Estimating velocity using Phase Information

In this script, velocity calculation using FMCW radar is performed.

Two consecutive chirps, spaced at a time interval Tc = 1 us are transmitted. The object is assumed to move a distance d in this time interval. The beat frequency change is practically negligible but the phase change is quite significant.

This phase change is used to estimate the velocity of the object.

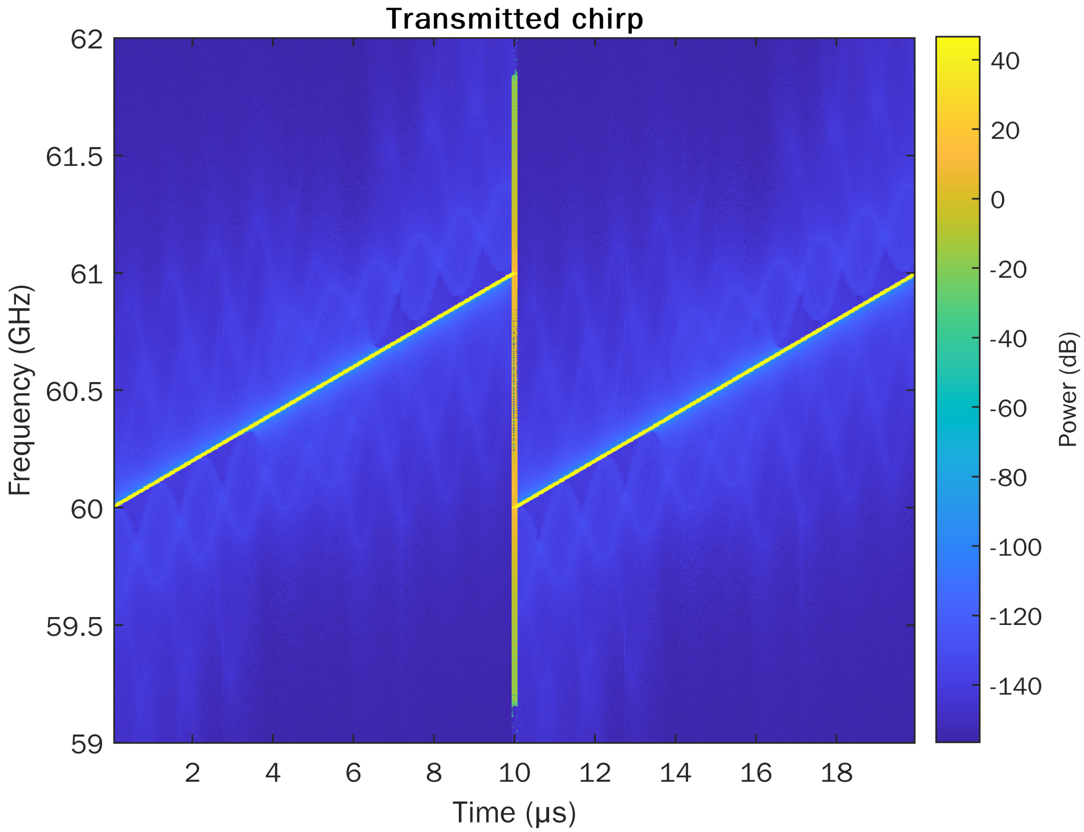
Defining Variables

```
fs = 140e9; %Sampling frequency 160 GHz
ts = 1/fs; %Sampling interval
L = 1400000; %Length of sequence
t0 = (0:L-1)*ts; %Time vector (first chirp)
t1 = (L:2*L-1)*ts; %time vector for second chirp
t = [t0,t1]; %Overall time vector

l = length(t0);
f = fs*(0:l/2)/l; %Frequency vector for single-sided spectrum
f_new = fs*(-l/2:l/2-1)/l; %Frequency vector for double-sided spectrum

f1 = 60*10^9; %Minimum frequency
f2 = 61*10^9; %Maximum frequency
K = (f2-f1)/((L-1)*ts); %Chirp slope

x0 = 100*cos(2*pi*f1*t0 + pi*K*t0.^2);
x1 = 100*cos(2*pi*f1*t0 + pi*K*t0.^2);
x = [x0,x1];

c = 3*10^8;

lambda1 = c/f1;
d1 = 5.3; % initial Distance
td1 = 2*d1/c; %Round trip delay for initial distance

d2 = 5.300111; %Final distance
td2 = 2*d2/c; %Round trip delay for final distance

v_o = (d2-d1)/((L-1)*ts) %Original velocity
```

