Implementation of FMCW Radar

Roopa Krishna Chandra[1], Tangirala Spandana[2], Loya Sravani[3],Yenumula Jahnavi[4]
[1]Assistant Professor, [234]UG students,
Department of Electronics & communication engineering,Andhra Loyola Institute of Engineering And Technology
Vijayawada,India.

Abstract- In this paper we are discussing about implementation of FMCW Radar .The entire system is designed using MATLAB software with version 2016a. The FMCW Radar has several benefits and advantages over the continuous wave radar. Now a day's FMCW Radar plays an important role. It is Radar which radiates continuous transmission power like continuous wave radar. This is an advanced version of CW radar where the delay is taken into consideration. If the delay is more the target is farer, if the delay is less the target is nearer to the radar. The difference between transmitted signal and the received signal is called beat note.This radar differs from pulsed radar which emits an RF signal that is usually swept linearly in frequency. In this project we are measuring the range between target and radar system, phase error correction, Doppler frequency range, and we are also designed Patch antenna array for FMCW radar applications.

Keywords- FMCW Radar, CW Radar, Phase error correction, Doppler frequency range, Patch array antenna for FMCW radar, directivity

I. INTRODUCTION

Radar is an instrument that radiates electromagnetic wave in the space, which detects and locates of objects. Today, it is widely used for velocity estimation, imaging, and many other functions. The principle of radar operates likes to sound wave reflection. If any wave sound incident on the object (target) (like rocky canyon and cave), it will be reflected and heard, this sound wave reflecting is called echo. If sound speed is known, we can estimate the distance and direction of the objects. Radar systems are composed of a transmitter that radiates electromagnetic waves of a particular waveform and a receiver that detects the echo returned from the target. Only a small portion of the transmitted energy is re-radiated back to the radar. These echoes will processed by the radar receiver to extract target information such as (range, speed, direction, position and others).

The range to the target is evaluated from the travelling time of the wave. The direction of the target is determined by the arrival angle of the echoed wave. The relative velocity of the target is determined from the Doppler shift of the returned signal. Radar can be classified in terms of ground based, air borne and ship based radar systems .Also can be classified into numerous categories based on the specific radar characteristics, such as the frequency band, antenna type, and waveforms utilized, also classified by the types of waveforms or operating frequency. The goal of this paper includes a discussion of several forms of the radar equations, and one of the equations of radar theory is the radar range equation, including those most often used in predicting radar performance. In this paper, we use MATLAB simulation program to representing the radar range equation, and how to model a 77 GHz 2x4 antenna array for FMCW applications. The presence of antennas and antenna arrays in and around vehicles has become a commonplace with the introduction of wireless collision detection, collision avoidance, and lane departure warning systems. The two frequency bands considered for such systems are centered around 24 GHz and 77 GHz, respectively. In this paper, we will investigate the micro strip patch antenna as a phased array radiator. The di-electric substrate is air.

II. EXISTED METHOD

Continuous-wave radar is a type of radar system where known stable frequency continuous wave radio energy is transmitted and then received from any reflecting objects. Continuous-wave (CW) radar uses Doppler, which renders the radar immune to interference from large stationary objects and slow moving clutter. CW radar can still provide ranging information. We have to use a frequency modulation on the CW signal, typically a linear FM. Then when we mix the returned signal with a reference signal, the difference in signals will tell us where in the linear sweep we are and we can use that to infer time which equates to radar distance. However, the primary drawback of CW is power. If we say we have a 10 kW transmitter, and you have CW radar, then that means that you are transmitting 10 kW continuously.

III. PROPOSED METHOD

FMCW Radar has traditionally been used in short range applications. Conventional FMCW radar requires the use of expensive microwave mixers and low noise amplifiers. A uniquely inexpensive solution was created, using inexpensive Gunn oscillator based microwave transceiver modules that consist of 3 diodes inside of a resonant cavity. However these transceiver modules have stability problems which cause them to be unsuitable for use in precise FMCW radar applications, when just one module is used. In order to overcome this problem, a unique radar solution was developed which uses a combination of 2 transceiver modules to create a precise FMCW radar system. This unique solution to FMCW radar power is proven to be capable of determining range target, and creating Synthetic Aperture Radar images, FMCW Gunn Oscillator, SAR, Linear SAR, Radar Imaging, and Measurement Systems FMCW radar has been around for ages. In this paper, a novel method to FMCW radar design is explored. In this paper a brief explanation of FMCW will be presented. FMCW radar was first widely used in radio altimeters, starting in the mid 1930's. FMCW has a number of design advantages, including a high average power and short range capabilities. FMCW is unique in its ability to range targets extremely close to the radar transmit and receive antennas. The major disadvantage It makes a contribution towards the understanding of these spurioussignals by analyzing and simulating the effects of digital phase errors on the beat spectrum of a FCMW-Doppler radar employing a direct digital chirp synthesizer.

