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## DSB-SC Modulator/Demodulator Example

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

Prepared for ELEC 301

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\*12.03.2020\*

## Program Initialization

---

```
%Clear Variables and Close All Figure Windows

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

## Read Song File

---

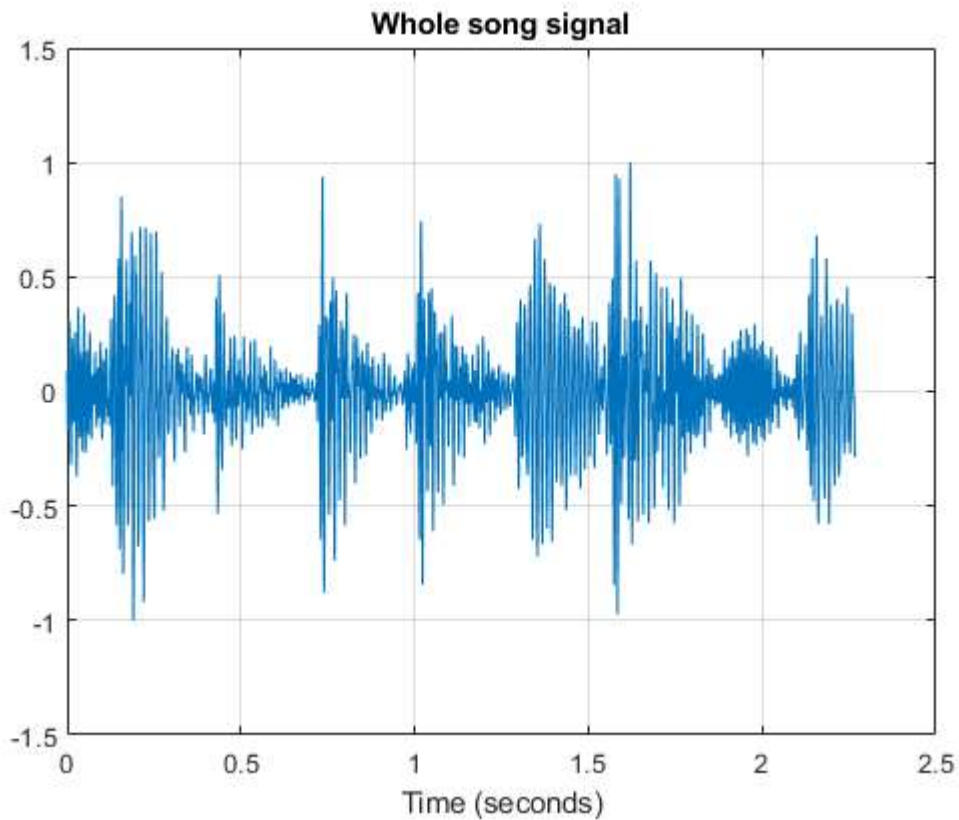
**song.mat** contains **song** variable containing Song samples and **Fs** which is the sampling frequency

```
% 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:(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;
```

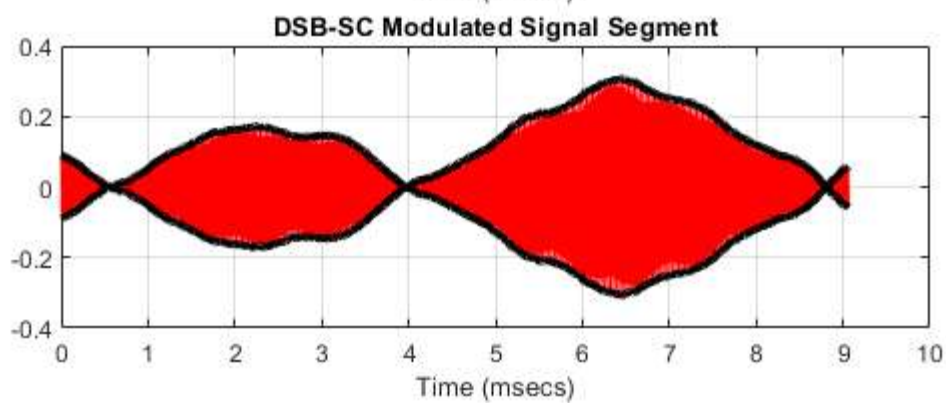
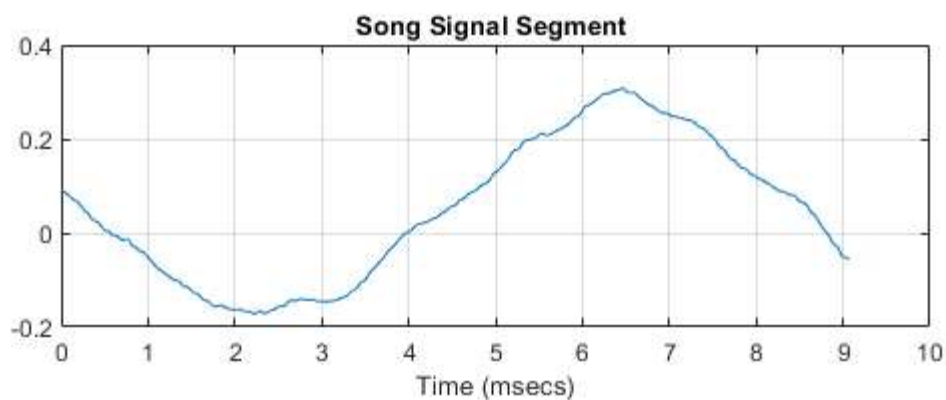
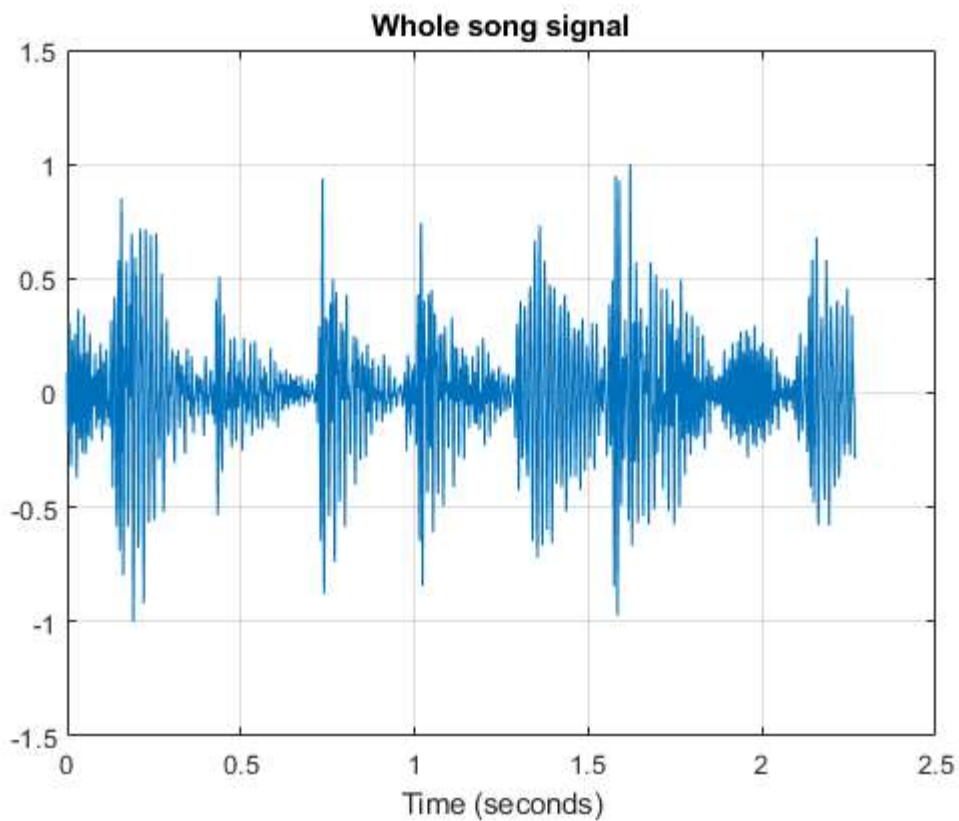
## Display the Segments of Signal and Modulated Signal

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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)

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

```
q = 0:20;
q = q.*pi.*0.1;
```

```
for i = 1:21
```

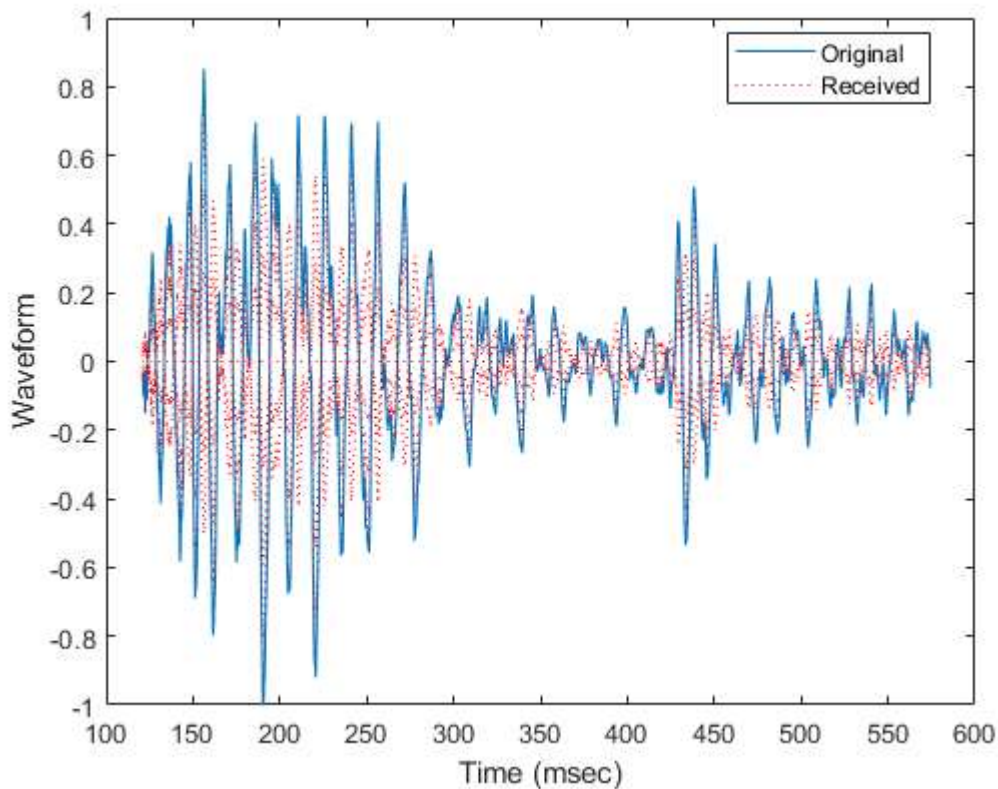
```
y = 2*x.*cos(2*pi*fc*t+q(i));
```

Then low pass filter this signal

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

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

