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Evaluation of two Doppler radar systems for proximity sensing

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Preface

First and foremost, we would like to express my heartfelt gratitude to my supervisor, Per Ängskog and examiner Jose Chilo, who give us considerable help to complete this thesis. Second I would like to thank all of our college teachers who have enlarged my knowledge and horizon during my studying.

Abstract

Most of Doppler Radar systems are expensive to build and hard to take out for the testing.Therefore a portable and easy building Doppler Radar system has been implemented in recent years.For this thesis two Doppler radar systems which working in different frequency ranges (24 GHz and 2.4 GHz) shall be implemented with evaluating the possibilities regarding proximity sensing based on radar technology. There are two designs including. One is based on an 'all-in-one' chip from RF-beam Microwave and the other is based on components from Mini-Circuits.Those Radar kit were developed by using a frequency modulated continuous wave(FMCW) architecture.

The radar works in three different modes:Doppler Time Intensity testing,Range Time Intensity and Synthetic Aperture Radar imaging.The whole system work with Matlab by recording the data.Doppler time intensity (DTI) plots with Doppler spectrum of passing vehicles and range-time intensity(RTI) plots with measuring the moving target versus time will be discussed.Synthetic Aperture Radar(SAR) image of urban terrain is acquired.

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1 Introduction

In this chapter,a brief introduction of thesis will be given by list the background of Doppler Radar ,the purpose and goal of thesis is discussed.Also the method and process for solving the problem is mentioned.

1.1 Background

Doppler radar was developed and put into used successful in 1960s because of the heavy hardware fall into disuse.Another reason is by using Doppler radar would improves the range performance while reducing power.After that Doppler radars were widely used in navigation aid area and spacecraft.One representative example was the Green Satin radar which used in the English Electric Canberra.The advantage of this system was allowed one single antenna to be used for transmitting and recording at the one time by using a low repetition rate pulse.[1]Doppler radar is a particular radar system which makes by using of the Doppler effect theory to measure velocity based on objects at a distance.[2]It means when sending a signal towards a target and analyzing how changes of frequency of the returned signal according to the motion of object.The variation shows the speed of the object accurately.However Doppler radar has their limitations in applications.For example when the radar works in speed testing,ranging distance and weather detection its required higher maintenance to keep the sensitivity stable.In this regarding it is necessary to make a easy build and portable Doppler radar system with low cost.

1.2 Purpose and Goal of Thesis

Since the construction of most of the radar system requires a large cost. Therefore the purpose of this thesis is to build two low-cost Doppler radar systems in different ranges(24 GHz and 2.4 GHz). One is based on an 'all-in-one' chip from RF-beam Microwave and the other is based on components from Mini-Circuits.The mainly work is to evaluate two Doppler radar systems for proximity sensing with Bench-marking,ranging test and synthetic aperture radar imaging.The radar kit is an S-band FMCW radar with 2.4GHz center frequency and using max 20mW in transmit power.The antennas are made by cans and all components are set up on a 20cm*15cm wooden board.The analog signal chain is implemented on a solder-less board for fast fabrication and easy modification.The video output and transmit port are fed into left and right audio input channels of a computer for the digitization.The radar system work with eight AA batteries.

The radar operates in three modes:Doppler,ranging, and SAR imaging.To record data with computer and annalize it with MATLAB.Doppler time intensity (DTI) plots with Doppler spectrum of passing vehicles and range-time intensity(RTI) plots with measuring the moving target versus time will be discussed.SAR image of urban terrain is acquired.

1.3 Outline

This thesis presents the designs and implements of Doppler radar evaluation and approximately sensing.Later on the Doppler Time Intensity(DTI) plots,Range Time Intensity(RTI) and Synthetic Aperture Radar(SAR) imaging have been successfully implemented .

The Outline of this report is organized as follows:

Chapter 2: Theory An brief introduction to the basic Radar theory which related to the project work is given in this chapter.A description of Doppler Radar system and Synthetic Aperture Radar is given in the chapter.

Chapter 3: Design and Results A detailed description of two different range Doppler Radar systems building and function verifying of designs.Doppler Time Intensity(DTI),Range Time Intensity(RTI) and Synthetic Aperture Radar(SAR) plots have been implemented in this chapter.

Chapter 4: Discussion and Conclusions Give a short discussion which the thesis can be improved in the future work and Summarize the project work with giving a conclusion of this project.

2 Theory

In this chapter the literature study of radar system will be discussed.The chapter starts with the basic principles of radar,later on the Doppler effect and Doppler radar will be introduced.

2.1 Radar principles

The word “radar” became an acronym, RADAR, for “radio detection and ranging.” Thus radar is also referred to as “radio positioning” by using radio communication system to locate the spatial position of the target.