IV. BLOCK DIAGRAM

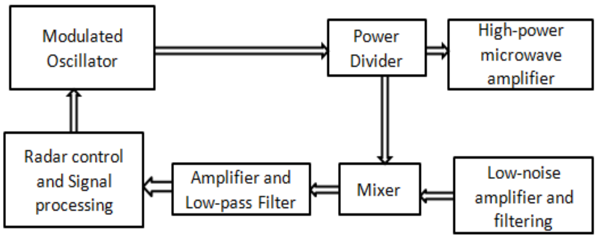

Fig.1: FMCW Radar

Principle of measurement:-

Characteristics of FMCW radar are:

The distance measurement is accomplished by comparing the frequency of the received signal to a reference (usually directly the transmission signal). The duration of the transmitted waveform T is substantially greater than the required receiving time for the installed distance measuring range. If the change in frequency is linear over a wide range, then the radar range can be determined by a simple frequency comparison. The frequency difference is proportional to the distance R. Since only the absolute amount of the difference frequency can be measured (negative numbers for frequency doesn't exist), the results are at a linearly increasing frequency equal to a frequency decreasing (in a static scenario: without Doppler effects). If the reflecting object has a radial speed with respect to the receiving antenna, then the echo signal gets a Doppler frequency (caused by the speed) measurement is performed with a sawtooth then the received echo signal is moved not only by the run time to the right, but also by the Doppler frequency down.

V. Theoretical Minimum Detection Range and Maximum SNR

The radar range equation is not derived from first princ ple, but it has been developed from several steps. The total peak power (watts) developed by the radar transmitter(P_t) is applied to the antenna system. Consider the antenna had an isotropic or omnidirectional radiation pattern (one that radiates energy equally in directions), the power density (P_0) (Watt per square meter) at a distance(R)(meter) from the radiating antenna would be the total power divided by the surface area of a sphere of radiuds(R).

$$P_D = \frac{Peak\ transmitted\ power}{Sphere\ area} \quad \frac{Watt}{m^2}$$

The power density at range(R) away from the radar:

$$P_D = \frac{P_t}{4\pi R^2}$$

Where (P_t) is the peak transmitted power and ($4\Pi R^2$) is area of sphere of radius (R). Radar system uses a directional antenna pattern in order to concentrate the power density in a certain direction, which is usually characterized by the gain (G) and the antenna effective aperture (A_e) they are related by:

$$A_e = \frac{G\lambda^2}{4\pi}$$

The antenna gain (G) is directly proportional to aperture, and the dimensions of an antenna depend on the gain (G) and wavelength (λ) . The higher the frequency, the smaller the antenna, or the higher is its gain by equal dimensions.

The relationship between the effective of antenna aperture (A_e) and the physical aperture (A) is

$$A_e = \rho A, \quad where \quad 0 \le \rho \le 1$$

ρ is indicated to aperture efficiency, when ρ=1 gain in transmitting is equal to receipting. When using a directive antenna of gain (G), then the power density is given by

$$P_D = \frac{P_t G}{4\pi R^2}$$

When the incident transmitted signal collide on the target, the signal will induce time varying currents on the target so that the target now becomes a source of radio waves, part of which will propagate return at the radar, the power reflected by the target toward the radar (P_r) is defined as the (RCS), which is symbolized (σ) of the target, and is given by

$$P_r = P_D \times \sigma$$

By substituting above equation, we get

$$P_r = \frac{P_t G \sigma}{4\pi R^2}$$

When the signal reflected from the target toward the radar systems over a distance(R), the power density (P_{Dr}) return at the radar is:

