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Design and Simulation of Frequency Modulation Continuous Waveform (FMCW) For Automotive Radar Systems

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ABSTRACT-- *Safety in car driving has become essential with the use of various radar systems. In this paper we consider the design and simulation of Frequency Modulation Continuous Waveform (FMCW) for Automotive Radar Systems. Here the FMCW radar is demonstrated in SystemVue which generates saw tooth waveform, frequency sweep in 24GHz band. Target model and clutter are set accordingly. Measurements included in this work are saw tooth waveform generation, frequency Vs time transmitted waveform and received waveforms.*

Keywords--*Frequency Modulation Continuous Waveform (FMCW), Sawtooth Waveform, Range, Velocity*.

I. INTRODUCTION

It is irrefutable that, with the regular innovation and technology in the automobile industry, cars have turn out to be a central part of our daily lives. For the same, safety is the main concern to prevent losses or serious injuries for the public [1]. The world health organization (WHO) [2] showed that 1.25 million people die each year from road traffic accidents .To conquer these challenges, many measures are been taken by automobile companies to advance the active-safety systems in cars. Presently, it is a constant investigation, which needs novel and efficient system, which is generally obtained through research and development. The safety of these cars depends on the performance of multiple sensors including among others. For this reason, FMCW radar for its simple and best performance is used by automotive industry to assisting drivers.

II. PROBLEM FORMULATION

Automotive industry shows huge attention in autonomous driving systems. A whole sensors system is the key for the autonomous driving systems. Comparing to the automotive sensors, such as camera, laser etc., radar plays a vital role due to its intrinsic advantages [3]. Radar provides steady performance for night and raining environments. These can easily detect the mobility of the object i.e micro Doppler effect in radars. In accumulation, with emerging technology of silicon germanium (SiGe) technology [4-5], 24GHz automotive Radar are available with affordable price. Therefore, there is a strong growing demand on millimetre wave (mmW) Radar in automotive application. FMCW is the most frequently used system in automotive radar today. FMCW radar has ability to sweep wide RF bandwidth (GHz) though keeping IF bandwidth small (MHz) . This has also good range resolution[6].

III. FREQUENCY MODULATION CONTINUOUS WAVEFORM (FMCW)

A radar system always transmits and also receives either pulsed waveforms or continuous waveforms for the purpose of target detection, tracking and imaging. Such systems generally have electronics, antenna, control system and operators, as shown in FIG 1. On the bases of the waveform getting transmitted the radar systems can be categorized.

- A pulse radar will transmit pulse waveform signals with short duration at some given time interval. In these transmission intervals the target echoes are reduced. The distance or range of the targets can be calculated by measuring the delay between transmission and reception.
- A Continuous wave radar will simultaneously transmit the frequency and also receive the signals. CW radar is useful in Doppler and angle measurements but not used for range measurements and observation of multiple targets.
- Frequency modulation is required for the continuous wave radar, so that it can be used for range measurements. Since it has various applications, it is used in police speed radar, radar altimeter also as motion sensors in automobiles. Here, in this paper we concentrate on implementing Automotive FMCW Radar with low cost and low power.

FMCW radar transmits a continuous carrier modulated by a periodic function of sawtooth waveform to provide range data [7] in this paper[8].

IV. GENERATION OF SAW TOOTH WAVEFORM FOR FMCW RADAR

There are different modulation techniques that are used for generating a transmitted signal, the based on the system requirement. The modulated signal will make use of the architecture and it encodes a marker or time stamp that can be used for the synchronization. FMCW Radar is involved with phase or frequency modulation according to the information to transmit with phase or frequency career wave.

This is mainly utilized in traffic environment. It does the simulation of the

a) Transmitter effects like phase noise,
b) Propagation effects like Doppler shifts and radar range equation,
c) Receiver effects like thermal noise.

The positions of transmit and receive antennas are designed to provide a good angular resolution. It will avoid the High Peak to Average Peak Ratio in transmission (PAPR). It simplifies the narrow band IF processing that is it does a good performance with small size, light weight and low cost. It improves the noise floor and reduces RF inter modulation

4.1 Range estimate

$$\tau = \frac{2R}{C} = \frac{f_b T_s}{\Delta f} \quad (1)$$

$$R = \frac{f_b T_s C}{2\Delta f} \qquad (2)$$

The three common signals used in generating different modulating waveforms are: sawtooth modulation, triangular modulation and sinusoidal modulation.