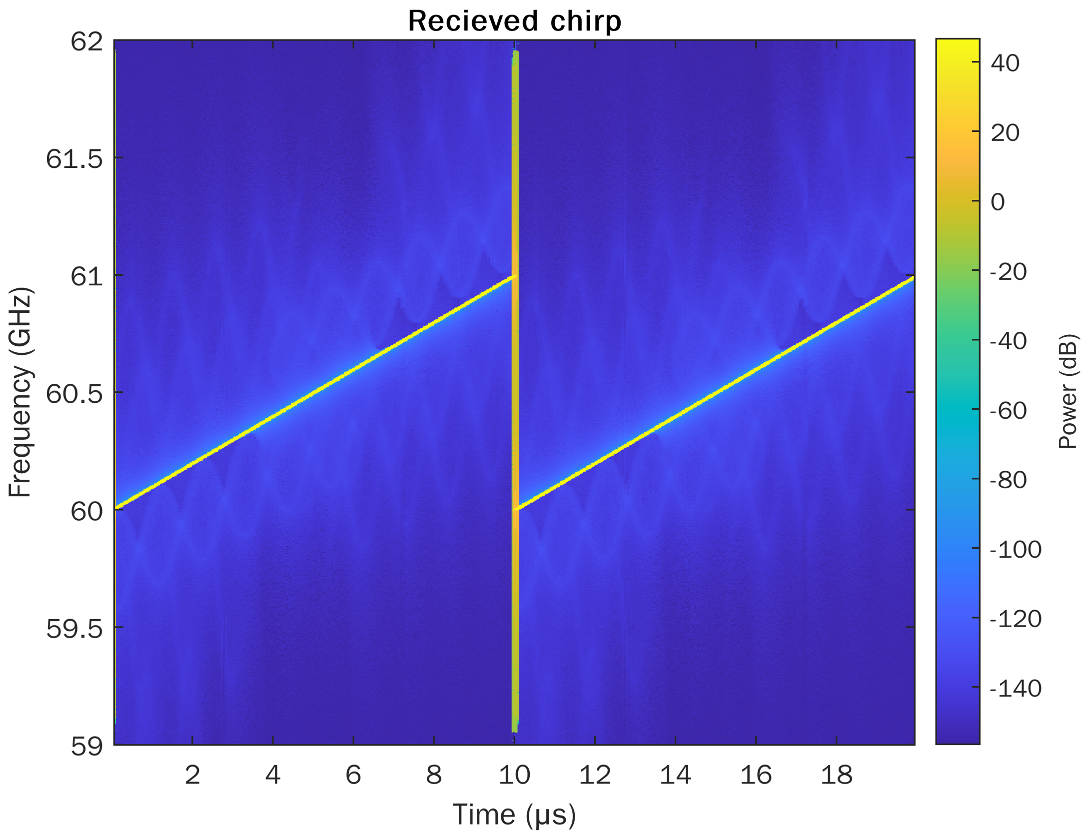
```
v_o = 11.1000
```

```
% s0 = 100*cos(2*pi*(f1)*t0 + pi*K*t0.^2);
% s1 = 100*cos(2*pi*(f1)*t0 + pi*K*t0.^2);

%delayed chirps
s0 = (delayseq(x0',td1,fs))';
s1 = (delayseq(x1',td2,fs))';
y = [s0,s1];

figure();
```

```
pspectrum(x,fs,'spectrogram','Reassign',true,'FrequencyLimits',[59*10^9,62*10^9],'Reass
title('Transmitted chirp');
```