```
maxrecorded(i) = max(abs(z(40000:60000)));
```



## 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

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

Calculate the Fourier Transform of the DSB-SC signal

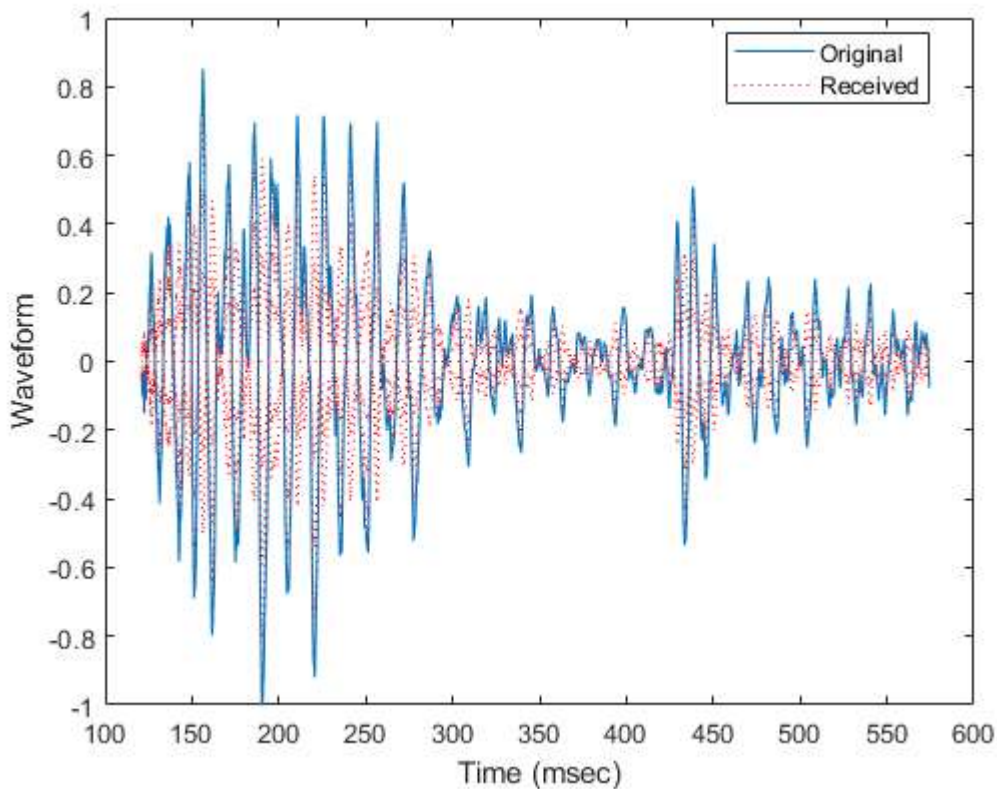
```
[ftr,~]=fouriertransform(x,Fs);
```

Calculate Fourier Transform after receiver carrier multiplication

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

Calculate Fourier Transform of the receiver output

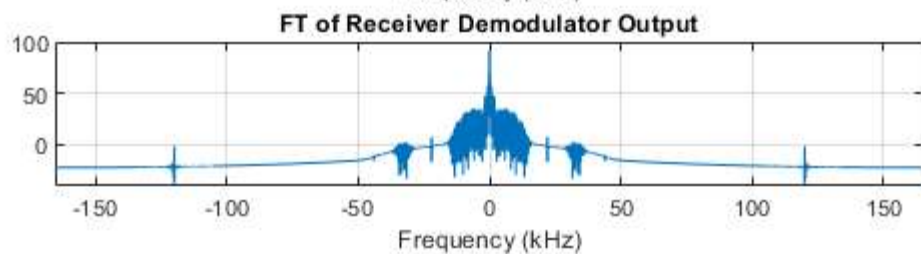
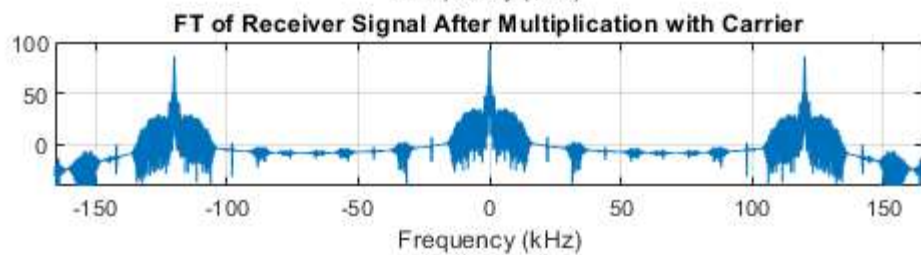
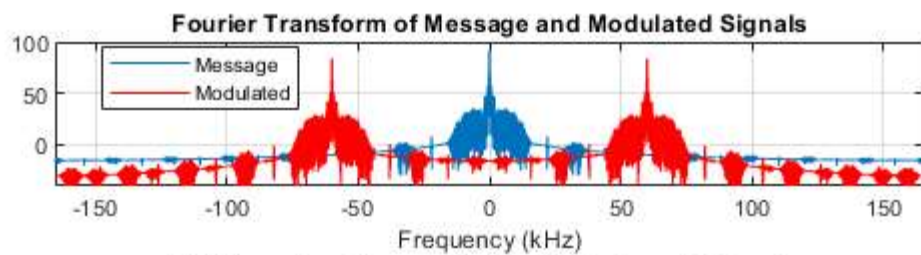
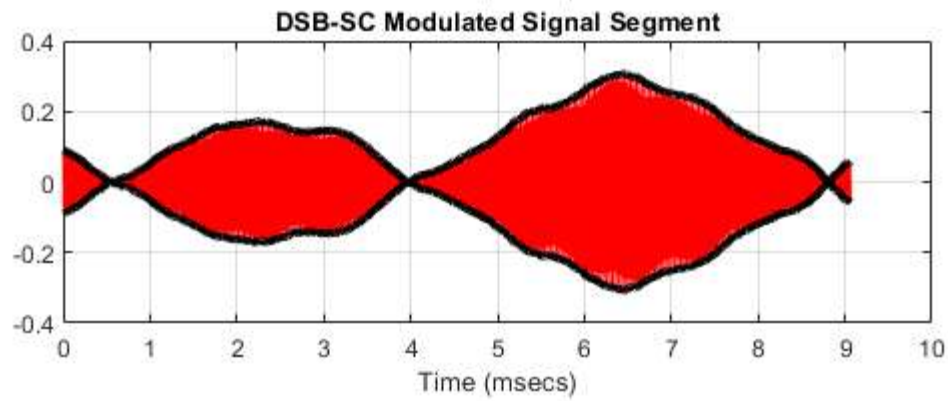
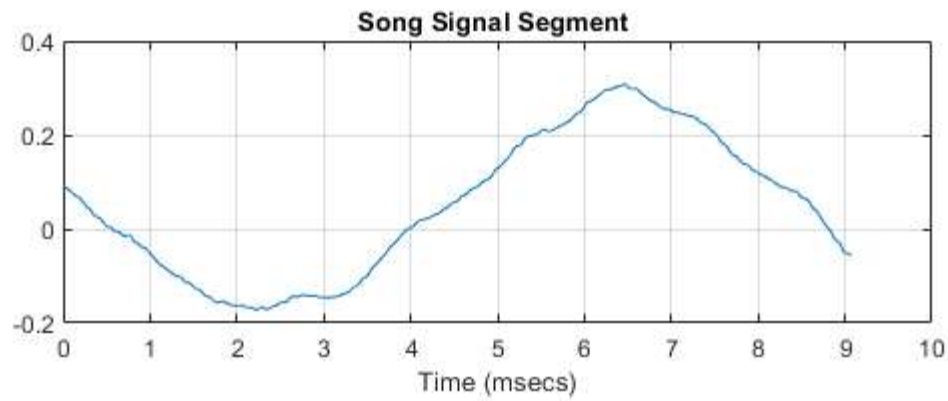
```
[FTz,freqs]=fouriertransform(z,Fs);
```



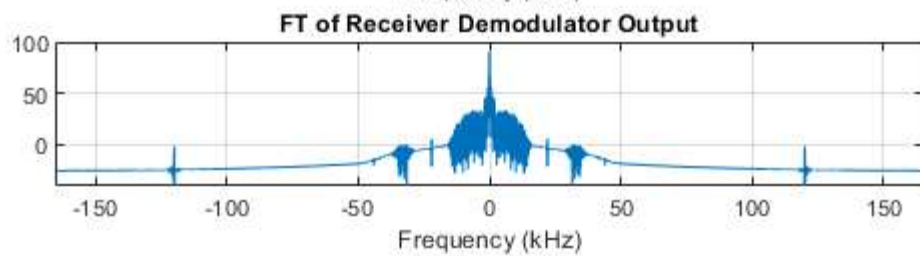
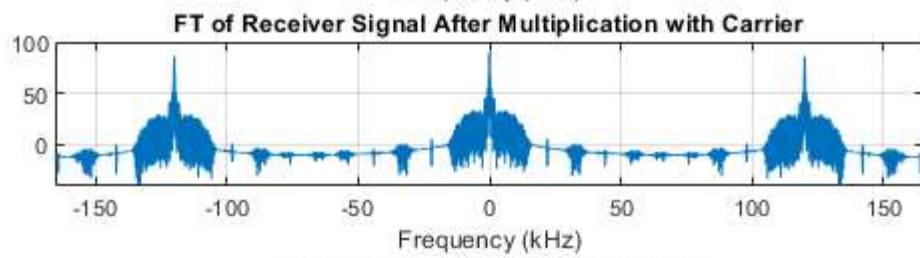
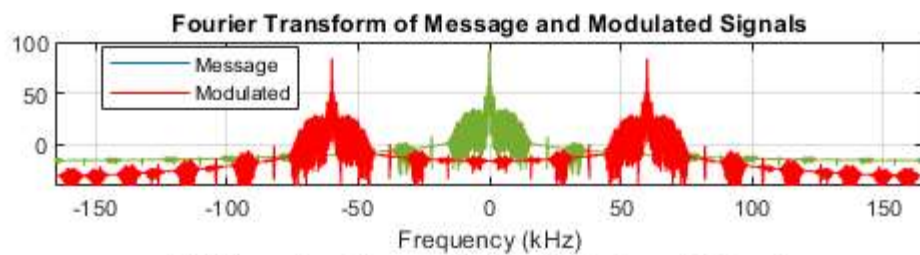
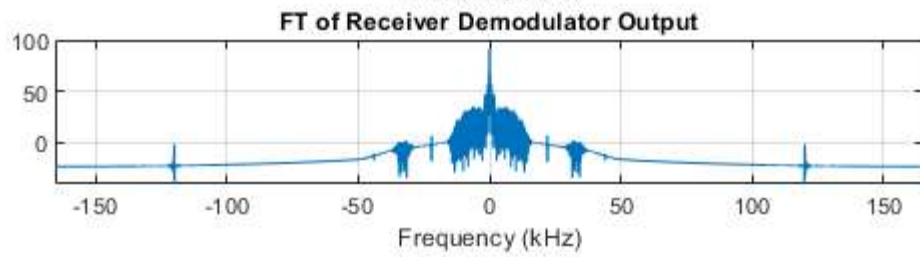
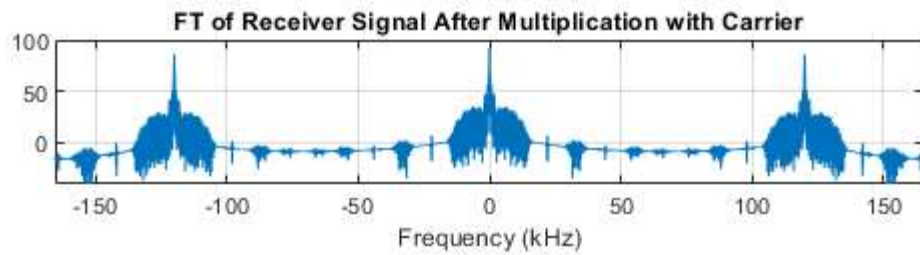
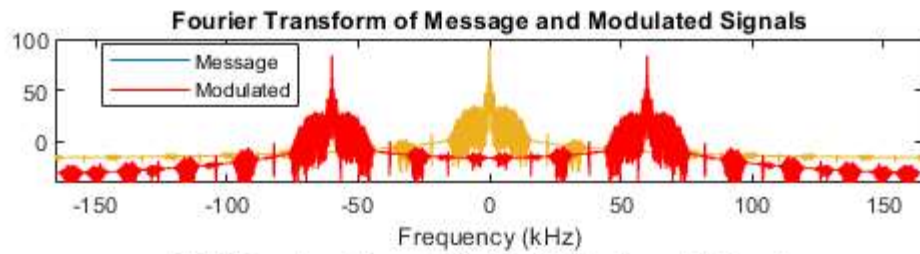
Display these Fourier Transforms

```
figure(3)
subplot(3,1,1);
plot(freqs/1000, 20*log10(abs(ftsong)));
hold on
plot(freqs/1000, 20*log10(abs(fty)), '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)

