

A Survey Paper on FMCW Radar Implementation Using FPGA

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ABSTRACT: Frequency Modulated Continuous Wave (FMCW) radar system are gaining importance in many fields as they measure objects and acquires information by changing the sending signal frequency along with the time and by measuring the receiving signal's frequency with respect to the sending signals. So, a practical FMCW radar signal processing method mainly used for eliminating noise interference from the sampled signal, checking out the objective signal, and extracting the data as the processing results is needed. FMCW radar is simple in design, small in size and weight and uses low transmitting power. This project mainly includes the digital signal processing that is to be performed on the signals obtained during range estimation of the FMCW radar which is obtained after modelling and simulation. Further a digital signal processing using FFT algorithm will be done for extracting and isolating targets in the return signal of FMCW radar.

KEYWORDS: FMCW Frequency Ramp Generator, Phase Locked Loop, ADC, Phase noise

I.INTRODUCTION

The Frequency Modulated Continuous Wave (FMCW) radar has many advantages over the commonly used pulse radars and has found a variety of applications. FMCW level radars have been used for years in the areas such as navigation and car anti collision avoidance. Owing to its low transmitting power and high accuracy in range measurement, the FMCW radar is ideally suitable for level measurement applications and has been used for years. One of the most unique features of the FMCW level radar is its high accuracy in range measurement which is usually in the order of 1mm. Since the frequency of the beat-note of the receiving signal is directly related to the range between the reflecting surface and the radar, most range estimation methods of the FMCW radar are based on frequency estimation of the beat-note signal. Frequency modulated carrier-wave (FMCW) radars have found numerous applications where the presence of one target is to be detected. However, this type of radar is more difficult to use where there are several targets as detection has to be based on the analysis of the frequency spectrum of the return signal. No effective methods have been developed for automatically processing the return to extract the targets, especially if the target return is of the same order of magnitude as the clutter level. In earlier work, where an FMCW radar was used to detect buried objects the interpretation of the frequency spectrum was performed by visual inspection of the output of a spectrum analyser. Such a method of interpretation is generally unsatisfactory. So through this project we try to find a method for target extraction using digital-signal-processing techniques.

II.LITERATURE SURVEY

The processing chain consisting[1]of a flexible FIR filter, a range-Doppler processing unit using windowed FFTs and an ordered statistics constant-false alarm-rate (OSCFAR)unit for optimal target detection and data reduction. Data acquisition and data pre-processing for high-performance radar sensors is possible, assuming a maximum ADC

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sampling rate of 250MHz for each receive channel. Possible to processed-MIMO radar sequences of up to 16 receiving channels in parallel. Single transmitter and a single[2]transmitting antenna array of five elements to measure distances at a high degree of accuracy for 24GHz FMCW radar. Analyses practical signal processing methods based on the[3] features of FMCW radar signals, including: FFT,accumulation, backward judgment,etc. Gives some solutions to the pertinent problems those may occur during the FMCW radar signal processing. The novel architecture is described, along with the size,[4]power consumption and performance for key radar processing operations. Architecturefeatures include a flexible compute unit optimized for FFT operations and a two-dimensional register file. The frequency ramp nonlinearity is investigated[5]with the modified short-time Fourier transform method by using the short-time Chirp-Z transform method with high accuracy The synthesizer is designed using 0.18 μ m UMC[6] technology CMOS process libraries, for achieving high linearity in frequency ramp over a wide operating frequency range coupled with fine frequency steps.

III.METHODOLOGY

1. RADARS

The word radar is coined from the initial letters of the phrase; Radio Detection and Ranging. Radar is used for remote sensing of objects, land, etc. This is accomplished via sending an electromagnetic wave in various frequencies and receiving the reflection from the object which is very similar to sound echo reflected back from a valley. Radar is designed to see through darkness, fog, rain and snow. It is also used to measure range and speed. According to Skolnik [1] these are the most important attributes of radar. However, radar is evolved over a hundred years of work and experience

Operation of Radar

Basically radar is composed of a transmitter, a receiver, a duplexer and an antenna (Fig 1). This configuration is called monostatic radar since transmitted and reflected waves use the same antenna. Power is transmitted through the duplexer to antenna in the form of electromagnetic wave with periodic pulses. The waves travel in free space and if there is an object, the incident waves are absorbed by that object. Then the object reradiates the waves around. A part of this reradiated wave returns back to antenna (reflected wave). Reflected wave at the antenna is directed to receiver by the duplexer. Hence a signal is sensed at the receiver by the presence of the object at a delay of τ after pulse transmission (Fig-2).The delay τ is related to range with the speed of radio waves which is a form of light. Speed of light is denoted by c and in free space it is equal to 3×10^8 m/s. Fig 1: Simple Monostatic Radar Configuration