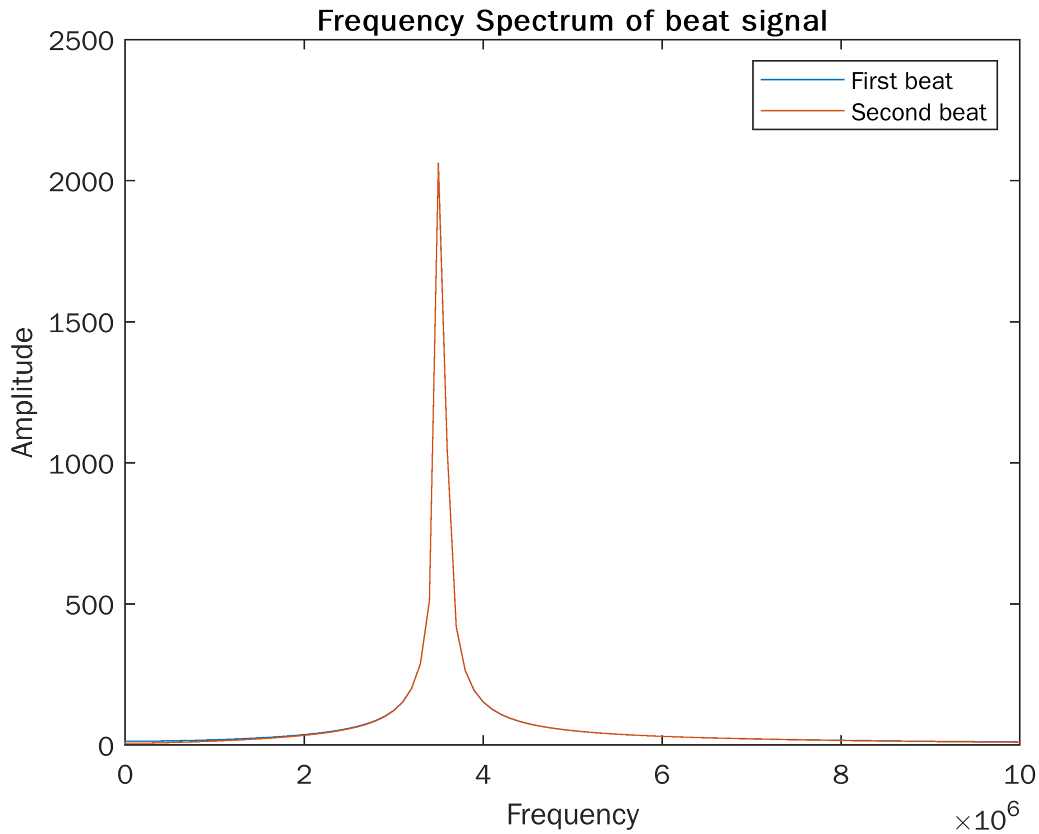



```
figure()
pspectrum(y,fs,'spectrogram','Reassign',true,'FrequencyLimits',[59*10^9,62*10^9],'Reass
title('Recieved chirp');
```