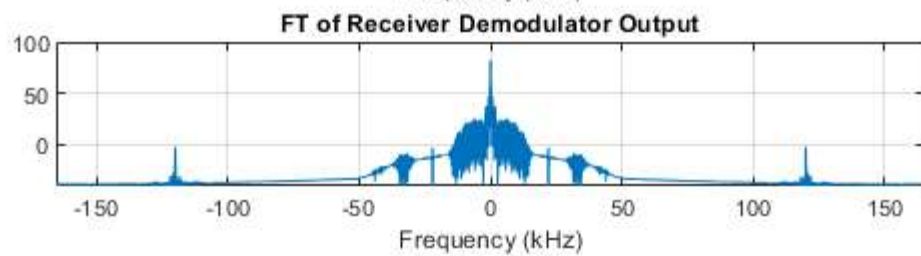
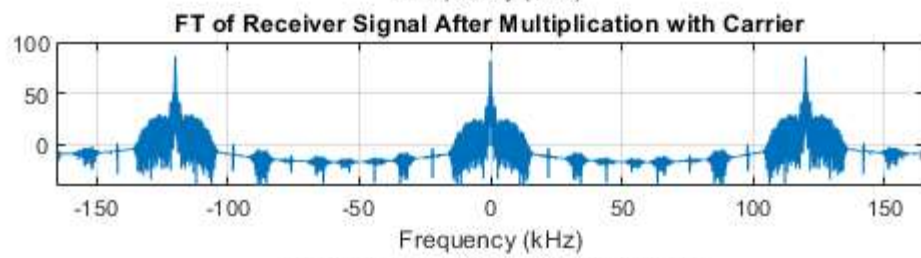
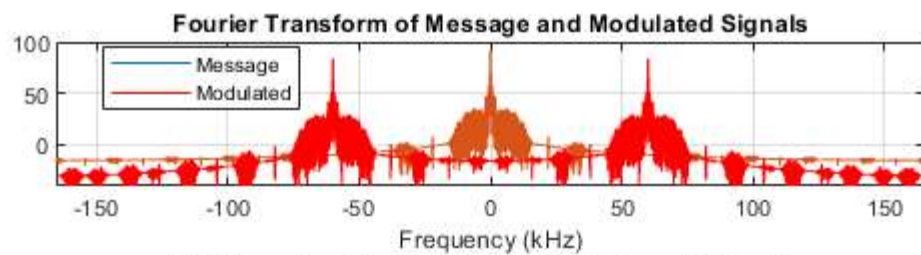
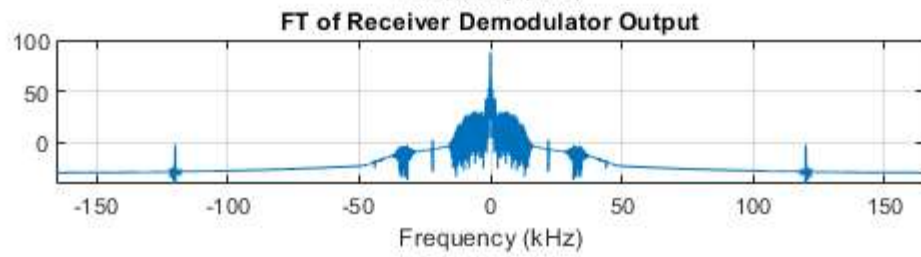
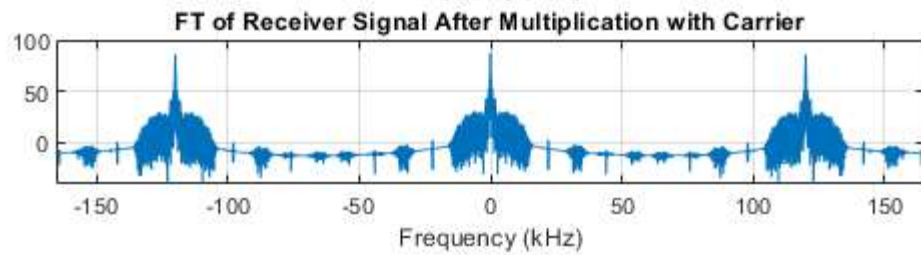
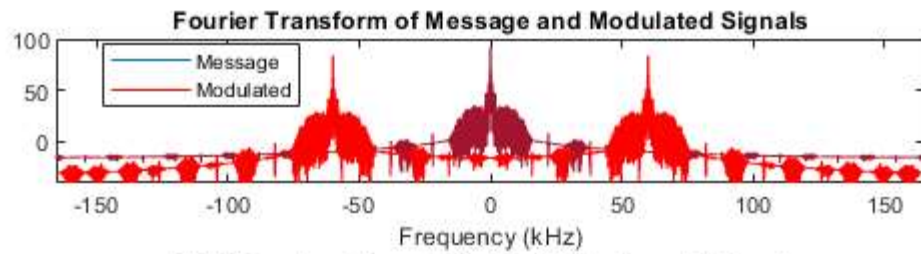
plot(freqs/1000, 20*log10(abs(FTz)));
axis([-Fs/2000 Fs/2000 -40 100])
grid
xlabel('Frequency (kHz)')
title('FT of Receiver Demodulator Output')
```

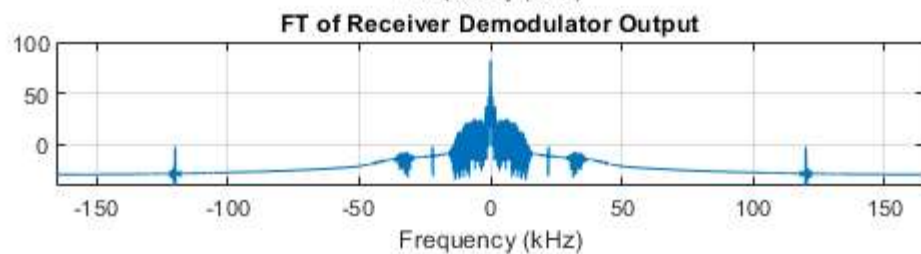
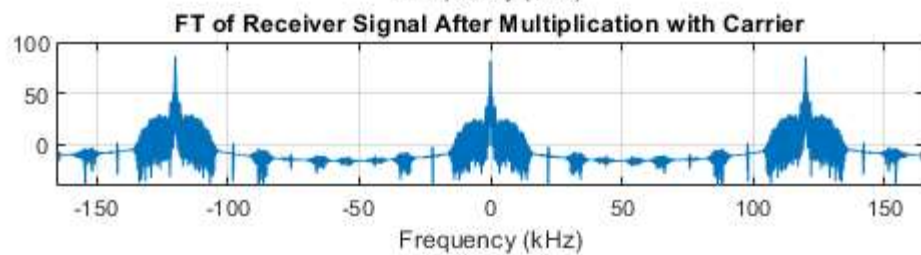
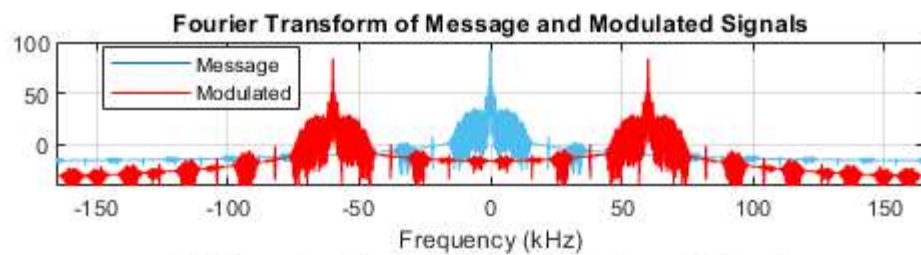
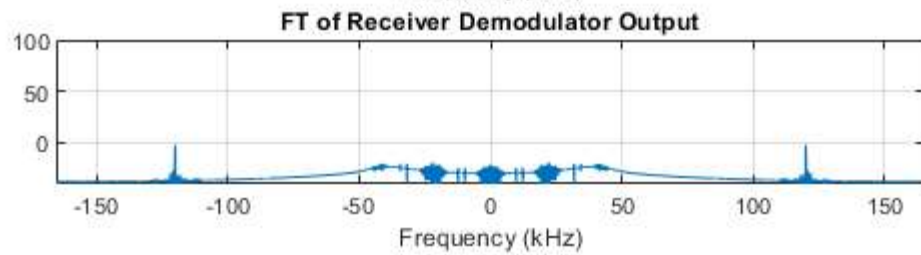
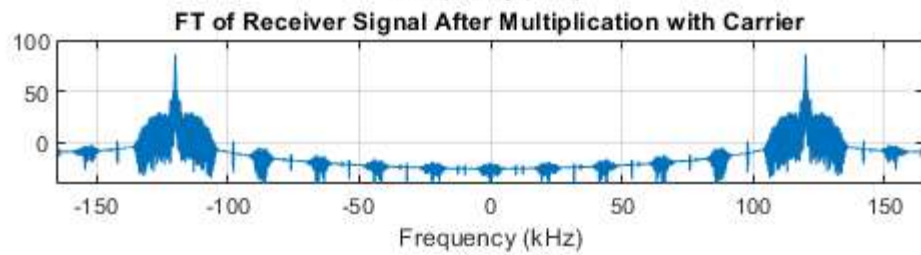
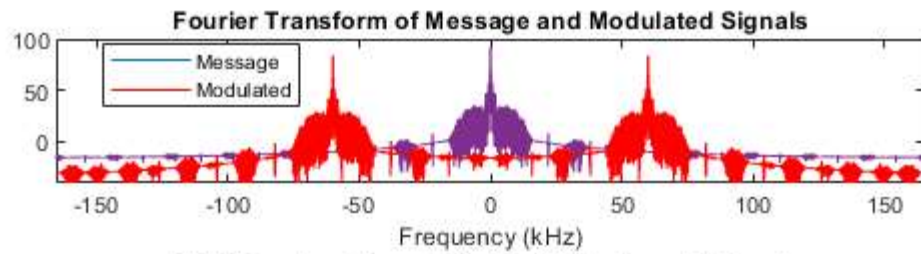


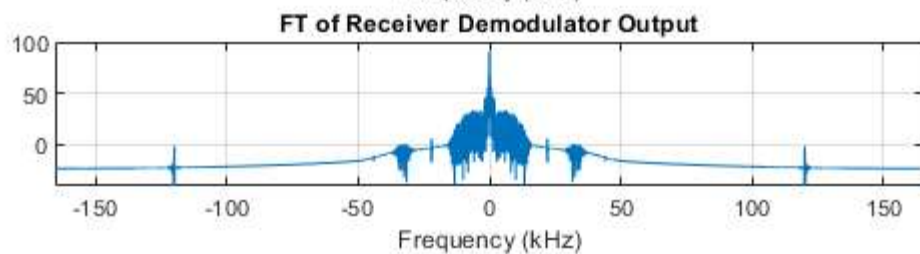
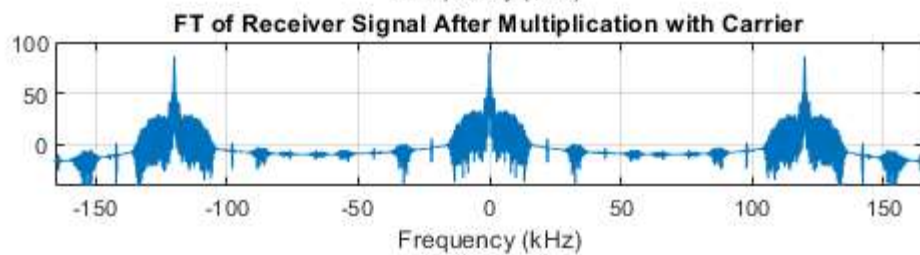
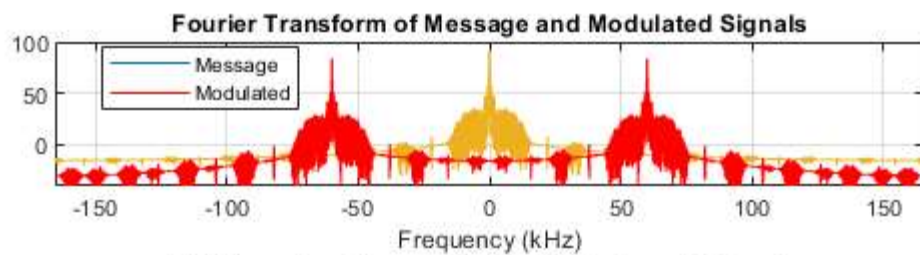
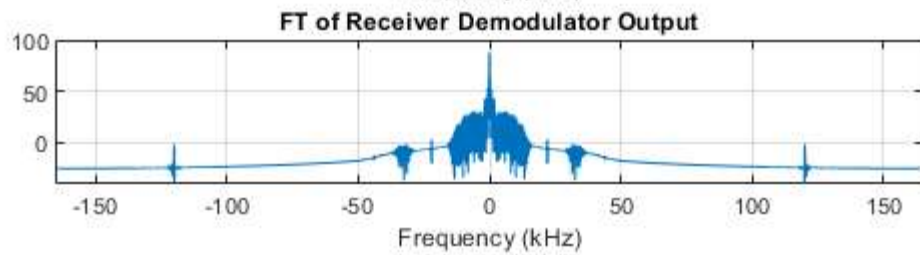