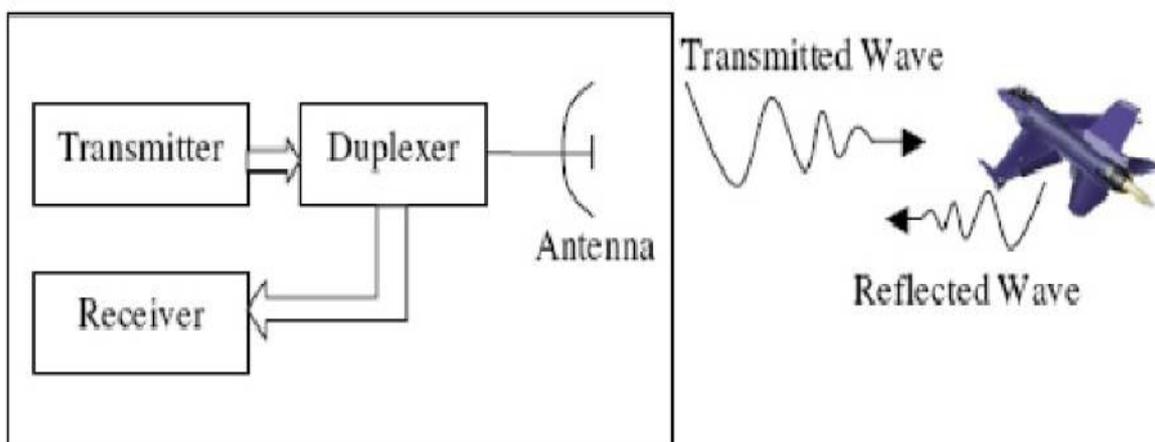


Fig.1: Simple Monostatic Radar Configuration

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Radio waves travel to object over R distance and backscatter to radar again over R distance with the speed c. Hence the distance R is given by the equation:

$$R = \frac{c \times \tau}{2}$$

With the above equation, range of an object is related to the time delay in free space. But since the electromagnetic waves are transmitted with periodic pulses, ambiguities may occur if the delay is larger than the pulse period. Besides pulse modulation, there are many different techniques such as pulse compression, pulsed Doppler or continuous wave those have their own advantages.

2. FMCW RADAR

FM-CW radar is a one type radar. In this radar the transmitted energy is frequency Modulated. The advantage of FM-CW technique is its ability to determine height very accurately over a large surface. Another advantage is continuous wave transmission, which allows accurate relative height measurement with low power outputs. The main disadvantage is the coupling of harmonics of modulation frequency to receiver (leakage from the transmitter to receiver) and nonlinearities in the modulating signal.

Operation of FM-CW Radar

FM-CW radar operates with continuous wave (CW) instead of pulse modulation. FM-CW is a subclass of CW radars. But in addition to CW (which has only speed detection) it has range detection capability. Doppler Effect is a well-known fact that if the observer and source of oscillation is in motion with respect to each other, a shift occurs in the frequency. Assume the wavelength of transmitted wave is λ and the range from radar to object is R, then the total phase difference ϕ between the transmitted and the received waves is given by $4\pi R / \lambda$. In the case of relative motion, R and ϕ change with time. This change is expressed with angular frequency as follows

$$w_d = \frac{d\phi}{dt} = \frac{4\pi}{\lambda} \frac{dR}{dt} = \frac{4\pi V_r}{\lambda}$$

Where V_r is the radial velocity of object with respect to radar. If f is the frequency of oscillation of radar then using above equation, Doppler frequency is:

$$f_d = \frac{2V_r f_o}{c}$$

As given in CW radars receive a signal which is shifted in frequency by an amount of f_d in the case of relative motion. But this information is not suitable to determine range from received signal. In FM-CW radars the transmitted signal is frequency modulated. Hence the delayed signal is received with a different frequency even if the target is stationary. The received and the transmitted waves are mixed in the radar to give a mixed signal which carries information about speed and range of the target. Fig-3 shows the block diagram of a simple FM-CW radar.