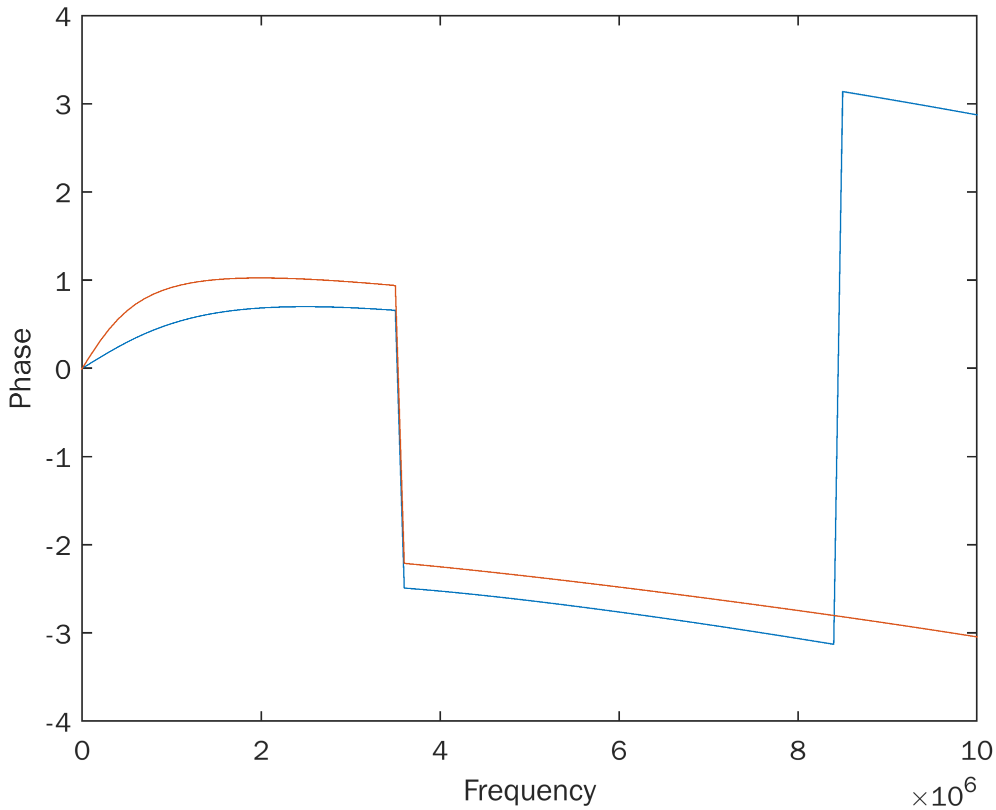
Dechirping

```
%beat signals
beat_1 = dechirp(s0',x0');
beat_2 = dechirp(s1',x1');

beat_fft_1 = (fftshift(fft(beat_1/l)));
beat_fft_2 = (fftshift(fft(beat_2/l)));
P2_1 = (abs(fft(beat_1/l)));
P1_1 = P2_1(1:l/2+1);

P1_1(2:end-1) = 2*P1_1(2:end-1);

P2_2 = (abs(fft(beat_2/l)));
P1_2 = P2_2(1:l/2+1);
P1_2(2:end-1) = 2*P1_2(2:end-1);

% plot(f,P1_1,f,P1_2);
plot(f_new,abs(beat_fft_1),f_new,abs(beat_fft_2));
xlabel("Frequency");ylabel("Amplitude");
title("Frequency Spectrum of beat signal");
legend("First beat","Second beat");
xlim([0,1e7]);
```



Finding Phase

```
%z1 = fftshift(fft(E_mod_ssb));
tol = 1e-4;
% beat_fft_1(abs(beat_fft_1) < tol) = 0;
% beat_fft_2(abs(beat_fft_2) < tol) = 0;
figure()
plot(f_new,angle(beat_fft_1),f_new,angle(beat_fft_2))
xlabel('Frequency');ylabel('Phase');
xlim([0,1e7])
```



Estimating Velocity

```
[max_val,i] = max(abs(beat_fft_1))
```

```
max_val = 2.0615e+03
i = 699966
```

```
f_beat = abs(f_new(i))
```

```
f_beat = 3500000
```

```
r = beat2range(f_beat,K,c) %range
```

```
r = 5.2500
```

```
range_error = (d1+d2)/2 - r
```

```
range_error = 0.0501
```

```
w1 = (angle(beat_fft_1(i)))
```

```
w1 = -0.6575
```

```
w2 = (angle(beat_fft_2(i)))
```

```
w2 = -0.9394
```

```
w = unwrap([w1,w2])
```

```
w = 1×2
   -0.6575   -0.9394
```

```
v_e = lambda1*(w(1)-w(2))/(4*pi*(L-1)*ts)
```

```
v_e = 11.2149
```

```
error = abs(abs(v_e)-abs(v_o))
```

```
error = 0.1149
```