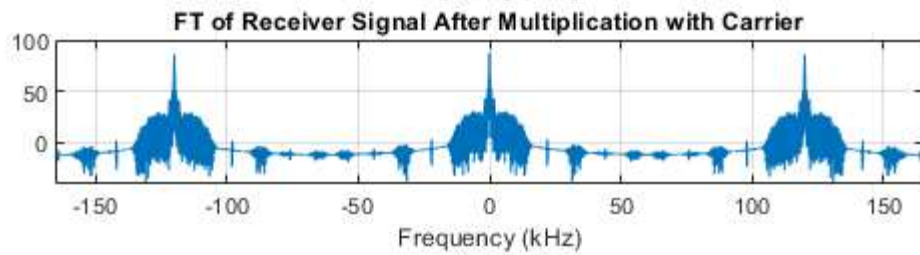
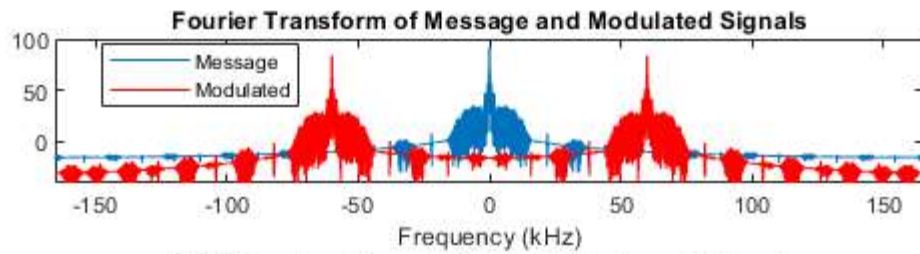


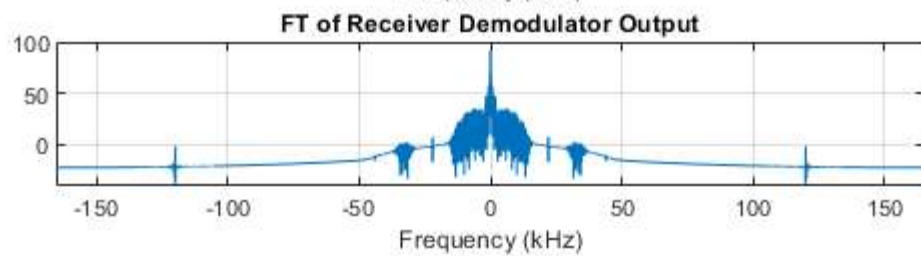
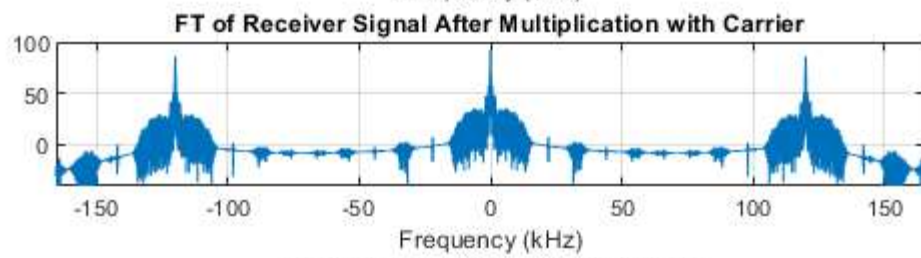
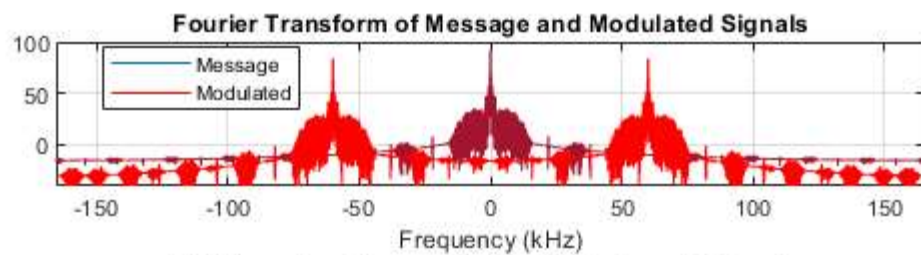
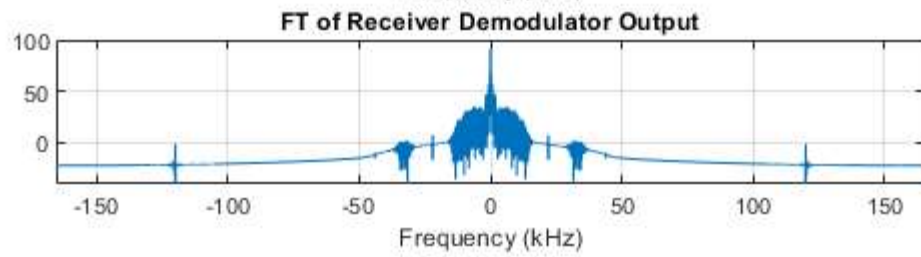
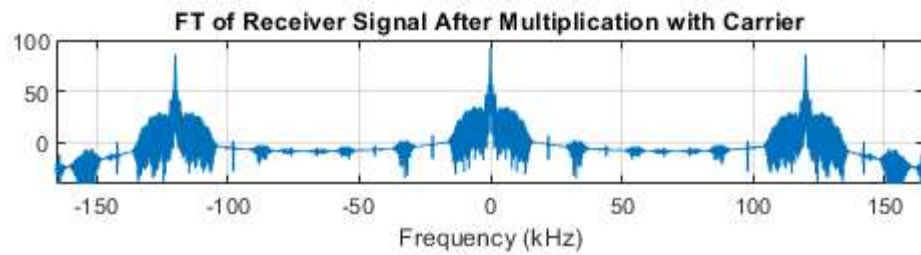
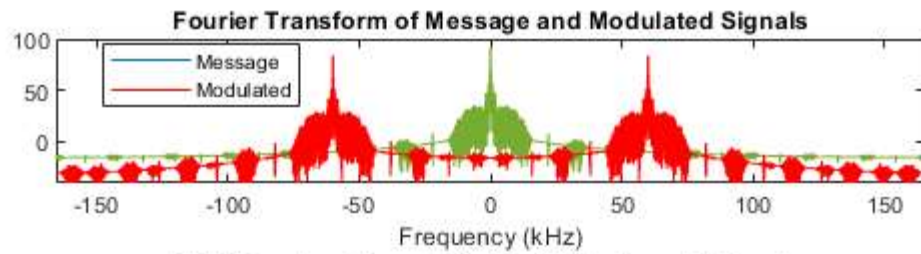




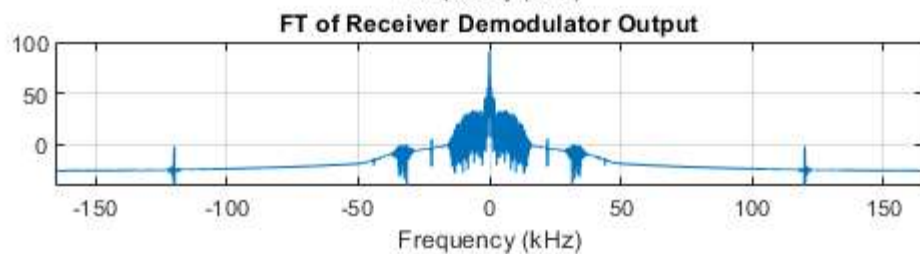
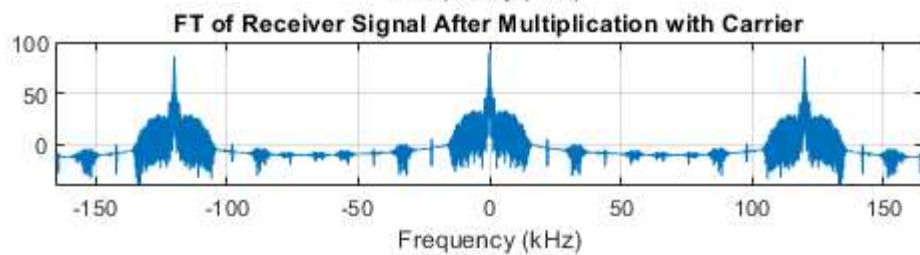
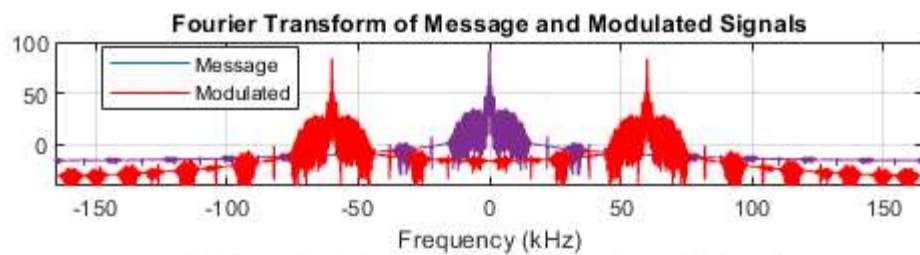
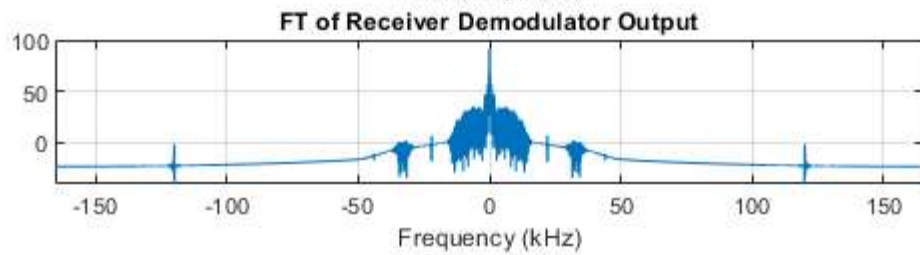
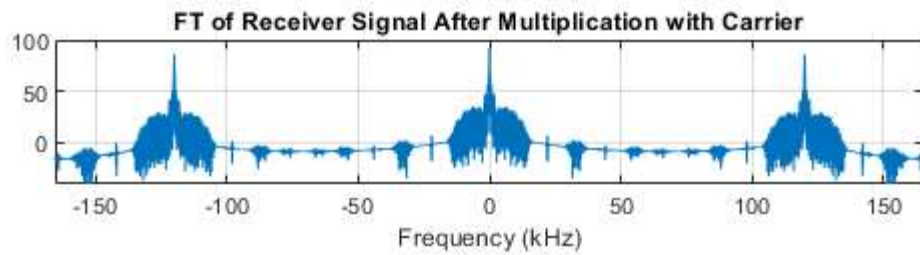
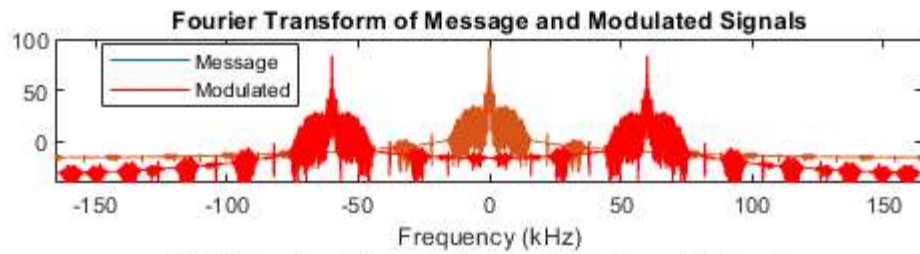


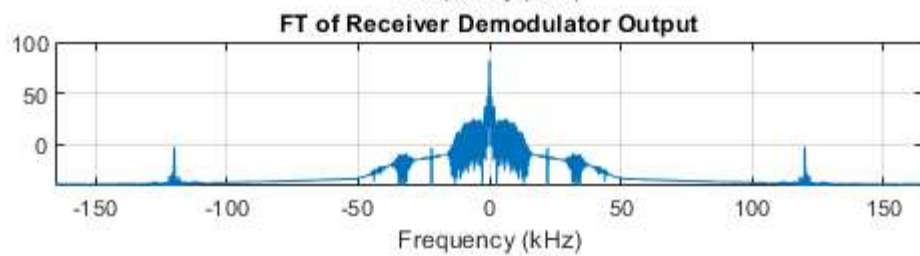
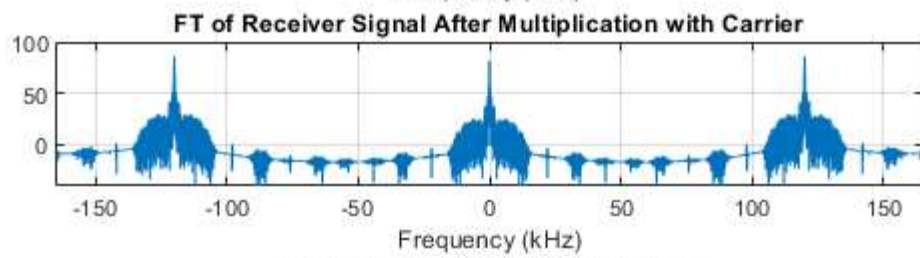
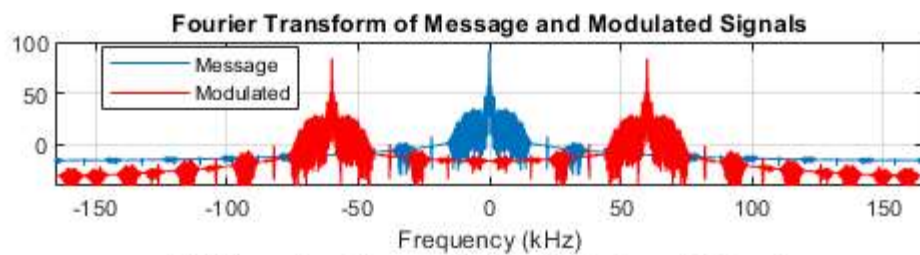
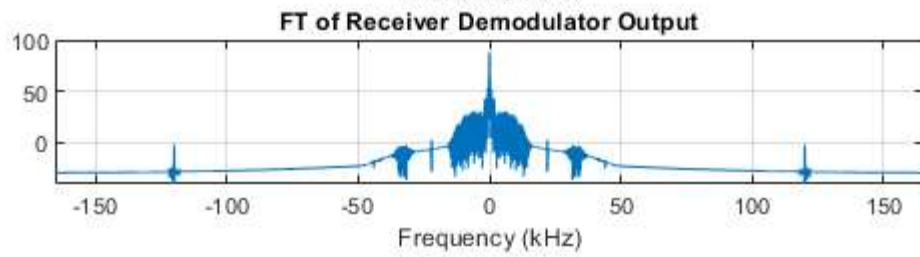
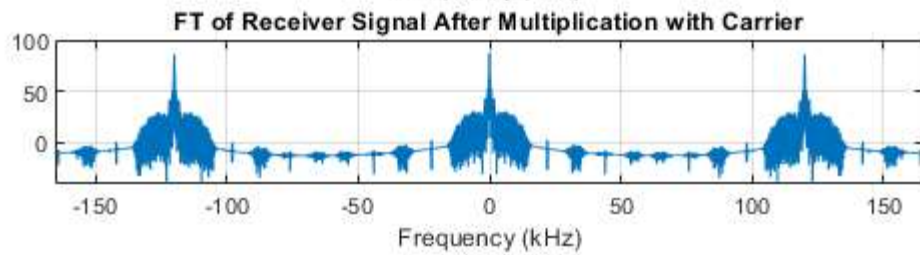
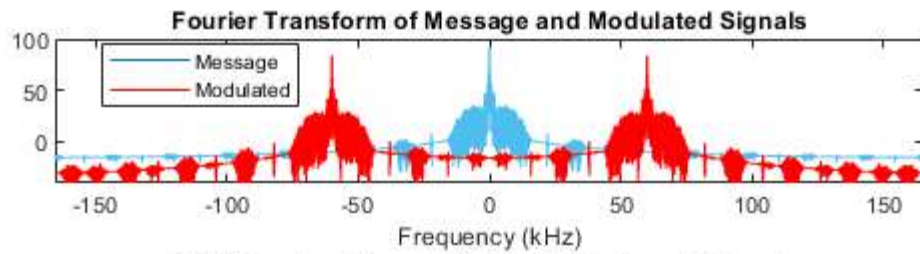