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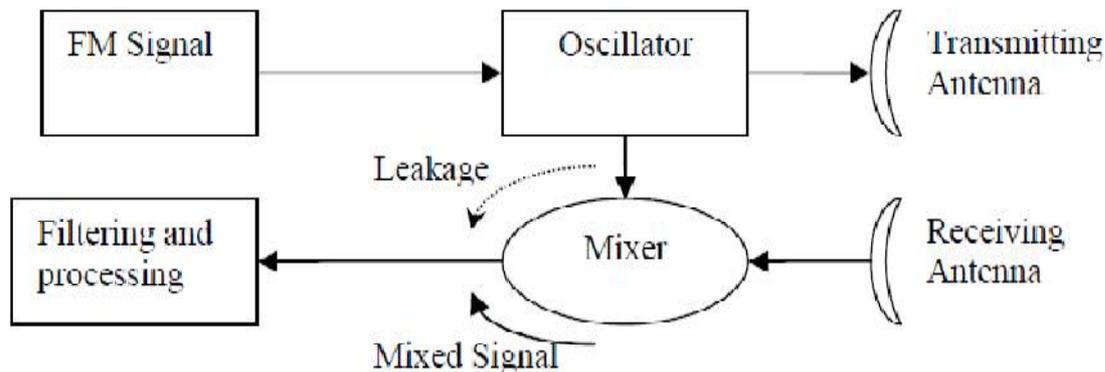


Fig.3: Block diagram of a simple FMCW Radar

In general an FM modulated signal $s(t)$ is transmitted where $\theta(t)$ is phase and A is the amplitude of the transmitted wave.

$$s_t(t) = A \cos(\theta_t(t))$$

Due to reflection mechanism of electromagnetic waves and reflections from different ranges $s_r(t)$ is received.

$$s_r(t) = A_r(t - \tau) \cos(\theta_t(t - \tau) + \phi_0)$$

A_r denotes the amplitude of the received signal in relation with delay τ , in order to reflect the effect of many different scatters from different ranges. ϕ_0 is the phase difference due to reflection.

3. ANALOG TO DIGITAL CONVERTER (ADC):

In electronics, an analog-to-digital converter (ADC, A/D, A-D, or A-to-D) is a system that converts an analog signal, such as a sound picked up by a microphone or light entering a digital camera, into a digital signal. An ADC may also provide an isolated measurement such as an electronic device that converts an input analog voltage or current to a digital number proportional to the magnitude of the voltage or current. Thus ADCs are used to process, store, or transport virtually any analog signal in digital form. Radar systems commonly use analog-to-digital converters to convert signal strength to digital values for subsequent signal processing. The ADC that we have selected here is AD9235 which belongs to multistage pipelined architecture, provides 12-bit accuracy at around 65MSPS.

4. DIGITAL SIGNAL PROCESSING (DSP):

Digital signal processing can be used to extract targets and also to separate two targets close to each other. Thus, a method of signal processing needs to be described and implemented to enhance the detection capability of the radar.

The steps that are to be performed in Signal Processing of the FMCW radar system will be as follows:

- Fast Fourier Transform (FFT)
Transform a time signal into the frequency domain.
 $x(t) \Rightarrow X(k)$
- Filtering
- Detection Rules
- Multiple Object Detection

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The signal processing terminal must embody the three cornerstones of the successful product as a whole: efficiency, portability, and feasibility. The system must be able to process radar data in real-time with minimal delay between scanning and graphical display of terrain/targets. For this reason, each block of the system has undergone run-time optimization by reducing the amount of operations performed for each second of data captured. The coherent detection and A/D transformation are the front steps of digital signal processing. They are aimed at converting the analog signals received from the radar to process able digital signals. Then processed with the digital processing using FFT algorithm.