$$P_{Dr} = \frac{P_r}{4\pi R^2}$$

By substituting above equation, we get

$$P_{Dr} = \frac{P_t G \sigma}{(4\pi)^2 R^4}$$

The total power received (S) by antenna receiving of effective area of (A_e) from a target at range(R):

$$S = P_{Dr} \times A_e$$

From above equations, we get

$$S = \frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 R^4}$$

The received power (s), can be written in terms of signal-to-noise ratio (SNR), and thermal noise power (BFkT$_0$) where (k) is Boltzmann's constant and is equal to1.38 × 10^{23}, (T$_0$) is the noise temperature of the radar, (B) is the noise bandwidth of the radar receiver, and noise figure (F)

$$S_{\min} = kT_0 BF (SNR)_{0_{\min}}$$

From the above equations, we get

$$R_{\max} = \left[\frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 kT_0 BF (SNR)_{\min}} \right]^{1/4}$$

Or, equivalently

$$(SNR)_{\min} = \frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 kT_0 BFR^4}$$

Where, (S_{min}) SNR is the minimum detectable SNR of the system. It is an important relationship for radar designers. If greater detection range is desired, then significant improvements to antenna gain or transmitted power must be realized, and the other parameters are often fixed.

Doppler range:

The radar measures not only the difference frequency to the current frequency (caused by the runtime), but additional a Doppler frequency (caused by the speed). The radar then measures depending on the movement direction and the direction of the linear modulation only the sum or the difference between the difference frequencies as the carrier of the distance information, and of the Doppler frequency as a carrier of the velocity information. If the measurement is made during a falling edge of a saw tooth, then the Doppler frequency is subtracted of by the runtime frequency change. If the reflecting object is moving away from the radar, then the frequency of the echo signal is reduced by the Doppler frequency additionally.

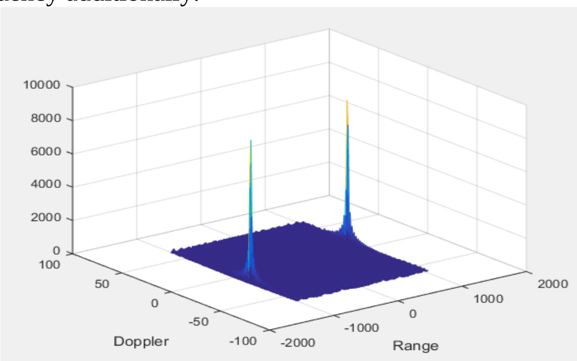

Fig.2: Doppler range

Design Realistic Patch Antenna:

The Antenna Toolbox has several antenna elements that could provide hemispherical coverage and resembles a pattern of cosine shape. Choose a patch antenna element with typical radiator dimensions. The patch length is approximately half-wavelength at 77 GHz and the width is 1.5 times the length to improving the bandwidth. The ground plane is λ on each side and the feed offset from centre in the direction of the patch length is about a quarter of the length.

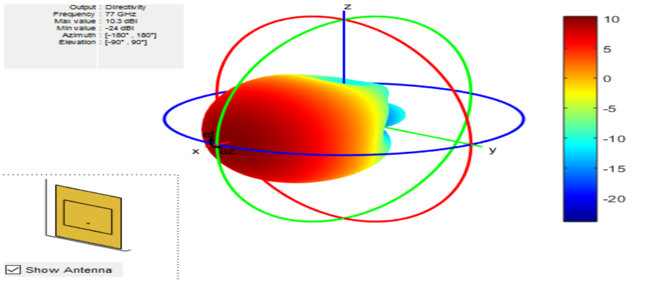

Fig.3: D pattern of patch antenna

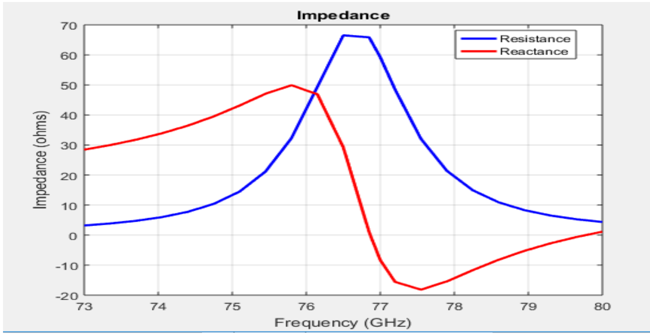

Fig5: Impedance behaviour

According to the figure, the patch antenna has its first resonance (parallel resonance) at 74 GHz. It is a common practice to shift this resonance to 77 GHz by scaling the length of the patch.

