FMCW RADAR

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***Abstract*— Frequency modulated continuous wave (FMCW) radar uses a very low probability of intercept waveform, which is also well suited to make good use of simple solid-state transmitters. FMCW is finding applications in such diverse fields as naval tactical navigation radars, smart ammunition sensors and automotive radars.**

I. Introduction

The basic FMCW system consists of a transmitter, receiver and mixer. A modulated signal is transmitted, received, and the transmitted and received signals are multiplied in the time domain and processed. This project proposal had contain:

- Explain how FMCW radar is used to determine range and velocity information
- Transmitted chirp signal for FMCW systems.
- MATLAB simulation of system.
- Signal processing, range and position estimation.

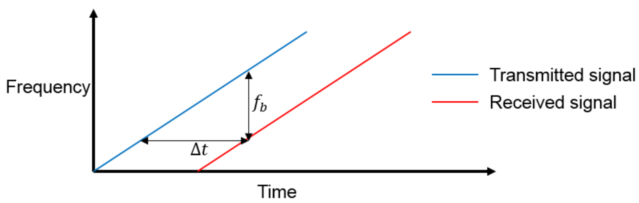
II. FMCW syatem configuration

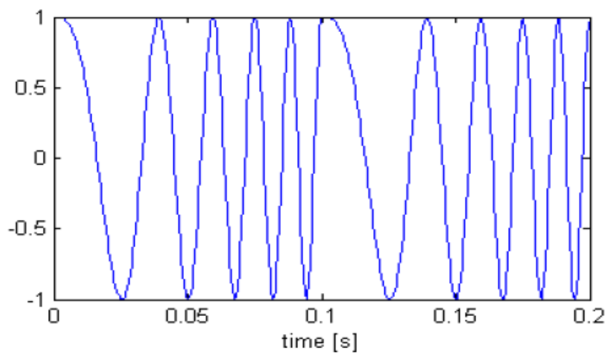
A. *Trasmitted signal*

An FMCW radar transmits a signal called a "chirp". A chirp is a sinusoid whose frequency increases linearly with time, as shown in the Amplitude vs timeMaintaining the Integrity of the Specifications.

A chirp is characterized by a start frequency (fc), Bandwidth(B) and duration (Tc). •The Slope (S) of the chirp defines the rate at which the chirp ramps up.

$$
\begin{aligned}
f_t(t) &= 2\Delta f(t - T/2) \\
f_r(t) &= 2\Delta f(t - t_d - T/2) + f_d \\
s_t(t) &= \cos(2\pi f_c t + 2\pi \int_0^t f_t d\tau) \\
&= \cos 2\pi (f_c t + \Delta f t^2 - \Delta f \cdot t \cdot T) \\
s_r(t) &= \cos 2\pi \left(f_c(t - t_d) + \Delta f t^2 - \Delta f \cdot t \cdot (T + t_d) + f_d t \right)
\end{aligned}
$$





Transmitted chirp

B. *Transmitter Antenna and reciver Antennas*

We considered one transmitter antenna and two receiver antennas.

antennaTx
x = 0
y = 0
z = 0
gain = 40

antennaRx1
x = 0
y = 0
z = 0
gain = 40

antennaRx2
x = 0
y = 0
z = 0
gain = 40

C. *Other parameters*

- Sample frequency = 100e6
- Carrier frequency = 10e9
- Transmitted power = 800
- Observation time = 5e-3
- Modulation time = 8e-6

D. *Target specification*

We modeled the target with its

- Position
- Velocity
- RCS

III Signal processing

1) Ideal simulation: The derivation above shows that simply taking the Fourier Transform will yield a single peak that contains both range and Doppler information (Figure 5). Therefore, additional signal processing is needed. A two dimensional signal processing method is demonstrated in [1, 6].

A system is simulated with two point scatters at 8 and 113 m from the target, moving 22 and 17 m/s away from the stationary radar, respectively. The carrier frequency $f_c = 77$ GHz and $\Delta f = 200$ MHz, with $T = 1ms$. The transmitted and received frequencies are shown in Figure 3. The difference in these frequencies is shown in Figure 4. Again, there is a frequency component dominated by high frequencies that is filtered out, thus only the difference is left.