IV. SIMULATION AND IMPLEMENTATION

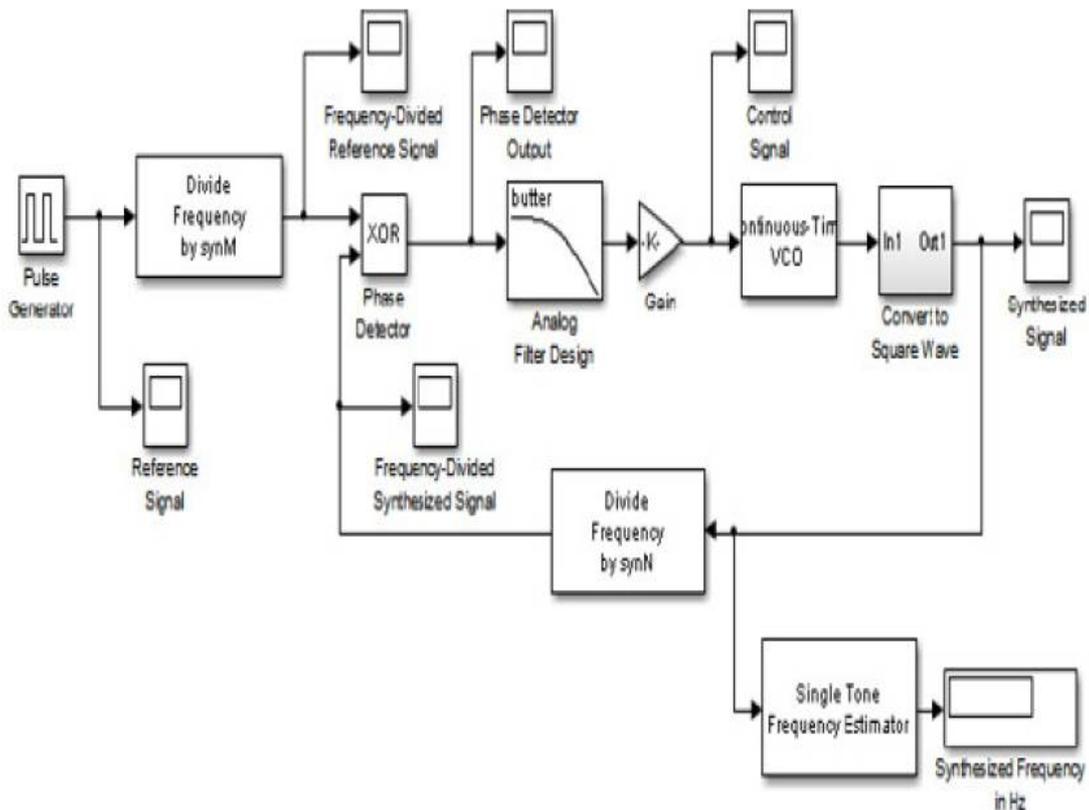


Fig 4: Signal generation of 10GHz using PLL

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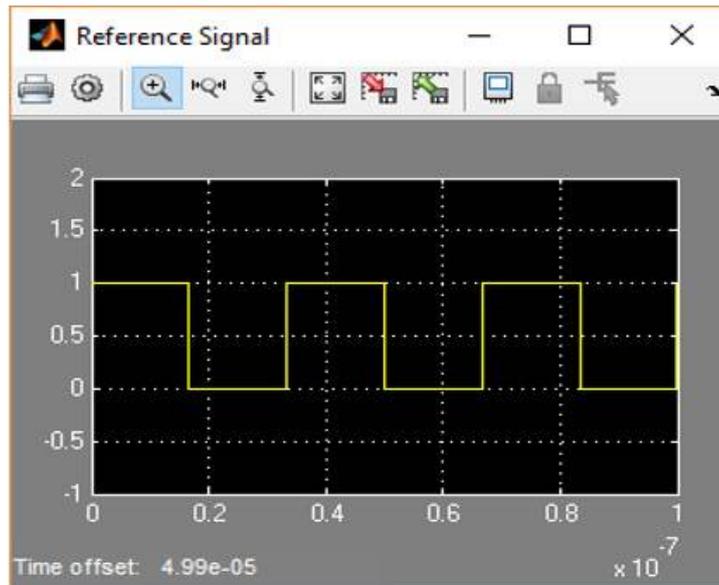