Create Array from Isolated Radiators and Plot Pattern:

Next, creates a uniform rectangular array (URA) with the patch antenna. The spacing is chosen to be $\lambda/2$, where λ is the wavelength at the upper frequency of the band (77.6 GHz)

The following figure shows the pattern of the resulting patch antenna array. The pattern is computed using a 5 degree separation in both azimuth and elevation.

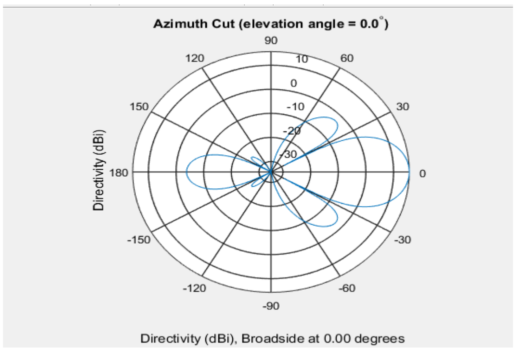

Fig.6: azimuth angle

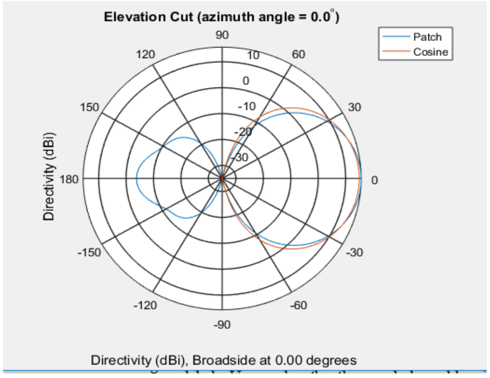

Fig.7: Elevation angle

The figures show that both arrays have similar pattern behavior around the main beam in the elevation plane (azimuth = 0 deg). The patch-element array has a significant backlobe as compared to the cosine-element array.

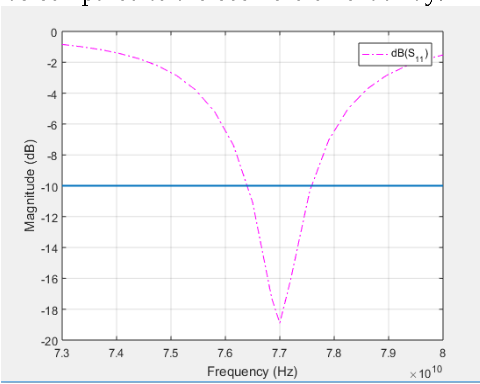

Fig.8: Frequency Plot

VI. RESULTS AND DISCUSSION

One of the main advantages of FMCW radars is their "homodyne" architecture and discussed Doppler radar, phase error correction. Hence, the design of antenna array for FMCW radar with an ideal cosine antenna and then uses a patch antenna to form the real array. It compares the patterns from the two arrays to show the design tradeoff. From the comparison, it can be seen that using the isolated patch element is a useful first step in understanding the effect that a realistic antenna element would have on the array pattern.

VII. REFERENCES

[1]. Adamski, M. E., K. S. Kulpa, et al. (2000). Effects of Transmitter Phase Noise on Signal Processing in FMCW Radar. Proc. International Conf. on Microwaves, Radar & Wireless Communications MIKON2000, Wroclaw, Poland.

[2]. Adler, E. D., E. A. Viveiros, et al. (1995). Direct digital synthesis applications for radar development. Radar Conference, 1995, Record of the IEEE 1995 International.

[3]. Beasley, P. D. L. (2006). The Influence of Transmitter Phase Noise on FMCW Radar Performance. Microwave Conference, 2006. 36th European.

[4]. Boashash, B. (1992). "Estimating and interpreting the instantaneous frequency of a signal. I. Fundamentals." Proceedings of the IEEE 80(4): 520-538.

[5]. ymans, A. J., Lait, J. (1960). "Analysis of a frequency-modulated continuous-wave ranging system." Proc. Inst. Elect. Eng. 107B: 365-372.