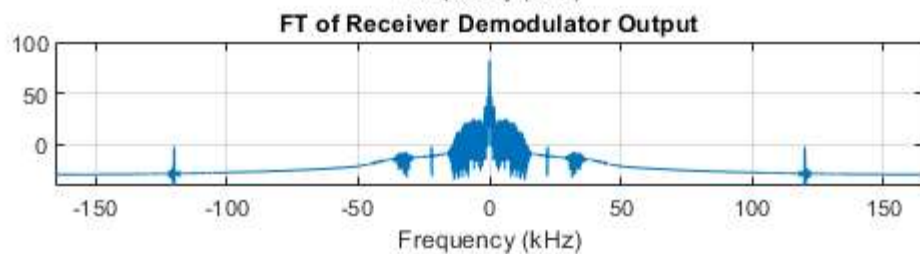
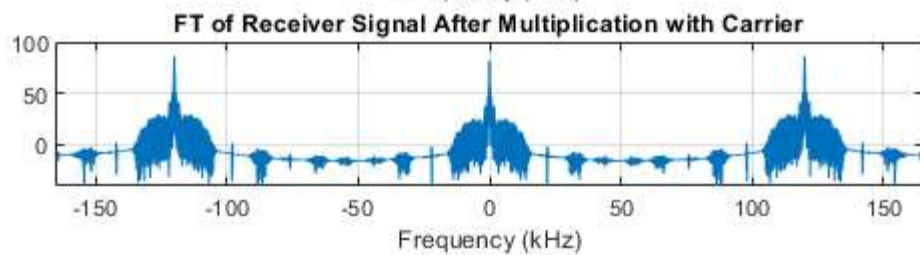
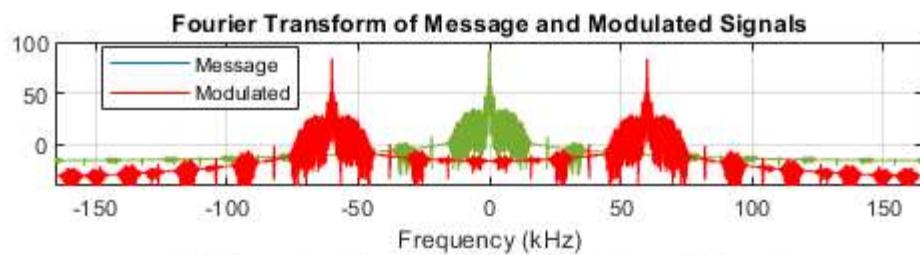
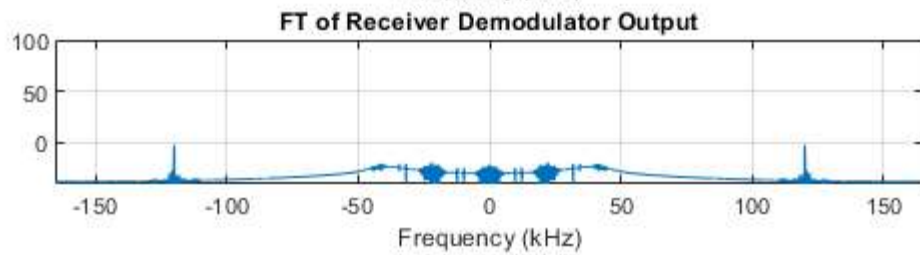
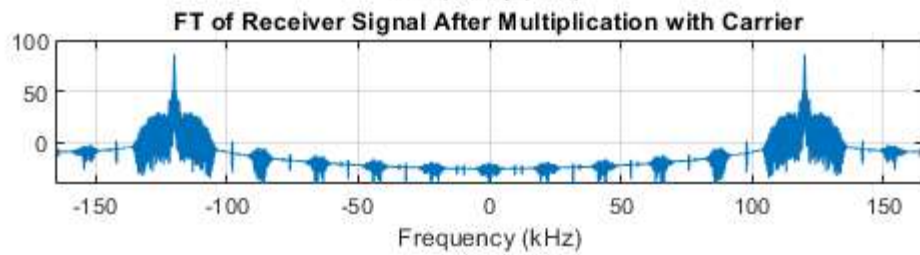
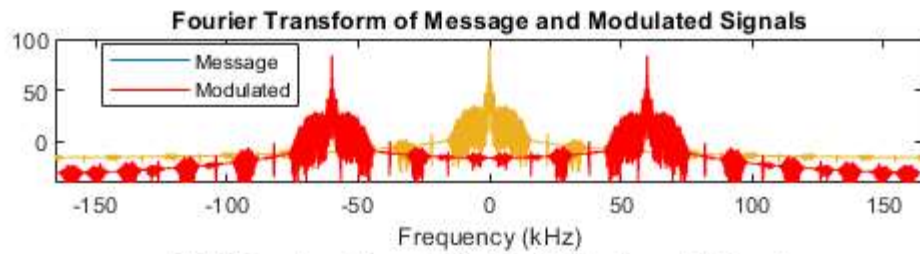




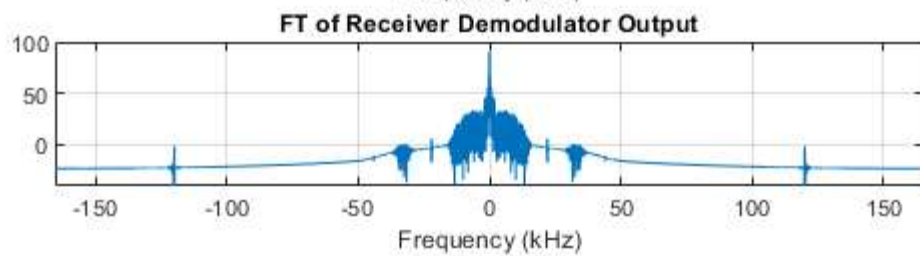
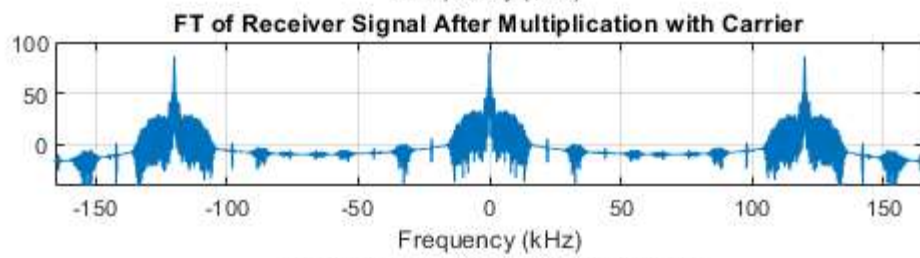
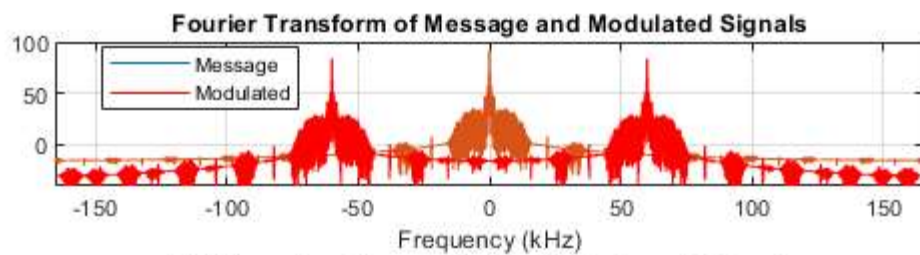
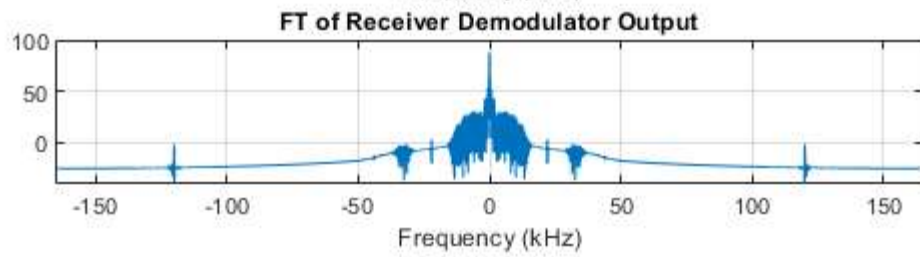
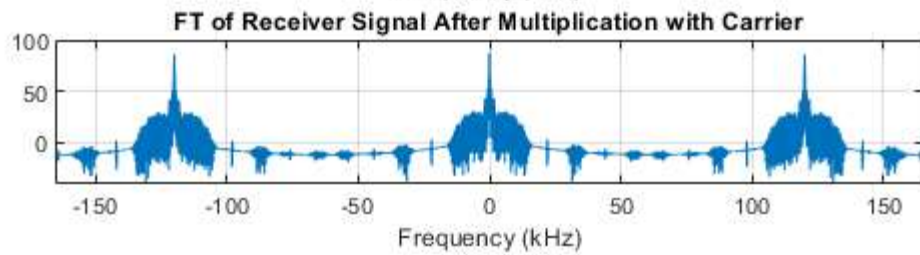
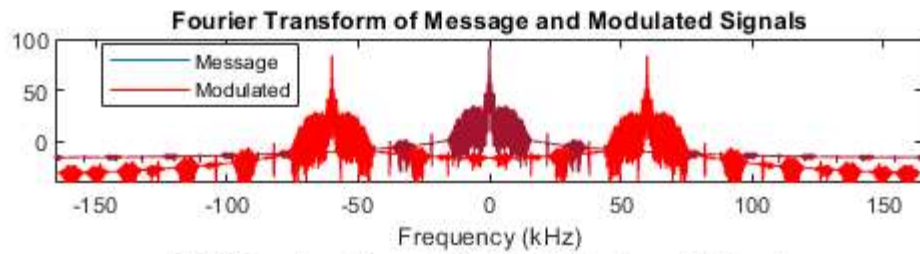


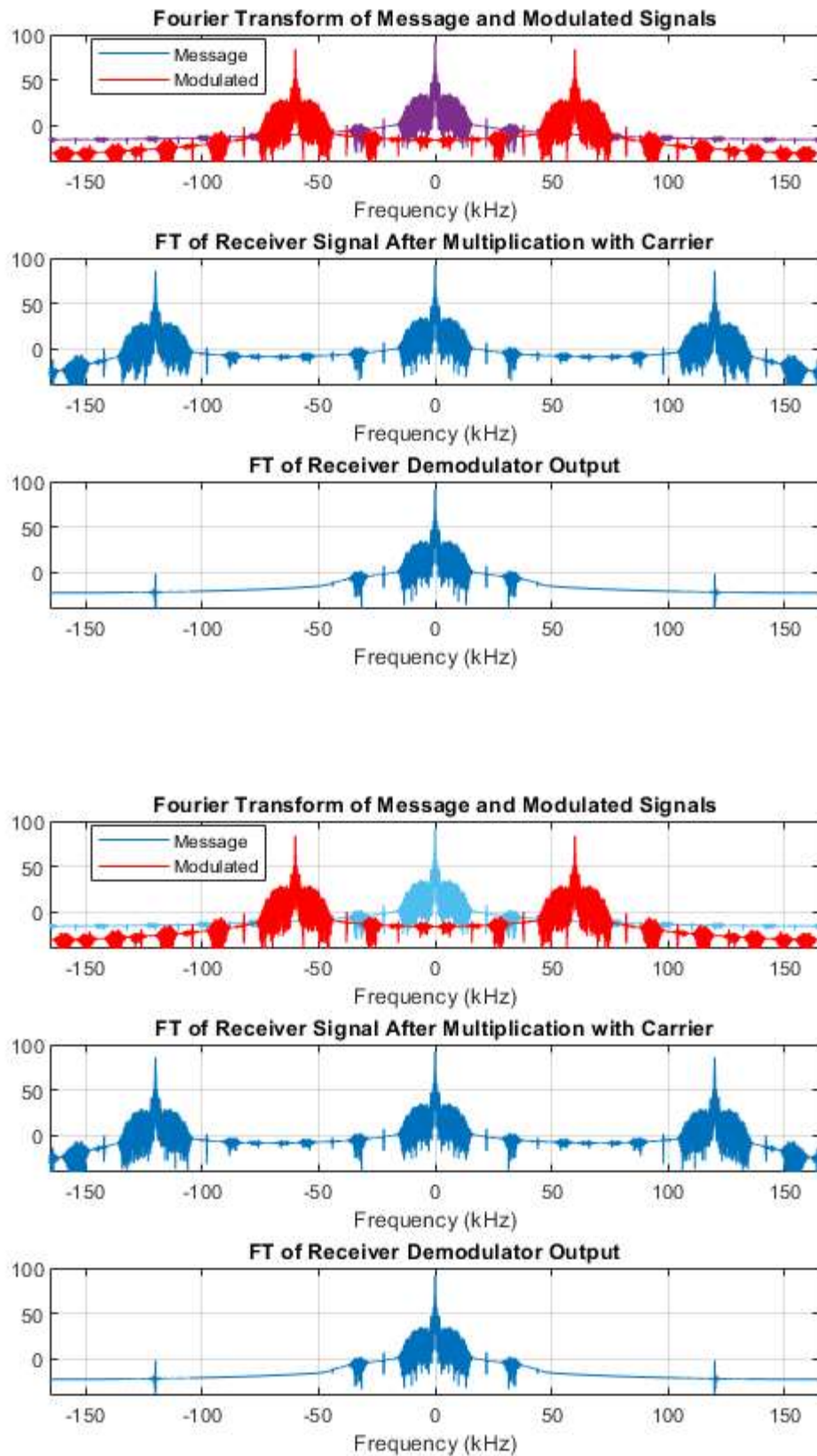












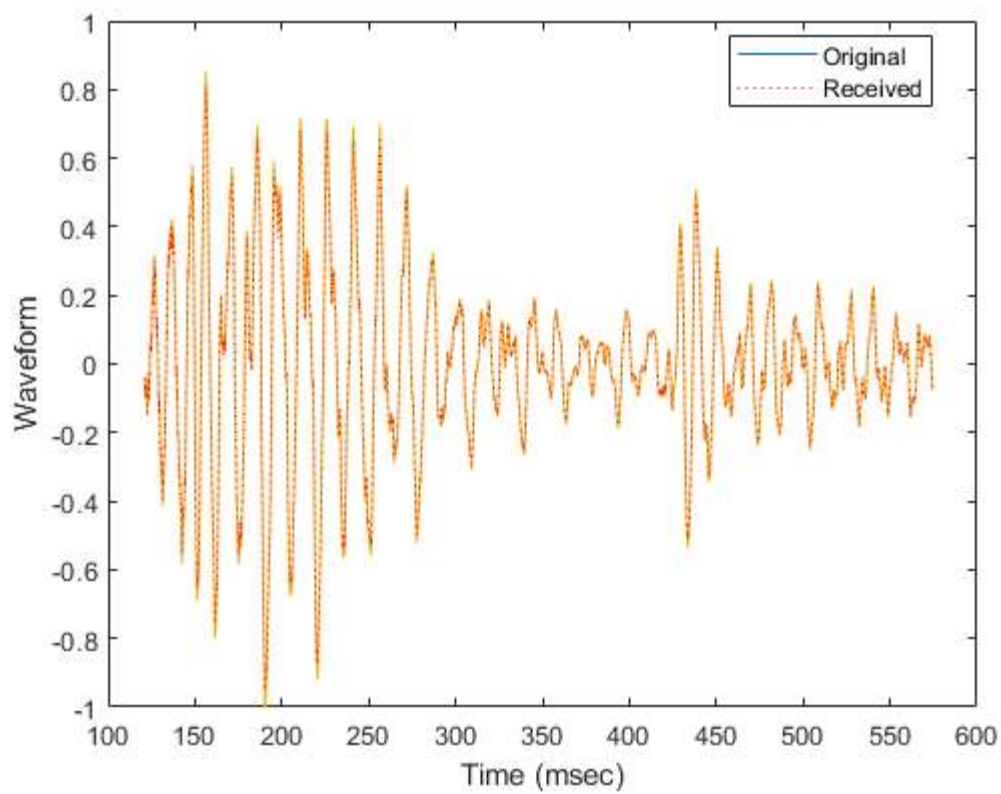
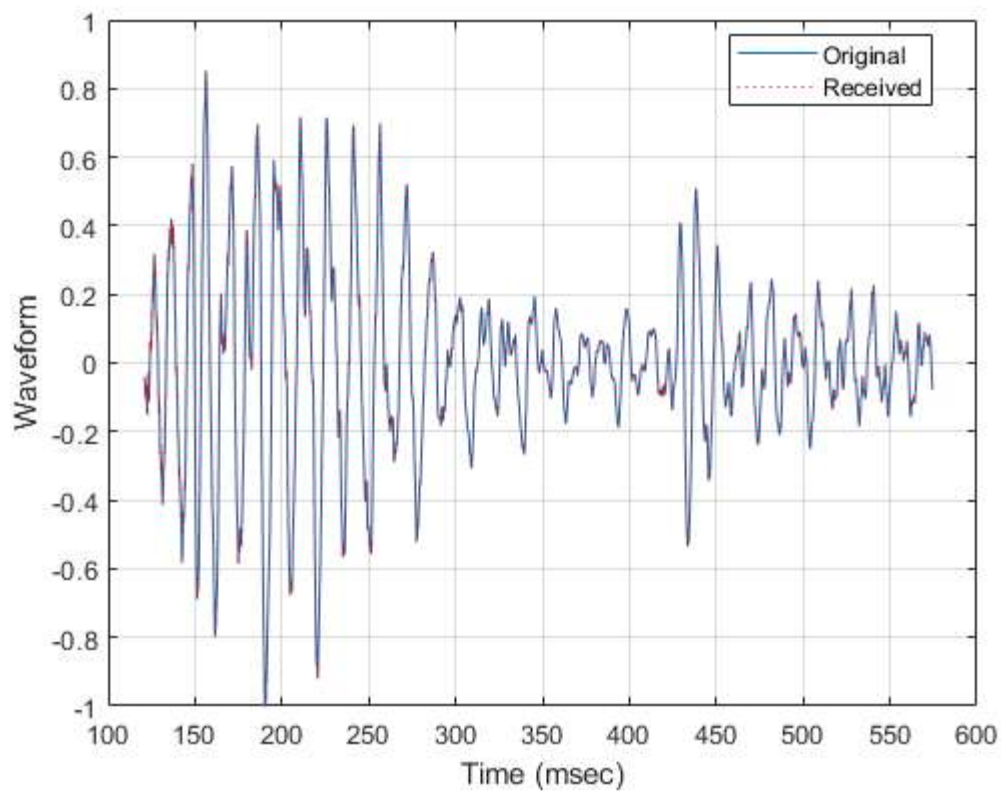
## Display the Original Song and the Receiver Output Segments

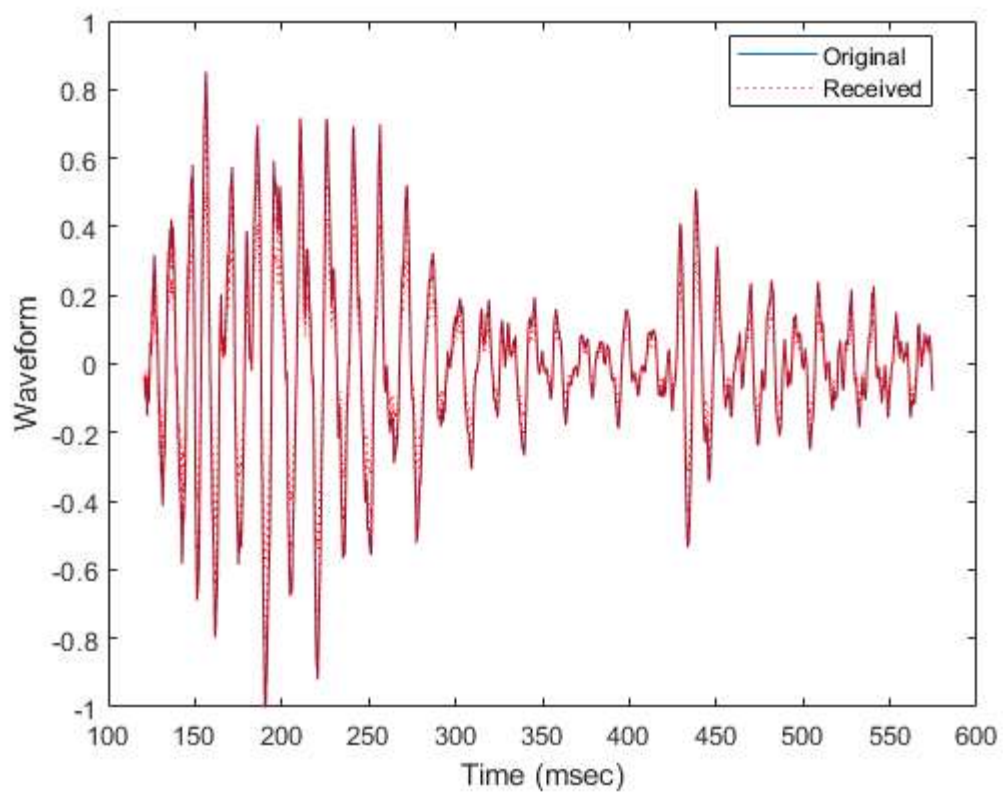
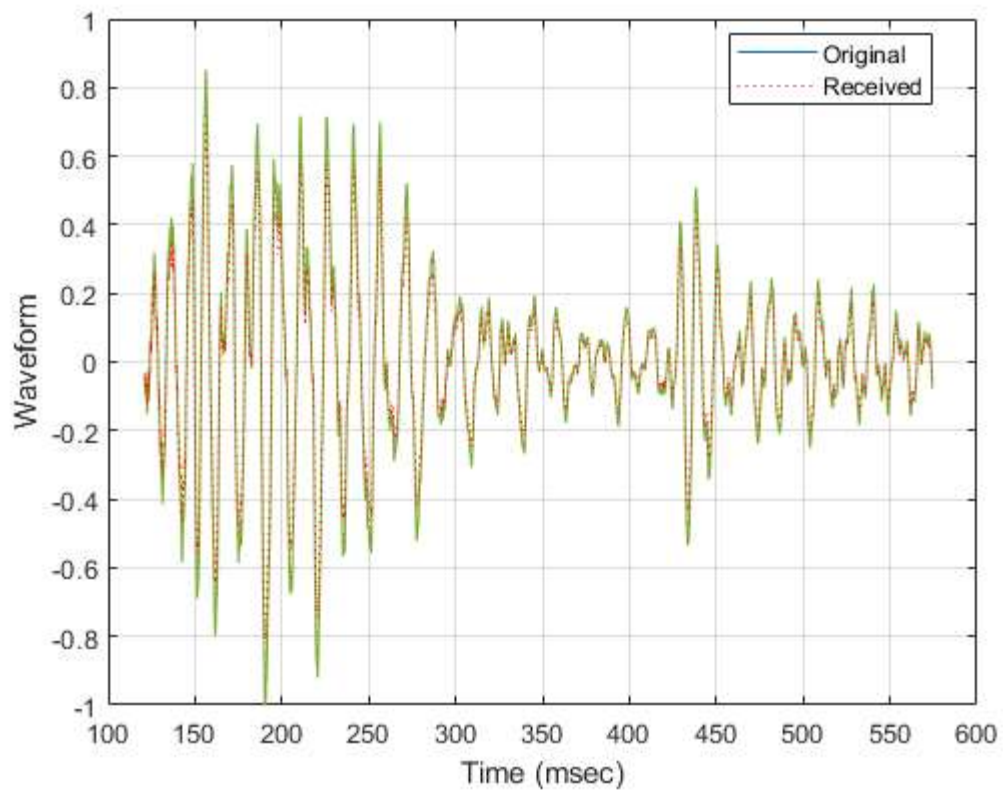
They are hardly distinguishable!

