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Implementation of Adaptive 24 GHz Doppler radar

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ABSTRACT

Doppler Radar which has got various applications in fields like weather forecasting, check speeding violations of vehicles, in air traffic control radar to detect incoming and out coming aircrafts, discover new planets and stars and also in medical application to measure heartbeat, blood pressure etc. The same may be advanced in order to measure the Doppler caused by rain so that rain effect can be nullified further in application like DTH where rain attenuation is still a burning issue. In this paper, the methods of low Doppler extraction and mitigation of same in the form of Radio Frequency adaption in accordance to the extracted Doppler is explained with viable algorithms and results.

Keywords:
24GHz, adaptive, Doppler radar, millimeter wave, Voltage Controlled Oscillator, Labview

1. INTRODUCTION

Continuous wave (CW) radar uses Doppler phenomenon to calculate radial velocity of a moving target also distinguishes between moving and stationary targets or objects such as clutter [1]. In Doppler phenomenon the center frequency of an incident waveform is shifted due to the motion of the with respect to the source of radiation. This change in frequency of a wave caused by the relative motion between the source and the observer is called Doppler Effect. The shift in frequency may be positive or negative depending on the direction of the motion, the frequency increases when the target moves nearer to the observer, and the frequency decreases when it moves away from the observer.

Microwave sensor radars are applicable to calculate the distance and velocity of a detected object. The operating frequency of the radar determines the Doppler resolution; higher the frequency, better is the resolution and smaller the size of the sensor [2]. Radars are being used for long range forecasting of southwest monsoon rainfall over India using Ensemble Linear Multiple Regression (EMR) and Projection Pursuit Regression (PPR) [3]. Radar validation is used for surface rainfall intensity which is more accurate because radar measurement is totally based upon reflectivity factor and the surface instrument observations [4]. Doppler radar application can also be implemented using FFT in FPGA. Heart rate detection accuracy can be generated using stepped frequency continuous wave in FPGA [5]-[6]. Doppler radar can also be used for human subject detection by exploring the different physical characteristics of human being which can further be helpful for disaster management system for search and rescue operation [7],[8], [9].

2. MATHEMATICAL MODELLING

Consider for a Doppler radar, the target is at a distance d having velocity v and Δt is the time interval during which the target moves into the pulse. Then [1]

$d = v\,\Delta t$

It takes the leading edge of pulse 2 seconds to travel a distance to strike the target. Over the same time interval, the leading edge of pulse 1 travels the same distance.

$$\frac{c}{f_r} - d = c\Delta t \qquad (1)$$

$$\Delta t = \frac{c/f_r}{c+v} \qquad (2)$$

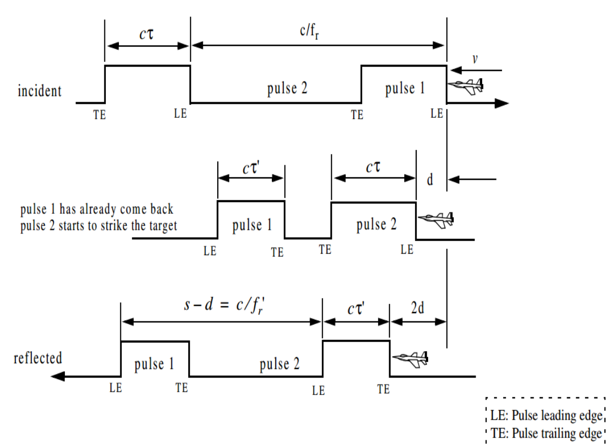

Figure 1. Effect of target motion on the radar waveforms [1].

The Doppler frequency f_d can be deduces as,

$$f_d = \frac{2v}{\lambda} \qquad (3)$$

Figure 2 represents the block diagram of a typical Doppler radar.

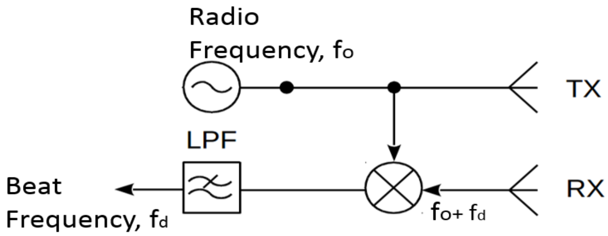

Figure 2. Block Diagram of Doppler radar

There are different methods that can be used to extract the target Doppler [10],[11],[12] and the simpler method is the use of Fast Fourier transform (FFT).

$$X(k) = \sum_{n=0}^{N-1} x(n) \cdot e^{-j\left(\frac{2\pi}{N}\right)nk} \quad (4)$$

Here, k = 0, 1…N-1. The FFT is the fastest method of finding the Discrete Fourier transform (DFT). A complicated signal can be broken down into simple waves. In Fourier transforms, a signal is analyzed in terms of the frequencies of the waves for the analyzed signal [5].