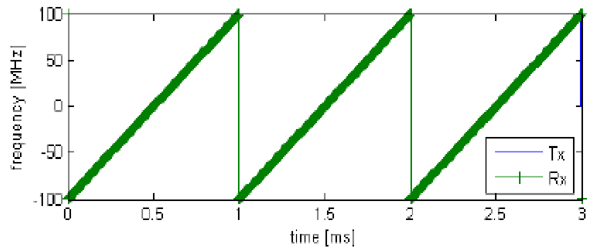
2) 1D FFT: If the LPFed signal is filtered or undersampled, the high frequency spike will not appear in the spectrum. Thus there is one frequency peak in the signal for each point scatter, as derived above.

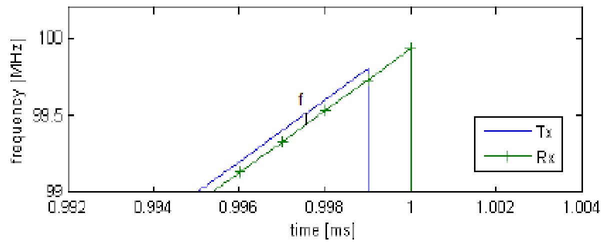
From the modulation derivation, for this scenario we should expect to see two frequency peaks at 21.96 kHz and 159.4 kHz, as in [1]. From a 1D FFT of the mixed signal, the spectrum exhibits frequency peaks at 21.99 kHz and 159.42 kHz, verifying that my model is working.

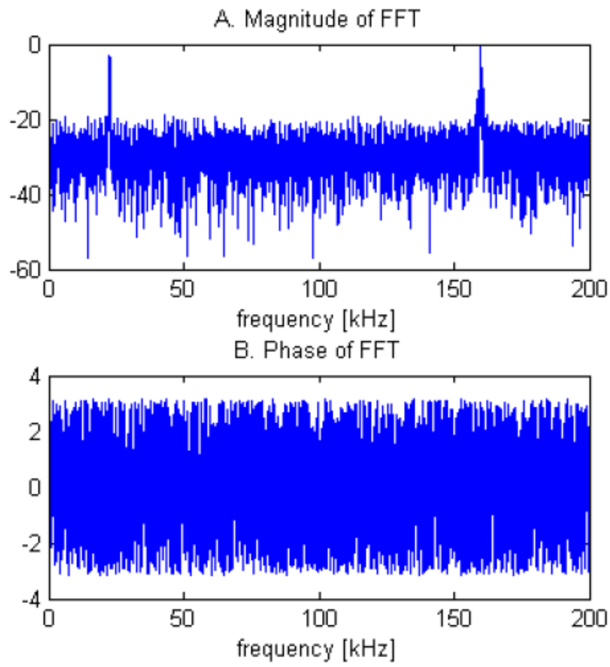
3) 2D FFT: As demonstrated in [6], a 2D FFT can be used to extract the range and doppler information from the spectrum. This is shown in Figure 6. The range axes are calibrated with the range and doppler axes calibrated based on the modulation derivation from above. The figure shown is based on 36 periods of modulation (36 ms). Note that the 20 dB dynamic range is consistent with the side lobe level from the 1D FFT. Also, the points aren't exactly at the appropriate range and doppler values. This is due to some 'drift' caused by the scatters physically moving. This is also evident in the 1D FFT - the width of the frequency peaks increases as the number of samples increases.