```
figure(4)
plot(t(40000:190000)*1000,song(40000:190000))
hold on
plot(t(40000:190000)*1000,z(40000:190000),'r:')
grid
```

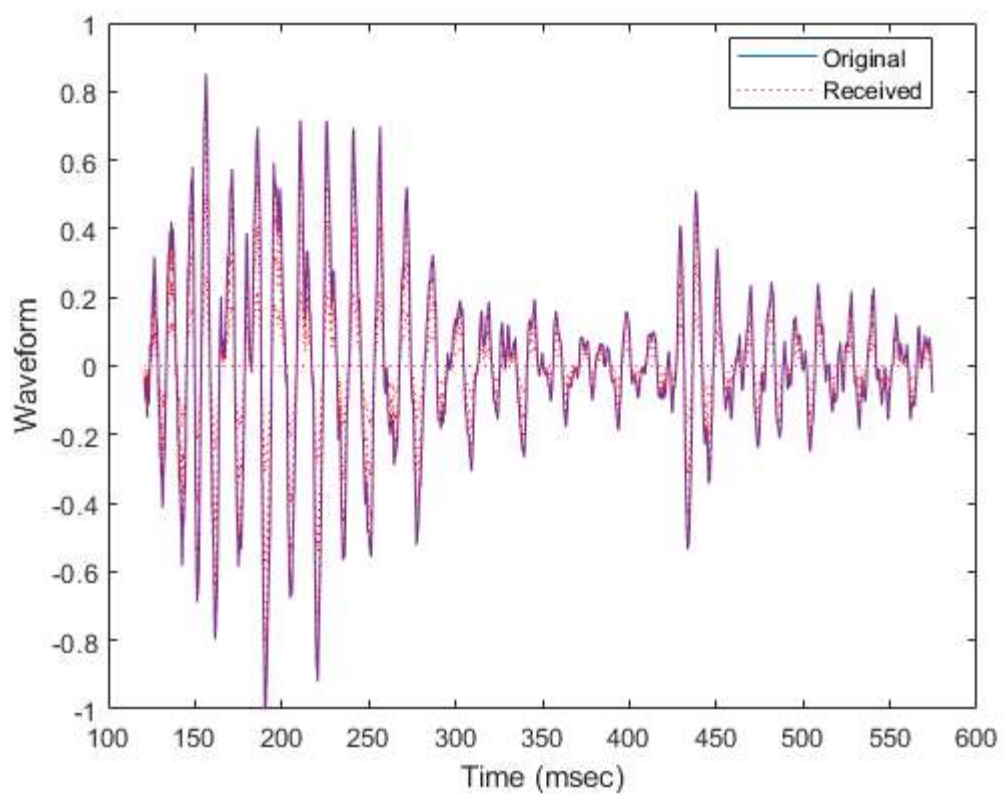
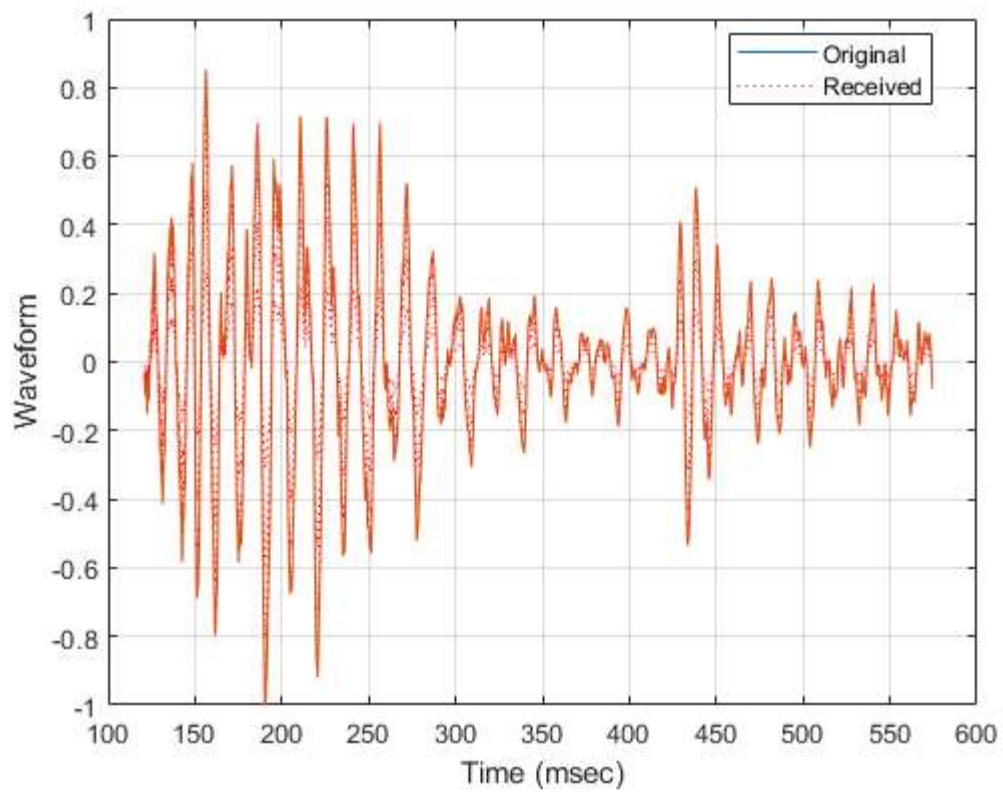
```
xlabel('Time (msec)');  
ylabel('Waveform');  
legend('Original', 'Received', 'Location', 'Best');
```

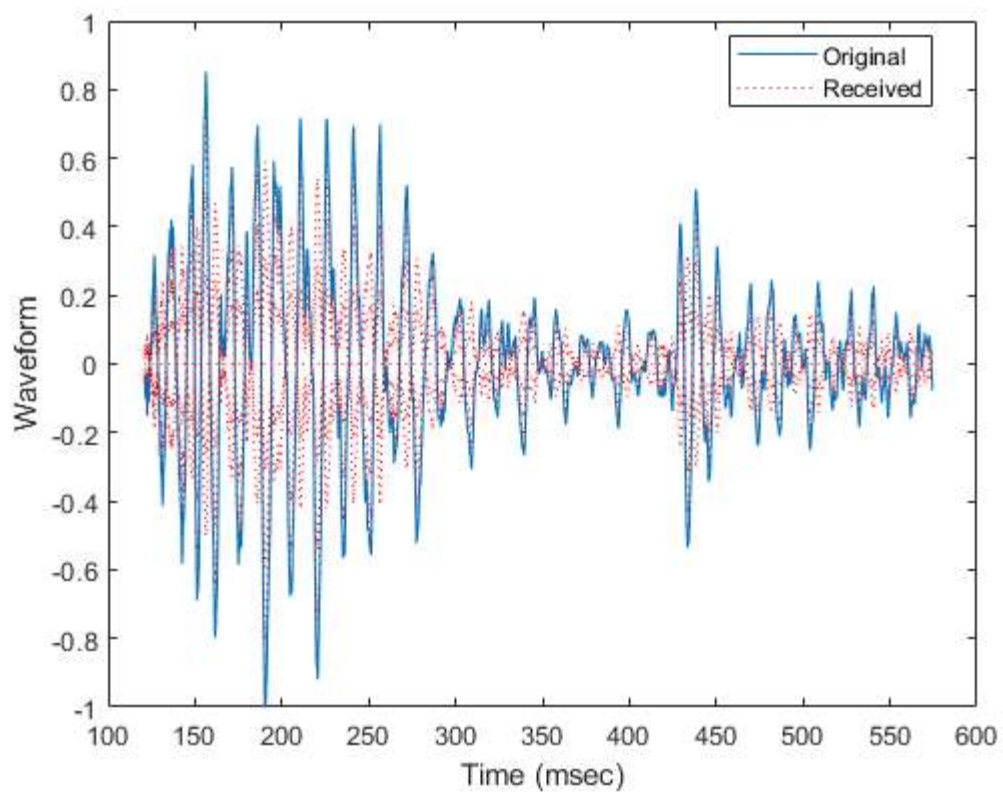
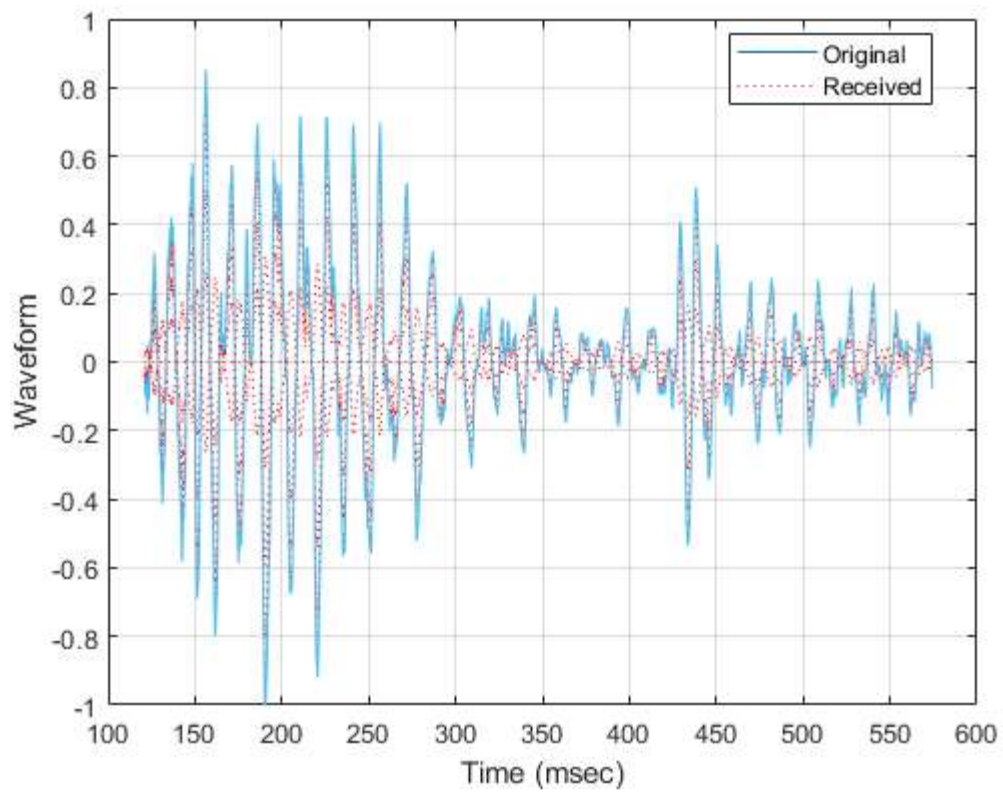
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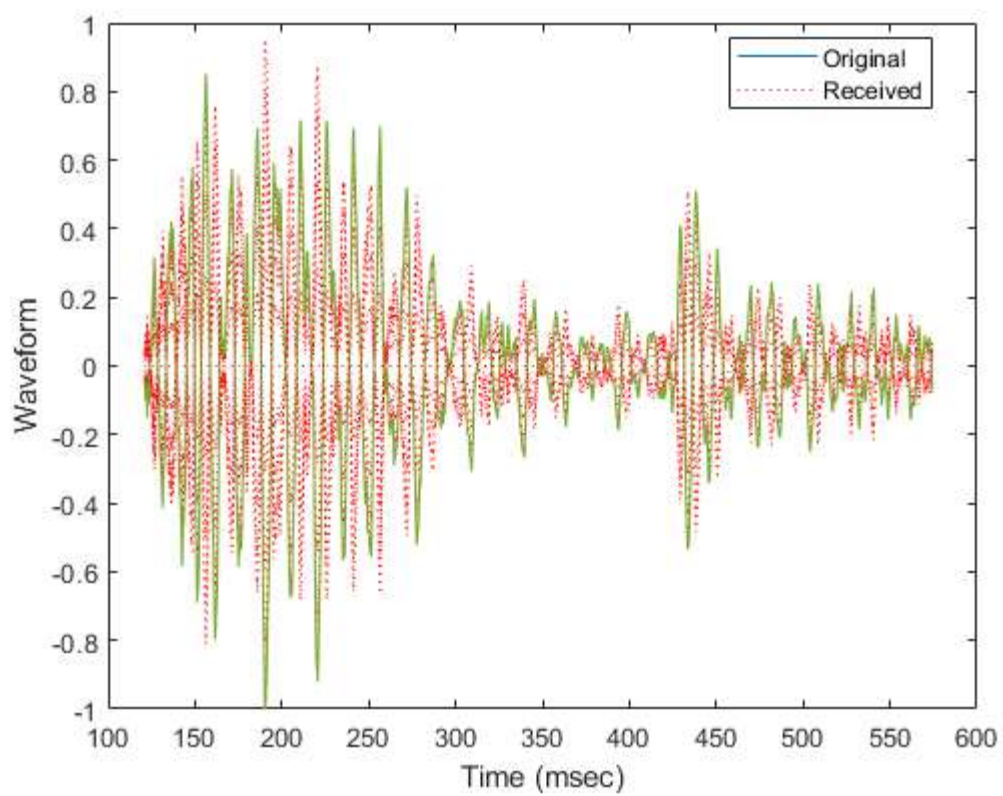
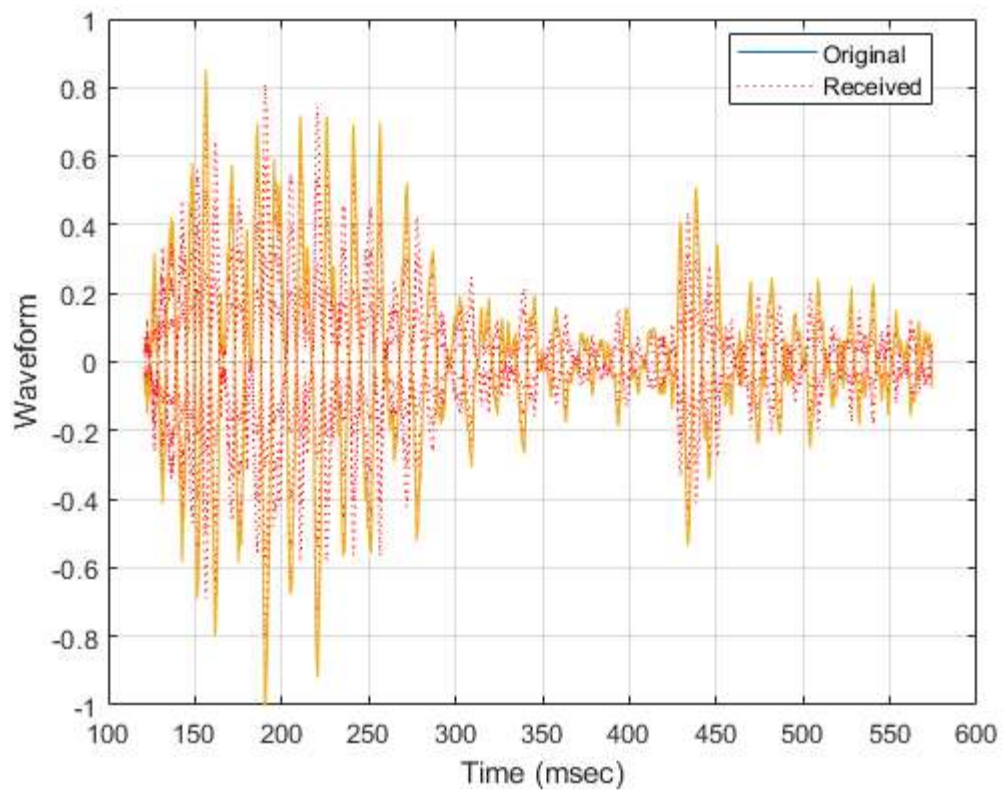




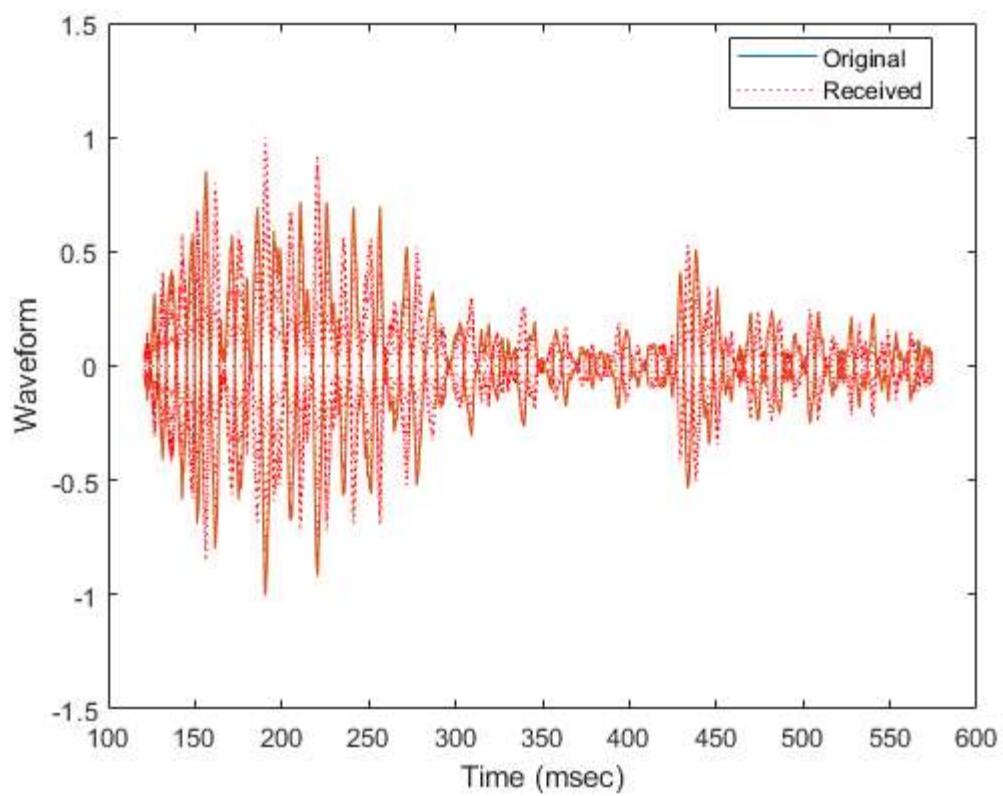
