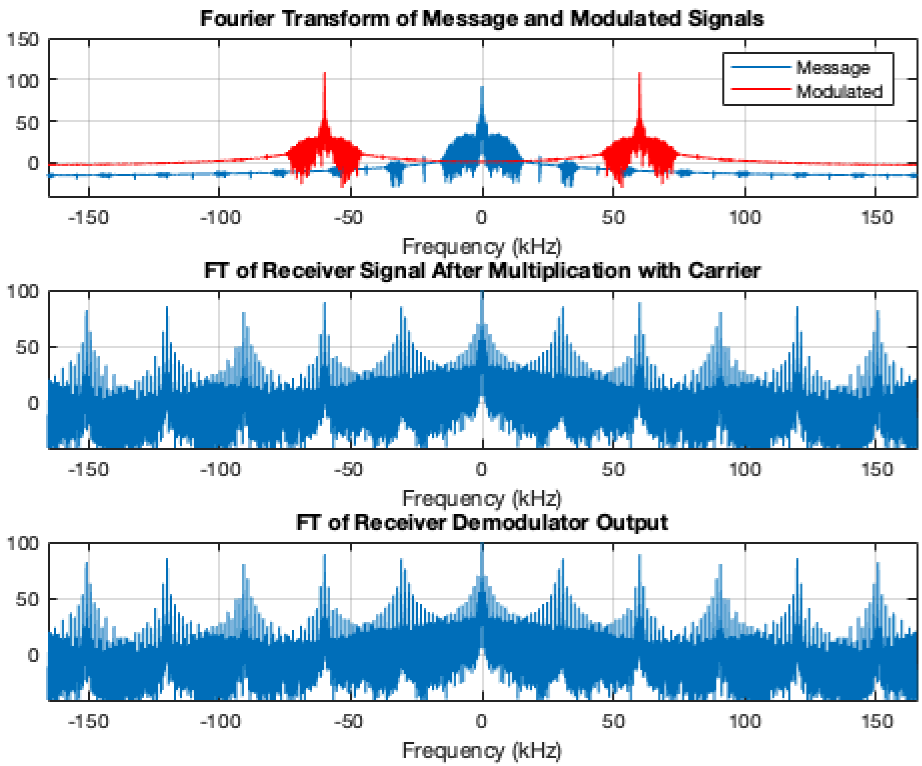
Calculate Fourier Transform of the receiver output

```
[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 -40 150])
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)
```

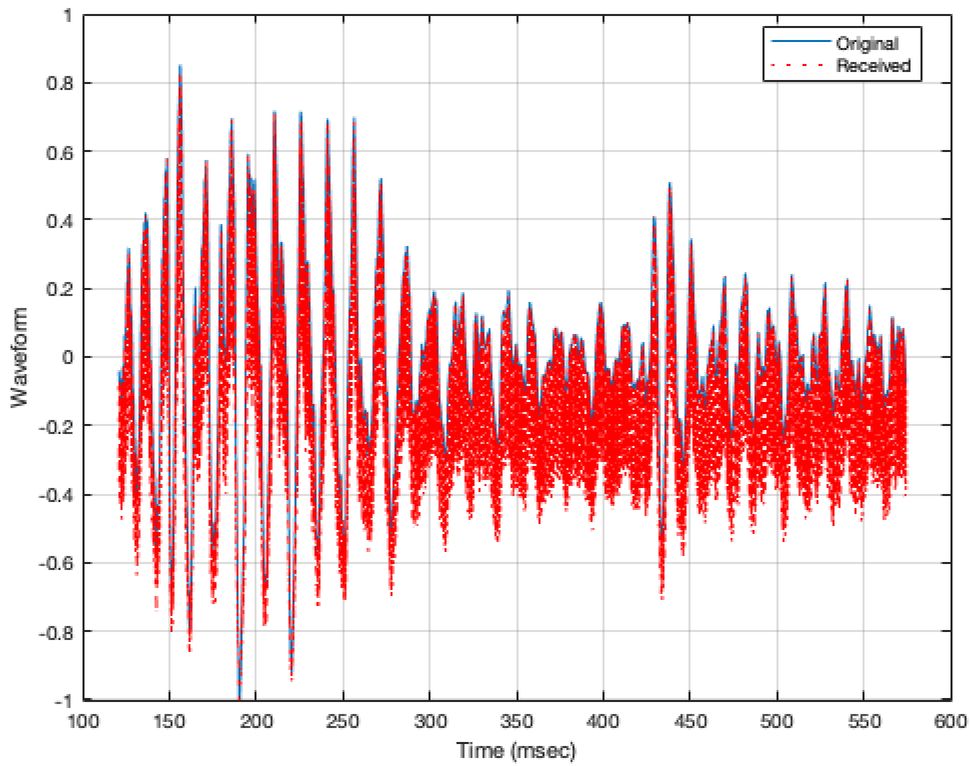
```
plot(freqs/1000, 20*log10(abs(FTz)));
axis([-Fs/2000 Fs/2000 -40 100])
grid
xlabel('Frequency (kHz)')
title('FT of Receiver Demodulator Output')
```