In FMCW Radar the signal which is generated by the radar is divided into two portions. One is allowed to pass into the upper port of radar mixer which is used as the reference signal for detection of the echo signal and the other portion passes through the circulator and then into the antenna. The circulator is an electronic device with multi ports that allows electrical signals to propagate in the clockwise direction. Once the signal exits the antenna, it is propagated into air out to the target and reflected to the antenna, and then it goes back to circulator in the preferred direction and passes into the horizontal port of the antenna. The mixer multiplies echo signal and reference signal that has come into the upper port of the mixer. This gives the sum and difference of the frequencies. The signal that comes out of the mixer is called as beat frequency of the target echo. This is the process of generating the waveform in FMCW Radar.

V. SAWTOOTH MODULATION

It is the simplest modulation form of FMCW linear modulation. In this process, VCO frequency is swept in linearly increasing manner, resulting in linear increase in transmitted signal frequency. This type of increase in frequency is called up-chirp.

The transmitted signal is continuous, once it reaches the upper frequency it will wrap back towards the low frequency.

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5.1 system architecture

The FMCW signal generator in the transmitter does the frequency modulation and generates the transmit waveforms and generates the transmit waveforms, which is amplified and then transmitted into the air through transmitter antenna. The waves once hit the object are reflected towards the transmitted direction. The receiver antenna receives the reflected waves. These waves are processed by low noise amplifier followed by mixer. By mixing transmit and receive waveform signals, and down converts the frequency to baseband. Now the data is given to the software tool for further processing. The basic operation of FMCW radar is shown in Figure 1

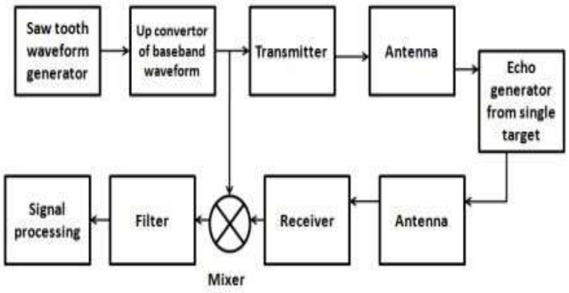

Figure 1. Block Diagram of FMCW radar

The transmitted signal is a saw tooth waveform up converted to 24GHz. The saw tooth waveform is generated with the parameters shown in Table1.

Table 1. Parameters of the saw tooth waveform generated

S.No	Parameter	Value
1	**Amplitude**	**1**
2	**Period**	**100e-6**
3	**Lower frequency**	**0**
4	**Delta frequency**	**200e6**
5	**Sampling rate**	**800e6**

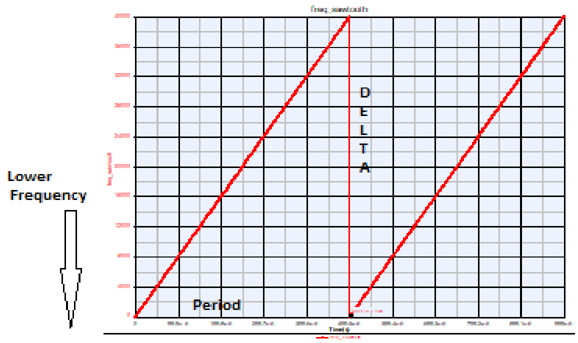

Figure 2. Generated Sawtooth Waveform

Up-conversion is realized by complex to Envelope Converter (CxToEnv). The CxToEnv converts the complex signal at *input* to a complex envelope signal at *output* using the characterization frequency which is set to 24 GHz. After up-conversion the signal is transmitted using a radar transmitting antenna. This antenna model supports two working models i.e. **search** and **tracking.** In this paper the antenna is used as search antenna with circular scan.

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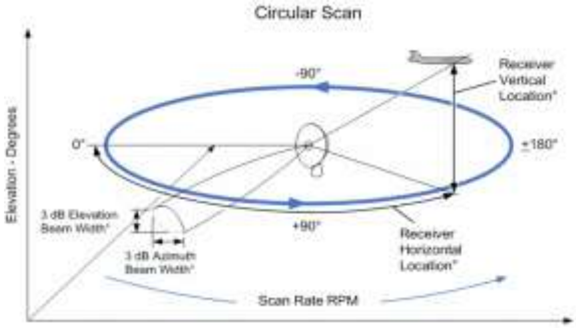

Figure 3. Circular Scan Antenna.