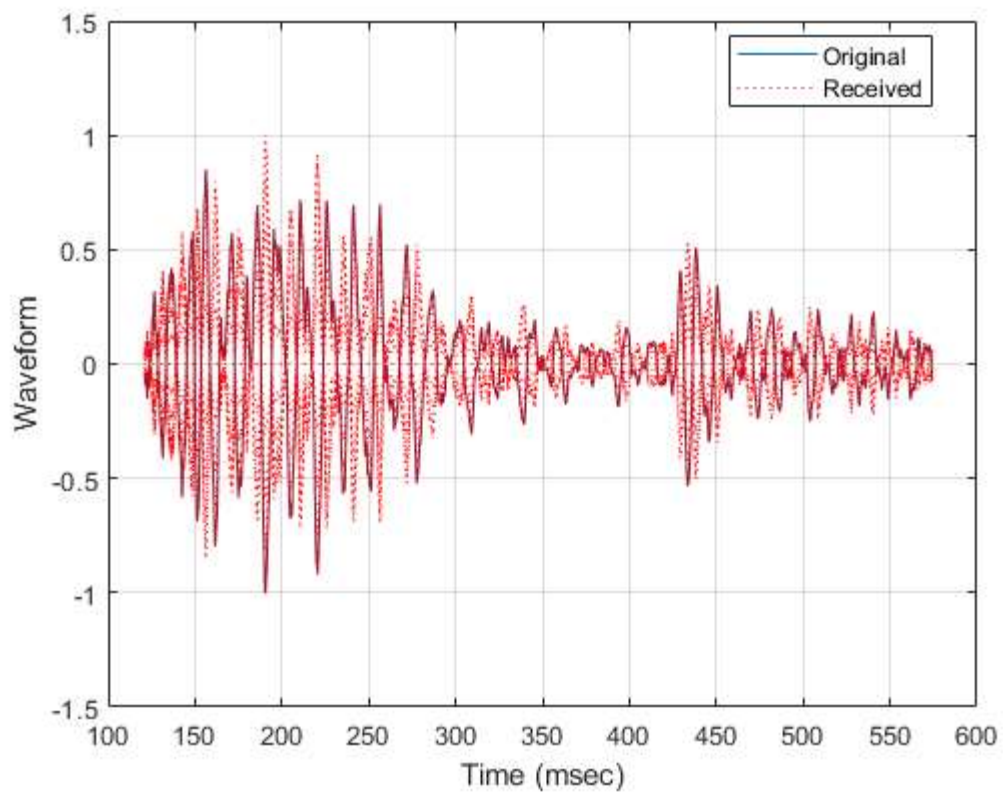


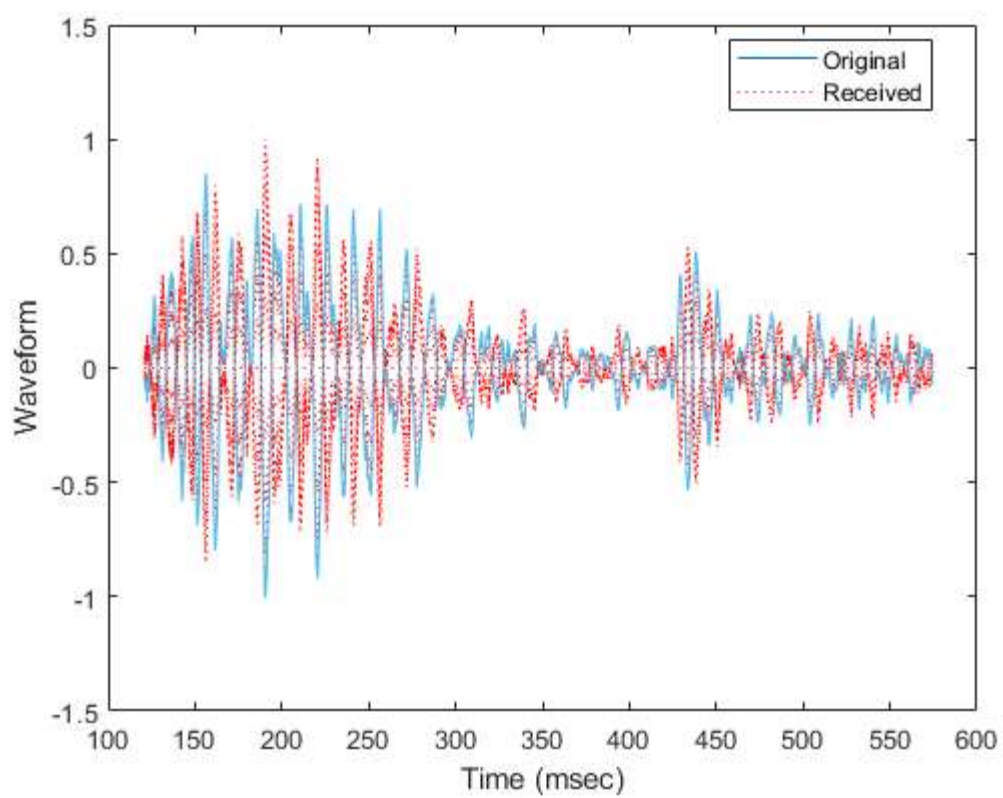
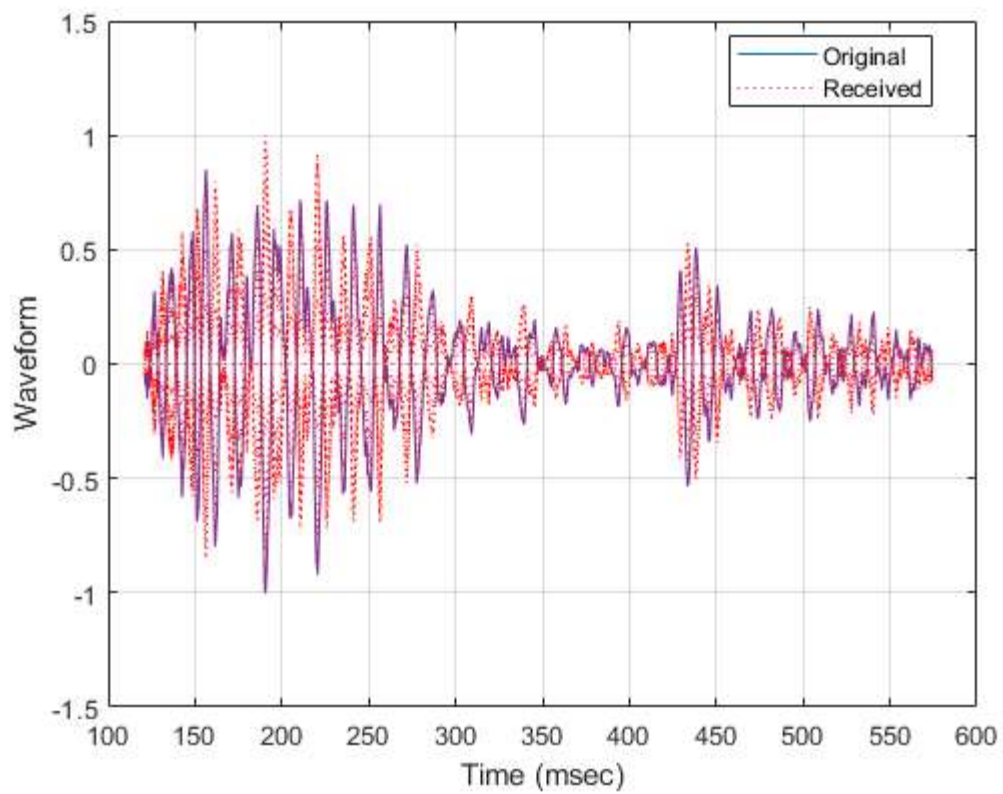


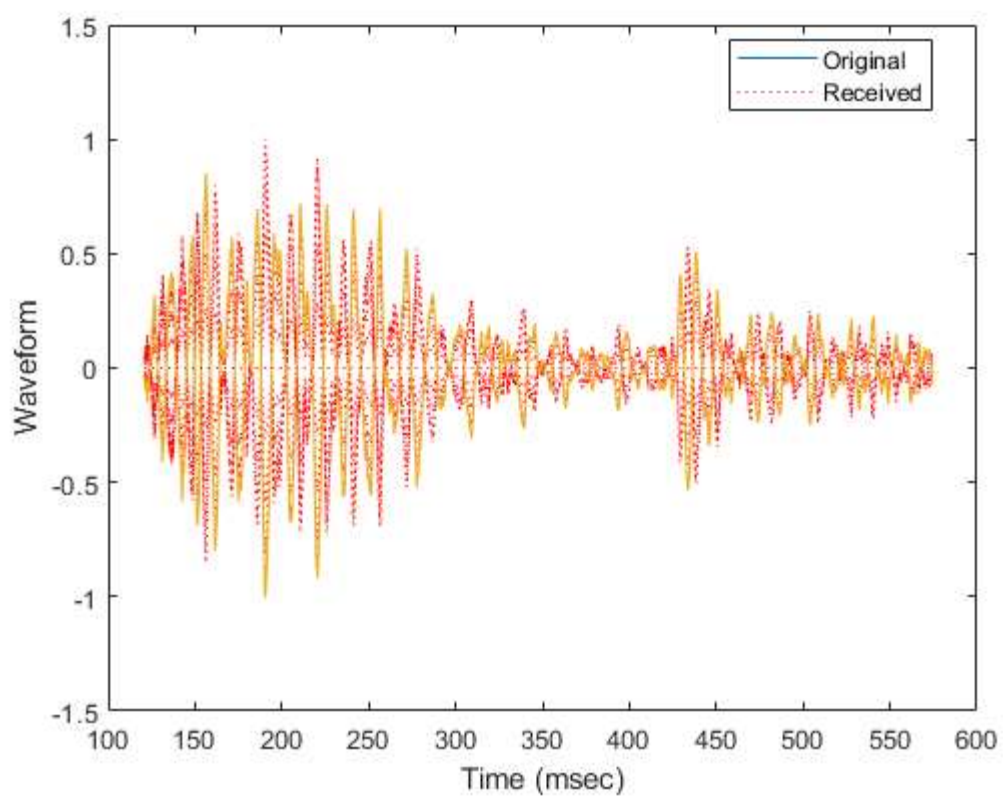
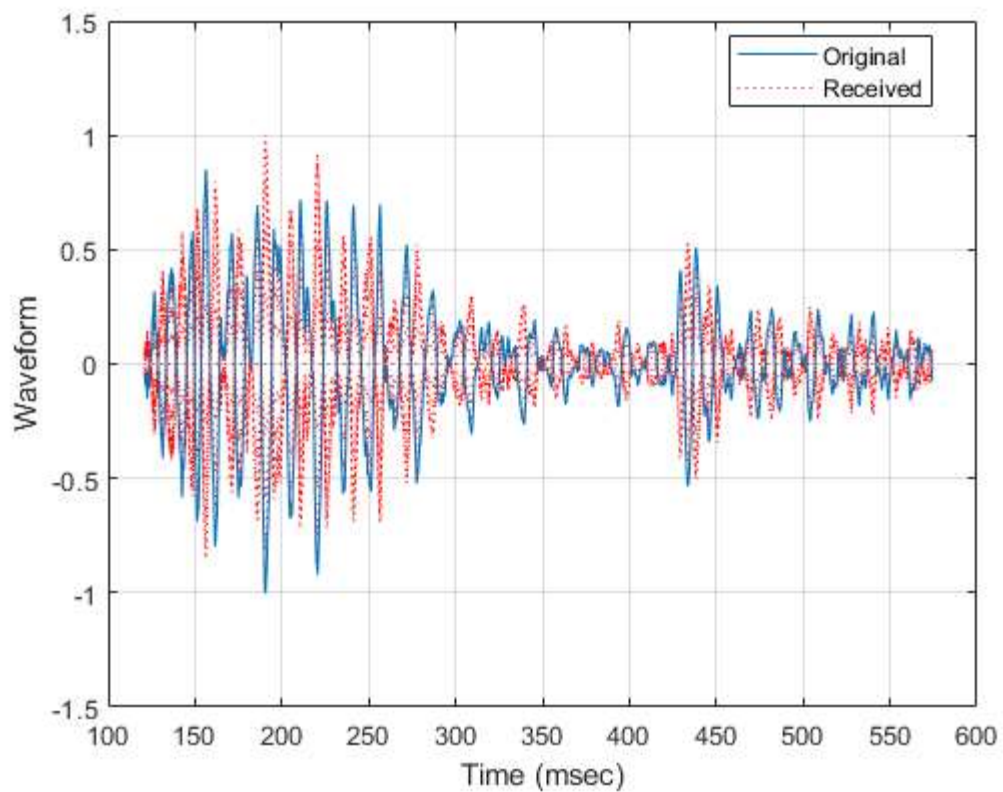


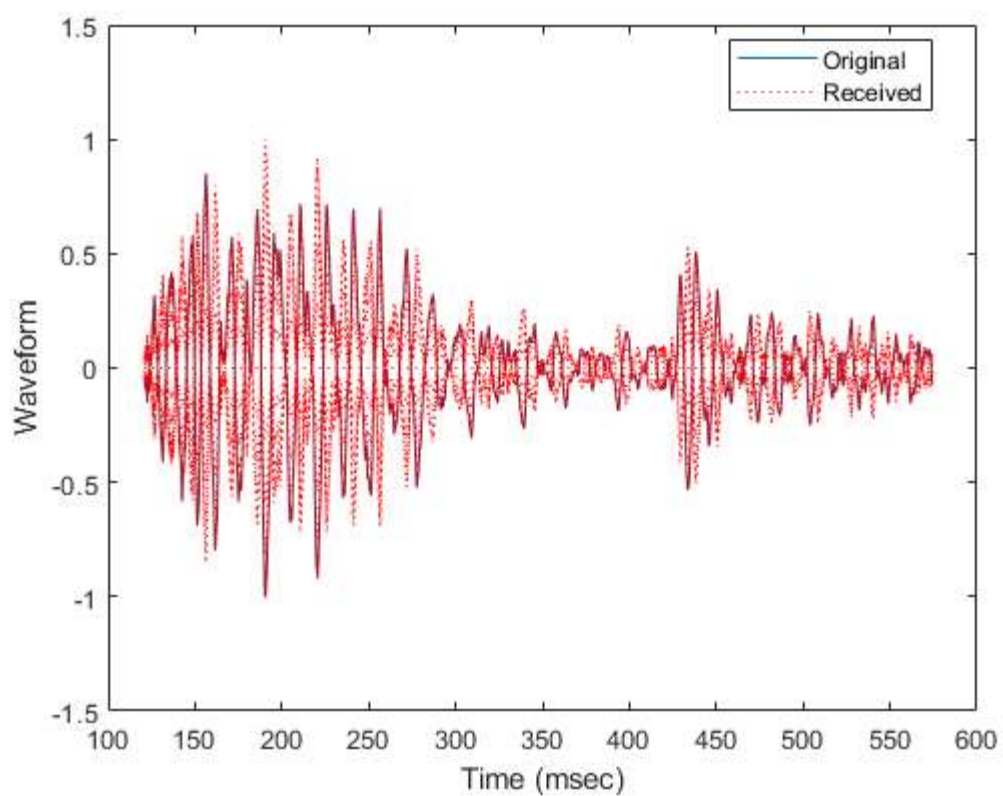
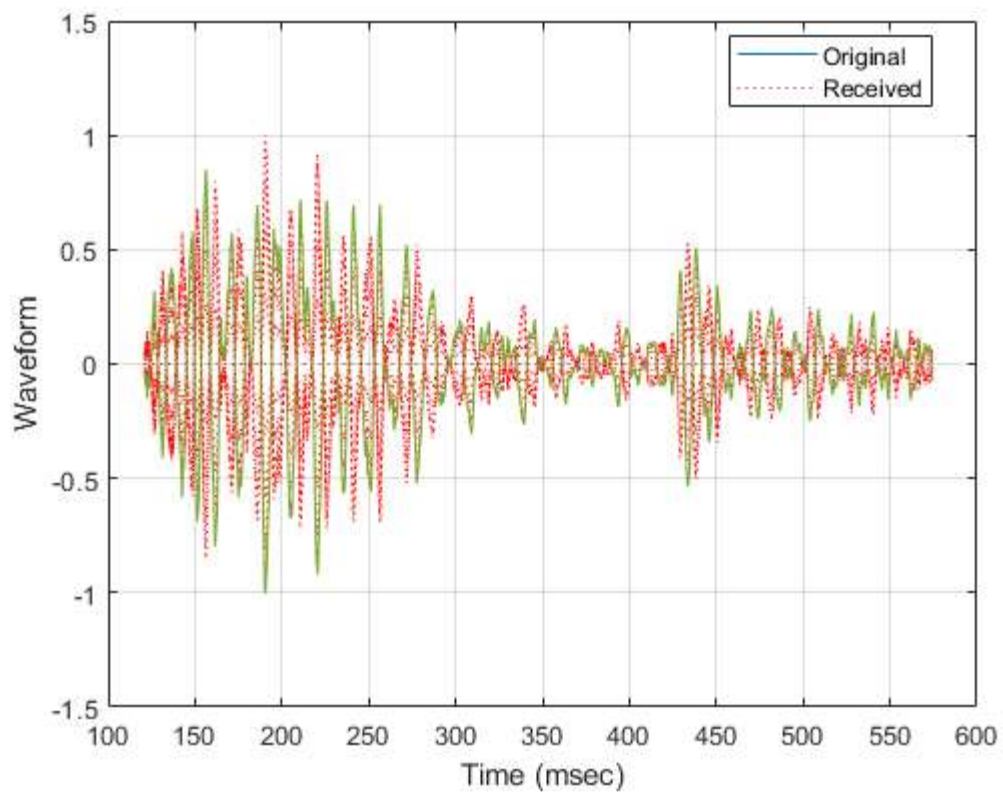


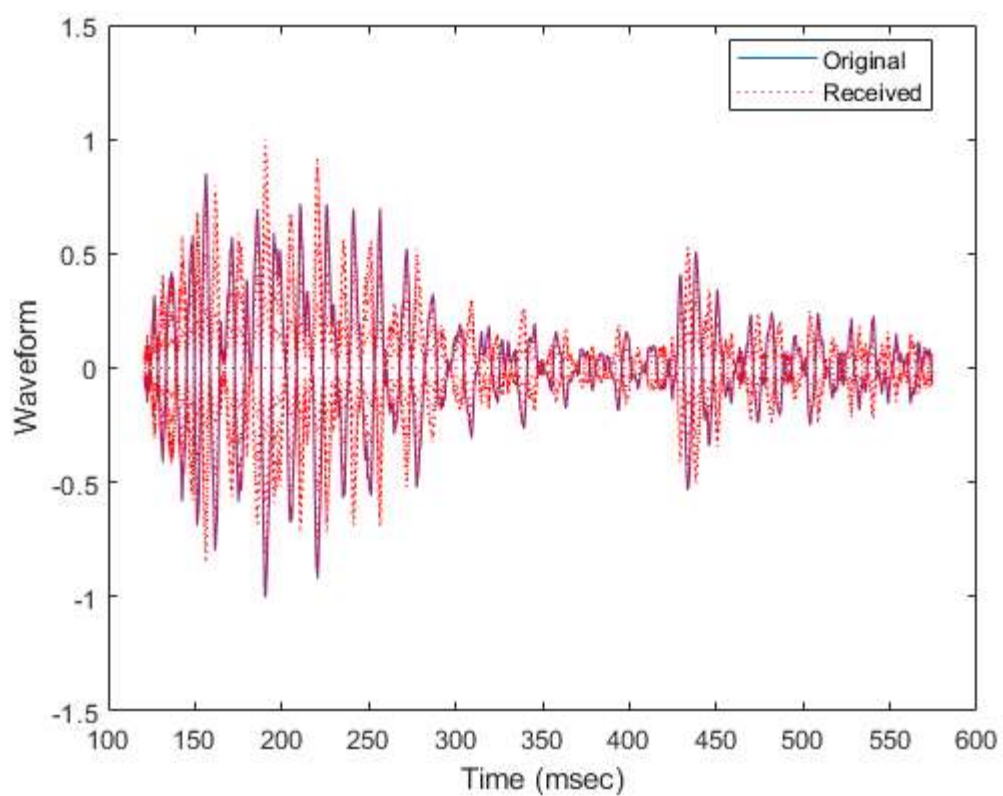
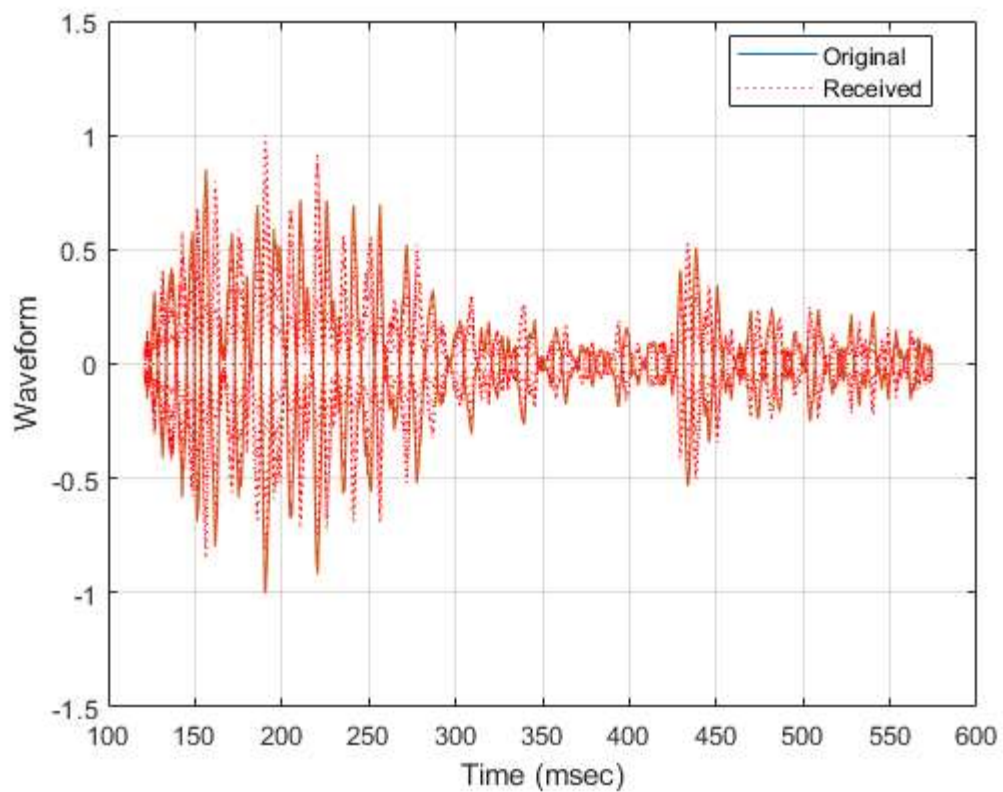




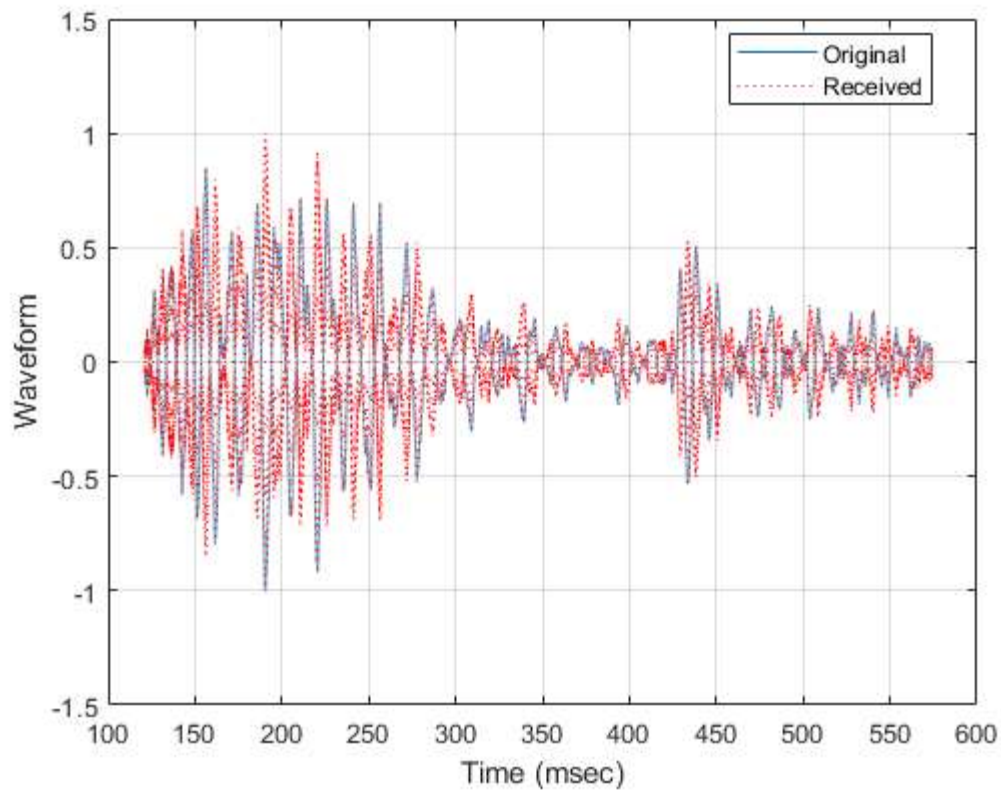










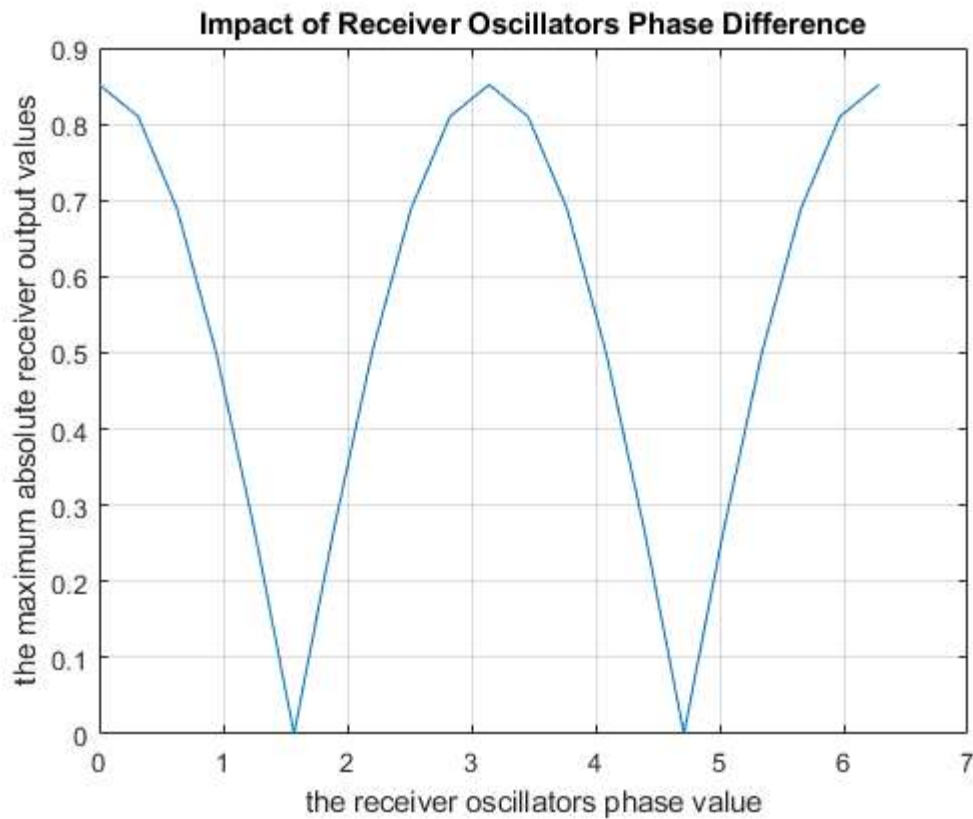


### Plotting Impact of Receiver Oscillator's Phase Difference

