RANGE RESOLUTION OF FMCW RADAR SYSTEM USING SIMULINK

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Abstract- The paper aims at improving the range resolution of FMCW radars by implementing our Simulink model on a dsp processor (DSK 6713). The first of its kind approach allows us to experiment with different models in Simulink, test their efficiency using test waveforms while the dsp implementation allows cheaper setup without compromising on expected outputs.

Keywords- Additive white Gaussian noise (AWGN), DSK 6713, Frequency Modulated Continuous wave (FMCW), Range resolution, Simulink.

I. INTRODUCTION

The basic idea in a pulsed radar system to measure the range is the measurement of the time difference between the transmitted and the received signals. To do this in FMCW radar we should use a feasible idea, i.e. a timing mark, because we continuously transmit signal in continuous wave radar.

This report is mainly about the non-ideal behaviors in FMCW radars and range resolution improvement in a short-range FMCW radar system.

There are different methods to improve range resolution in FMCW radar, which are mainly signal processing methods for the beat frequency, i.e. the frequency difference between the transmitted and the received signals. Improvement of range resolution is directly related to resolution of the beat frequency.

The paper is organized into 6 sections. Section 1 gives an overview of the paper. Section 2 describes the basics of FMCW radar. In section 3, describes the basics of range resolution of FMCW radar. Section 4 is dedicated to the Simulink model and its testing and section 5 to simulation results. Finally, section 6 presents conclusion and future work.

II. BASICS OF FMCW

In frequency modulated continuous wave (FMCW) radar, the transmitter frequency is varied as a function of time in a known manner.

Assume that transmitter frequency increases linearly with time as shown in Fig 1a. If there is a target at range R, an echo signal will return as shown in Fig.1b. Time difference between the transmitted and the received signals is

\[ T = \frac{2R}{C} \]

If the transmitted and the received signals are multiplied within a mixer then filtering out the high frequency term of the output we will get a beat frequency \( f_b \). When there is no Doppler shift in the signal, the beat frequency is a measure of the target’s range and \( f_b = \frac{2R}{c} \) where \( f_b \) is the beat frequency due only to the target’s range. If the slope of the frequency change of the transmitted signal is \( m_t \), then:

\[ f_b = T \cdot m_t = \frac{(2R/c)}{m_t} \]  

(1)

In any practical CW radar, the frequency cannot be continuously changed in one direction only periodicity in the modulation is necessary. The modulation can be triangular, saw tooth, sinusoidal, etc. When triangular frequency modulated waveform is used as in Fig.2 the resulting beat frequency will be as in Fig.3.

\[ f_b = T \cdot m_t = \frac{(2R/c)}{m_t} \]  

(1)

Figure 1: Frequency change of (a) transmitted signal (b) transmitted and received signals

Figure 2: Triangular frequency modulation for transmitted and received signals
Figure 3: The beat frequency of triangular frequency modulated signal

As shown in the Fig.3, beat frequency is constant except at the turn-around region. If the frequency is modulated at a rate $f_m$ and deviation of frequency is $\Delta f$ then the beat frequency except the turn-around region is:

$$m_f = 2\Delta f f_m$$  \hspace{1cm} (2)

Using (2) with (1):

$$f_b = \frac{4Rf_m\Delta f}{c}$$  \hspace{1cm} (3)

Thus as seen in (3) the measurement of the beat frequency determines the range $R$. If we define $K$ factor as:

$$k = \frac{4f_m\Delta f}{c}$$  \hspace{1cm} (4)

then

$$f_b = KR$$  \hspace{1cm} (5)

We can use two basic block diagrams to illustrate the principle of the FMCW radar. One is the structure with separate transmitting and receiving antennas as shown in Fig.4 and the other structure is with only one antenna, which transmits and receives the signal as shown in Fig.5. In either structure, a portion of transmitted signal acts as the reference signal to produce the beat frequency. This reference signal is introduced directly into the mixer. The isolation between transmitting and receiving antennas is critical to reduce transmitter leakage signal to a negligible level that arrives at the receiver via the coupling between antennas.

III. BASICS OF RANGE RESOLUTION

The target resolution of radar is its ability to distinguish between targets that are very close in either range or bearing. Weapons-control radar, which requires great precision, should be able to distinguish between targets that are only yards apart. Search radar is usually less precise and only distinguishes between targets that are hundreds of yards or even miles apart. Resolution is usually divided into two categories; range resolution and bearing resolution.

Range resolution is the ability of a radar system to distinguish between two or more targets on the same bearing but at different ranges. The degree of range resolution depends on the width of the transmitted pulse, the types and sizes of targets, and the efficiency of the receiver and indicator. Pulse width is the primary factor in range resolution.

Range resolution should not be confused with accuracy. Nevertheless, in most radar projects, a first guess for the accuracy figure (one standard deviation) will be half the value of the corresponding resolution. When the radar is realized, the accuracy is frequently better than the first guess because: e.g., the range accuracy is a characteristic of the measurement of the elapsed time between the departure of the transmitted pulse and the arrival of the echo at the receiver.

If the transmitted pulse is a perfect rectangular one, the received pulse will look like a Gaussian curve because the receiver bandwidth is finite; in addition the noise will disrupt the Gaussian shape of the received pulse. Hence it is obvious that the accuracy of this measurement is not really linked to the pulse width (which defines the range resolution) but rather on the receiver signal strength (which is linked to the range). Hence the range error should increase with the range.
IV. SIMULINK BLOCK DIAGRAM

The block diagram depicts 3 stages of the FMCW radar: 1. Transmitter section 2. AWGN channel 3. Receiver parts. 1. Transmitter: includes the signal generator modulated with a chirp signal, 2. the channel: includes addition of AWGN noise and 3. The receiver includes regeneration of the original signal and delayed signal to be compared (using the AND gate) to generate a trigger pulse at 70% of the peak signal value.

![Figure 7: Simulink block diagram to implement transmitter, channel and receiver parts of FMCW radar.](image)

V. RESULTS

![Figure 8: End result of Simulink block diagram](image)

![Figure 9: Waveforms of comparator 1 and 2](image)

![Figure 10: Waveforms of comparator 3 and 4](image)

CONCLUSION

Thus, we implemented a Simulink based FMCW radar model in which we used time based analysis to obtain a firing pulse at 70% peak input signal. After burning on the DSK 6713 kit, we now plan to further our study on range resolution by testing the made model practically using antenna setup to provide efficiency on the field. FMCW radars in the GHz spectrum provide excellent distance measurement performance in applications where high accuracy, repeatability and reliability are needed.

REFERENCES