Table 2**.** The parameters of the antenna model

S.No	Parameter	Value
1	**Radar work model**	**Search**
2	**Pattern**	**Uniform**
3	**Antenna Width**	**1m**
4	**Antenna height**	**1m**
5	**Antenna Scan Rate**	**15rpm**
6	**Antenna Scan Pattern**	**Circular**
7	**Target Elevation Angle**	**0**
8	**Target Azimuth Angle**	**0**

In radar frame an object is located at 0 degrees azimuth and elevation angles. 15 rpm is set as scan rate when the antenna is at scan mode. The antenna is set in uniform illumination when it behaves like a sinc function. For example: if the target is behind the plane of antenna, its gain is set to be 0.

Echoes can be generated through radar generators. The quantity of propagation path is the product of number of transmitter platforms, the number of receiver platforms and the number of target scatters of all the targets.

In this paper we have considered the simplest case i.e. the number of radar transmit platform = 1, the number of radar receive platform =1, the number of target =1 and the number of scatters of this target is equal to 1. The amount of the propagation paths is also 1. The parameter System Loss is used to set the overall system losses and here it is zero.

VI. SIMULATION RESULTS

Since maximum number of the systems is being used in automotive radars, hence FMCW radar is more focused one. In heavy traffic conditions very appropriate calculation is necessary, so here automotive FMCCW radar is used. It is also used in smart robots for driverless cars and assistant system for drivers. Once all the designs of the radar systems are set up properly, then desktop simulation is done under proper testing conditions. The simulated design is used in real time measurements for further verification when running this simulation spectrum of transmitted and received signals.

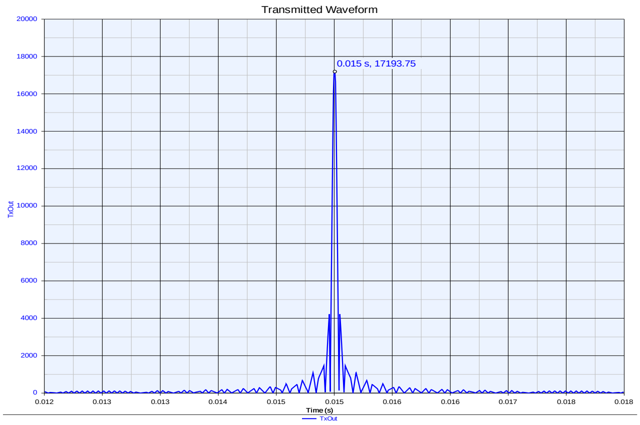

Figure 4. Time Domain Representation of Transmitted Waveform

Finally, to complete the verification, real measurements were performed using the simulated design.

A graph of time vs. amplitude of the signals transmitted will show the performance of the transmitter antenna. The transmitter is swept over the range the nby studying the transmitted amplitude this is the basic theory which is used to check out the transmitter performance. The output peak amplitude at the receiving antenna is 42.86e-6 at 0.015s. The loss in the signal strength confirms the presence of target and loss in the signal from transmitting to receiving antennas of this system had a peak power level of -40 dBm at 1 MHz.

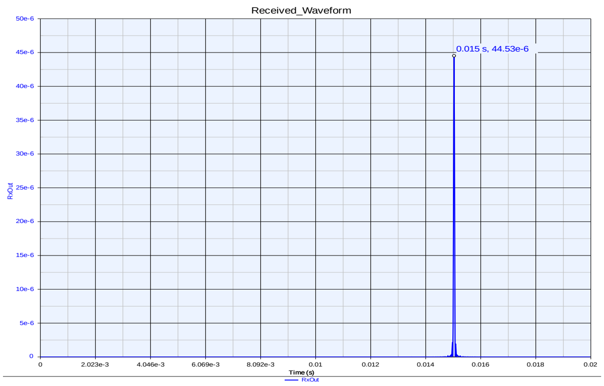

Figure 5. Time Domain Representation of Received signal

VII. CONCLUSIONS

This paper addresses the general analysis of FMCW radar in single target scenario. Specifically, it discusses signal propagation in media encountered one target, signal scattering from target using search .Understanding these basic parameters provides general insight of a FMCW radar possible performance and operation and allows its general analysis to be conducted, which are essential toward the design of radars in automotive systems for sensing applications. The saw tooth waveform provided a way to measure distance. The measurement result is encoded as a frequency in the baseband output.

VIII. ACKNOWLEDGMENTS

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