```

end
figure(5)
plot(q, maxrecorded);
hold on
xlabel('the receiver oscillators phase value');
ylabel('the maximum absolute receiver output values');
title('Impact of Receiver Oscillators Phase Difference');
grid

```



## Frequency Division Multiplexing for DSB-SC

```
triangle=@(t) 2*(abs(mod((2*t+1), 2))-1))-1;
f2=150e3;
twave=triangle(3e3*t) ;
c2=cos(2*pi*f2*t);
x=song.*c+twave.*c2;
y2=2*x.*c2;
z2= lowpass(y2,30e3,Fs);
```

```
%[t,freqs]=fouriertransform(twave,c2);
```

```
figure(6)
subplot(4,1,1);
plot(t(1:3000)*1000,z(1:3000),'r');
grid
xlabel('time msec');
title('time of z');
subplot(4,1,2);
plot(freqs/1000, 20*log10(abs(FTz)));
grid
xlabel('frequency khz');
title('ft of z');
subplot(4,1,3);
plot(t(1:3000)*1000,z2(1:3000),'r');
grid
xlabel('time msec');
title('wave of z2');
axis([0 1 -2 2]);
subplot(4,1,4);
plot(freqs/1000, 20*log10(abs(FTz2)));
grid
xlabel('frequency khz');
title('ft of z2');
```



Unrecognized function or variable 'FTz2'.

Error in ExampleDSBSC (line 252)

plot(freqs/1000, 20\*log10(abs(FTz2)));