Display the Original Song and the Receiver Output Segments

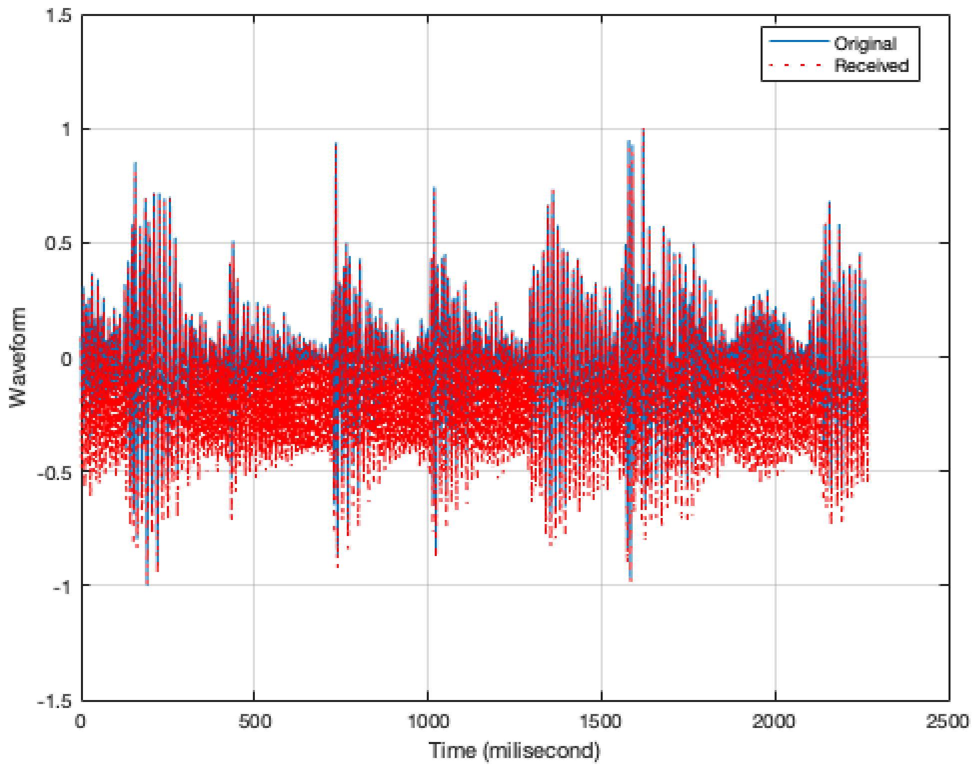
They are hardly distinguishable!

```
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 whole song single and demodulated version

```
figure(5)
plot(t*1000,song)
hold on
plot(t*1000,z,'r:')
grid
xlabel('Time (milisecond)');
ylabel('Waveform');
legend('Original','Received','Location','Best');
```



Play the demodulated sound

Downsampling

```
zlowrate=downsample(z,10);
% Listen to
sound(zlowrate,Fs/10);

% I could not figure out how to get exactly the same signal

% I changed the RC constant to many different values, and this one is
 the
% best that I can find

% Since my demodulated signal includes noice, I hear a beep sound in
 the
% demodulated song, sorry :(
```

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