As discussed earlier that one of the application of Doppler radar may be in extraction of rain Doppler which is a burning problem in DTH systems and act as interferer. So in such situation if the Doppler due to rain can be detected and as a measure the interferer can be avoided by switching over to a different Radio frequency, the "No signal" problem may be eradicated or in other words the interferer can be fooled. Therefore in this paper, the same adjustment is done by generating a low RF (as a substitute) indicating the adjustment in the RF as just proposed solution to rain attenuation.

3. Doppler Radar Simulation

The Doppler radar is first simulated in LabView software platform which allows the virtual implementation of the hardware components on a software platform.

In the simulation, a Doppler of 50 Hz is being created. And figure 3 depicts the extracted Doppler. After the simulation validation, Doppler through actual hardware is being considered as described in the following section [13].

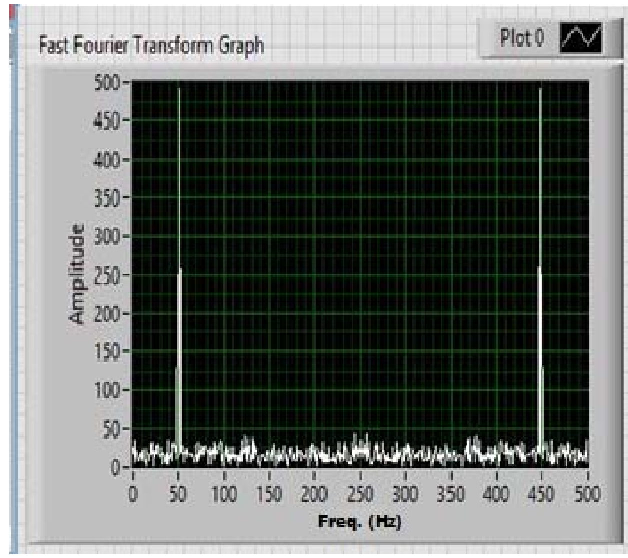

Figure 3. LabView Front Panel Doppler extracted signal

4. Hardware Result

The Hardware (in figure 4) consists of the following setup:

1. 24 GHz continuous wave radar transceiver.
2. Doppler effect creation by using a rotating fan
3. The beat frequency is acquired using NI USB 6009 Data Acquisition Card in LabVIEW followed by FFT processing.
4. The actual RPM of the rotating fan is measured using Stroboscope.

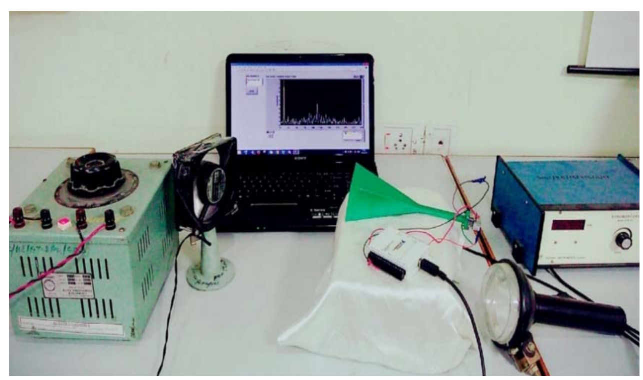

Figure 4. Hardware setup

Table 1 depicts the different values of Doppler extracted by the doppler radar by varying the rotation speed of the fan which acts as moving target and figure 5 implies the doppler frequency at a particular doppler instant.

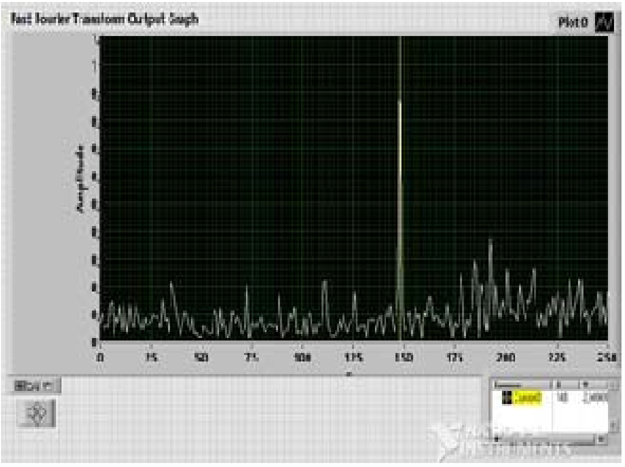

Figure 5. FFT of real time signal and faster signal

Table 1. Measured RPM and the respective Doppler shifts

Rotations per minute(RPM)	Velocity (m/s)	Doppler Shift at 24GHz C.F (Hz)
591	3.52	283.56
521	3.10	249.72
499	2.977	239.25
482	2.87	231.19
451	2.69	216.69
335	1.99	160.31
284	1.69	136.14

The next step is the addition of the remedy to the Doppler caused by the moving target. Thus, a voltage-controlled oscillator (VCO) is being designed whose voltage is varied in accordance to the Doppler that is being extracted. Figure 6 represents the VCO circuit that is being considered. The pin 5 of 555 timer is voltage control terminal and its function are to control the threshold and trigger levels. Therefore, the control signal is passed through pin 5.