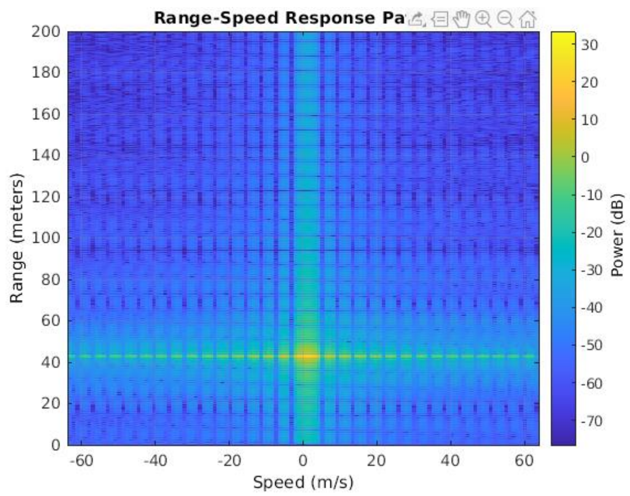
5) Effects of noise and phase error: White noise was added into the mixed signal in the time domain, to model what would happen in an RF mixer. Phase noise was also added in this step to model random phase error.

This noise and phase error does not affect the 1-D FFT other than raising the sidelobe level. This is to be expected, as the Fourier transform of white noise has a flat power spectral density, as shown in Figure 7. Thus, the 1D spectrum of the actual mixed signal, with a white noise signal included, is just the original signal with higher sidelobes. Thus, the MTD method is also not really affected, provided that the side lobes are still low enough that a frequency peak can be identified.









III. MATLAB simulation Result

A. Targets simulated

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Target #1: Range = 100m  Speed = 15m/s
Target #2: Range = 120m  Speed = 25m/s
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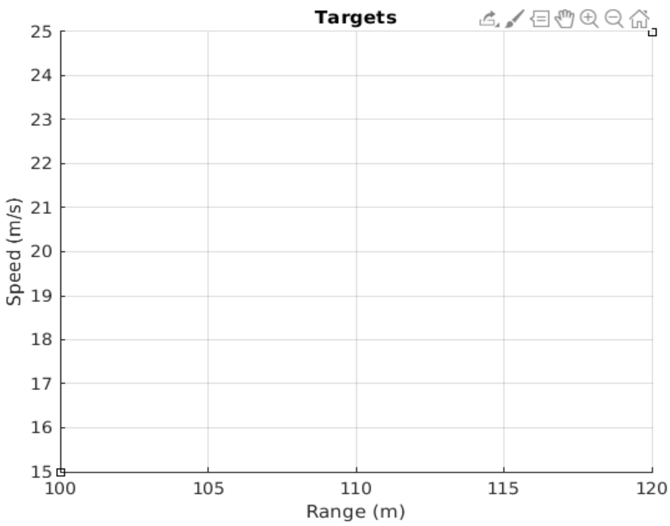
RCS = 10 (for both Target)



B. Targets detected

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Target #1: Range = 101.25m  Speed =16.5m/s
Target #2: Range = 121.87m  Speed =25.5m/s
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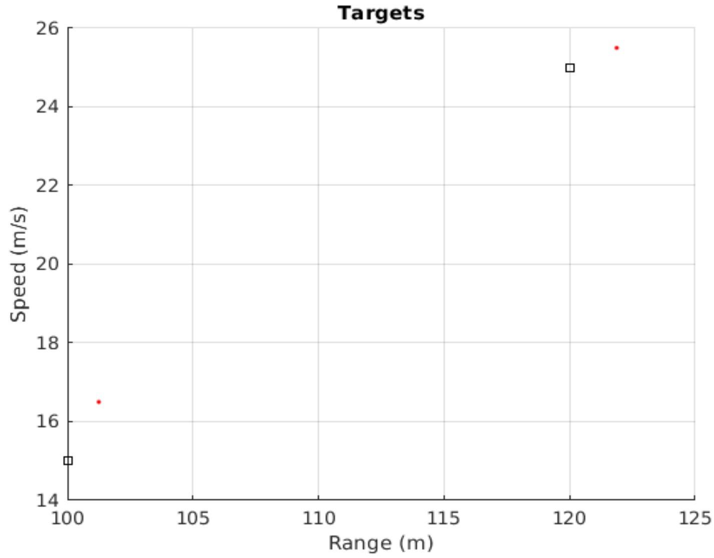

IV. References

A. Automotive Adaptive Cruise Control Using FMCW Technology MATLAB example

B. Introduction to mmwav eSensing: FMCW Radars sandeep rao