Fig 6: Reference Signal of 30MHz

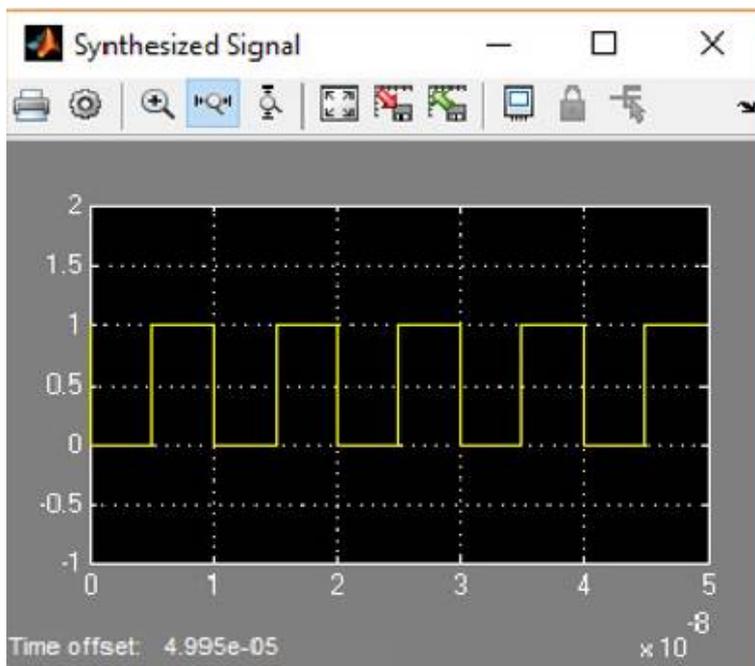


Fig 7: Synthesized Signal of 10GHz

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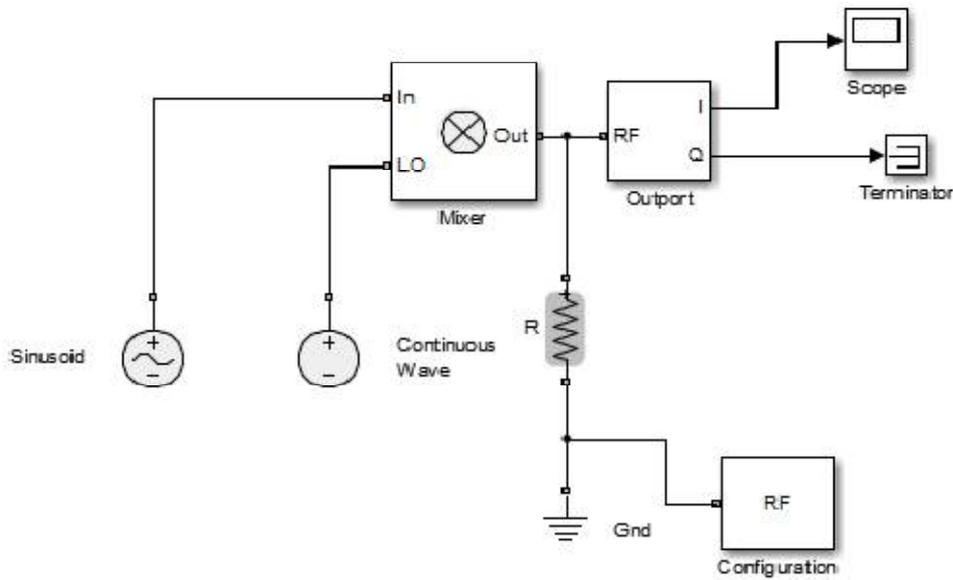


Fig.8 Generation of IF signal using Mixer

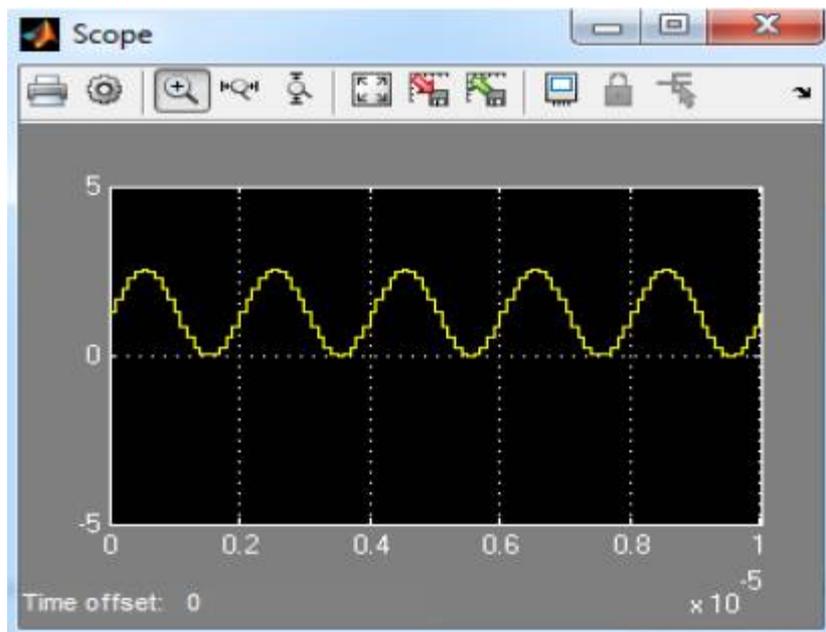


Fig.9 IF signal of 100KHz

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V.CONCLUSION

As per requirements of the system, for FFT implementation and better digital signal processing of FMCW received signal, FPGA (Zync-7000) could be used and for converting this analog signal to digital form a high speed ADC (AD9235) can be interfaced to FPGA. Design of PLL is done using MATLAB/Simulink and signal of 100MHz is generated. This paper presents a simulation of FMCW radar in Simulink and study of implementation of the FFT algorithm for the FMCW radar system. Here we have generated 10 GHz of signal using PLL and using mixer we have generated IF frequency of range 50 KHz to 500 KHz.

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