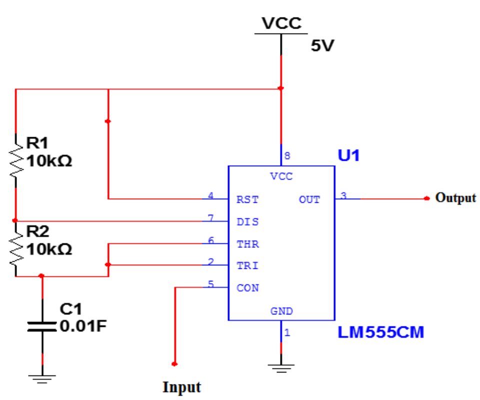

Figure 6. Circuit for VCO using 555 Timer

The final circuit with the addition of the VCO is shown in figure 7. The NI USB 6009 data card is used to acquire doppler data and send the control signal to the VCO after the decision making. The NI card also acquires the signal generated by the VCO and displays for further verification.

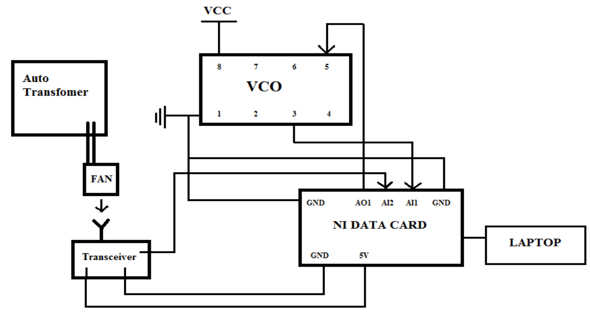

Figure 7. Block Diagram of Doppler radar with VCO

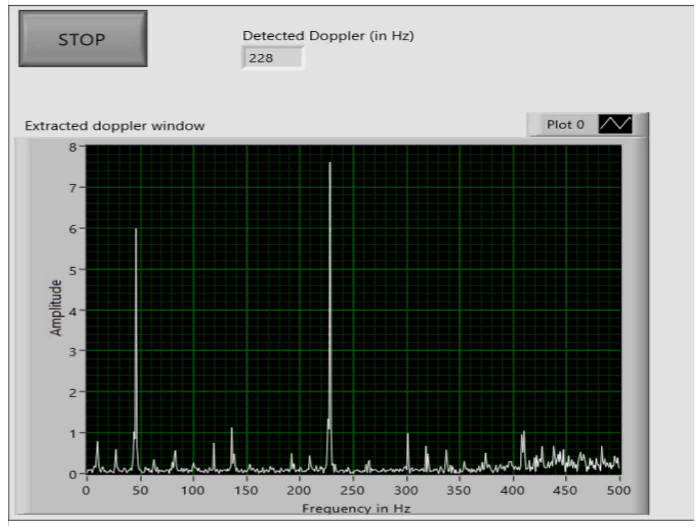

Figure 8. Extracted Doppler Waveform

Figure 9. The Complete Setup

Here for simplicity, if the Detected Doppler is more than the Reference Doppler then the green light is turned on otherwise it remains off. In figure 8, the extracted Doppler value is 228 Hz which happens to be more than the reference Doppler therefore as indicator, the green LED in figure 10 is glowing and the corresponding RF is generated by the VCO and the generated VCO signal is displayed in the LabView display (figure 10).

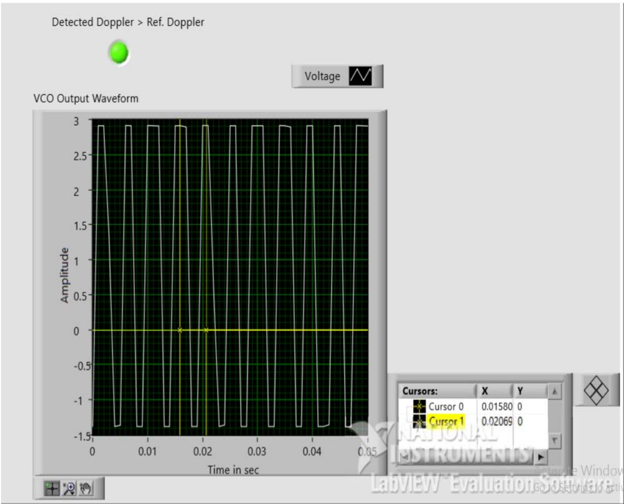

Figure 10.VCO Output Waveform

5. Conclusion

This paper involves development of 24 GHz Doppler radar using simple fft method which has its own cognition to avoid further Doppler Effect by switching to a rather lower RF where the effect of the Doppler is much less than the previous condition. The same radar can be used for a non-contact monitoring of heart rate and respiratory activity, as vehicular radar where the radar can easily switch over to a new RF if there is any co-channel interference.

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