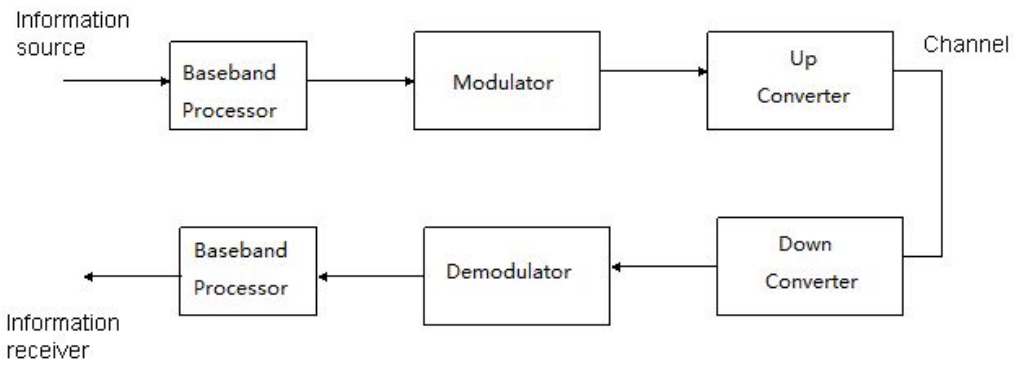


Figure.1 Block diagram of simplified radio communication system[3]

Some authors written have about radar performance like above.A simplified radio communication system is essentially described according to Figure.1.The transmission part including a base-band and a modulator which are mainly filtering of the input signal by adjusting the bandwidth to the required level and digitalize the signal by using analog-to-digital conversion.In the second stage of transmission part is a Up-converter which is using to translate signal to required frequency and a power amplifier that pumps up the modulated signal in a desired level through antenna[3].At the receiving part the signal that through wave propagation is received by the antenna.Received signal is down-converted ,demodulated and filtered to the original signal through the output chain.

2.1.1 Radar equation

Some authors have written about radar theory: suppose in a radio communication system the transmitter transmits a large pulse with a peak power of “ Pt ” watts, a width of “ τ ” seconds,and a wavelength of “ λ ” meters.The pulse is radiated by the antenna and the pulse travels to the object at a range “ R ” meters.The power density that reaching the object is shown as below[4]:

$$Pd = \frac{PtGt}{4\pi R^2}(W/m^2) \tag{2.9}$$

The object has a scattering area of “ σ ” square meters.The power is scattered equally in all directions so that the power density returning to the radar is:

$$P_{dr} = \frac{PtGt}{4\pi R^2}\frac{\sigma}{4\pi R^2}(W/m^2) \tag{2.10}$$

The antenna gain measured with wavelength as shown below:

$$G = \frac{4\pi E_f}{\lambda^2} \tag{2.11}$$

The receiving power Pr is given by the equation[10]:

$$\Pr = \frac{PtGtAr\sigma F^4}{(4\pi)^2 R^4} \tag{2.8}$$

Where

Pt is transmitter power;

Gt is gain of the transmitting antenna;

Ar is effective aperture(area) of the receiving antenna;

σ is radar cross section(scattering coefficient);

F is pattern propagation factor;

Rt is distance between transmitter and target;

Rr is distance between target and receiver;

The receiver bandwidth is taken to be the reciprocal of the transmitter pulse width "τ" seconds,Thus the signal-to-noise ratio at the receiver is:

$$SNR = \frac{PtGt}{4\pi R^2}\frac{\sigma}{4\pi R^2}\frac{Gr\lambda^2}{4\pi}\frac{\tau}{kT} = \frac{Pt\tau GtGr\lambda^2\sigma}{(4\pi)^3 R^4 kT} \quad (2.12)$$

relative velocity between the radar and the moving target[6].

2.2 The basics of Doppler effect

The Doppler effect is the frequency change between a relative movement of the wave source and the observer.Generally when a train driving towards to the observer with fast speed,the sounds of the whistle becomes shrill whistle(i.e. the frequency becomes higher, the wavelength becomes shorter).And in the same situation the observer heard whistle becomes muffed while the train is leaving from him(i.e. the frequency becomes lower, the wavelength becomes longer).

It can be represent as below:

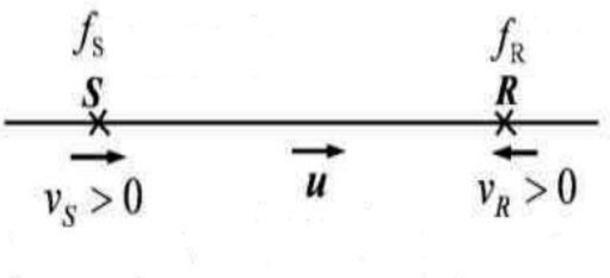


Figure.1 Frequency and velocity between source and observer

Where

f_S is the frequency of source;

f_R is the frequency of observer;

f_W is the frequency of full-wave.

v_S is the velocity of source;

v_R is the velocity of observer;

u is the velocity of full-wave;

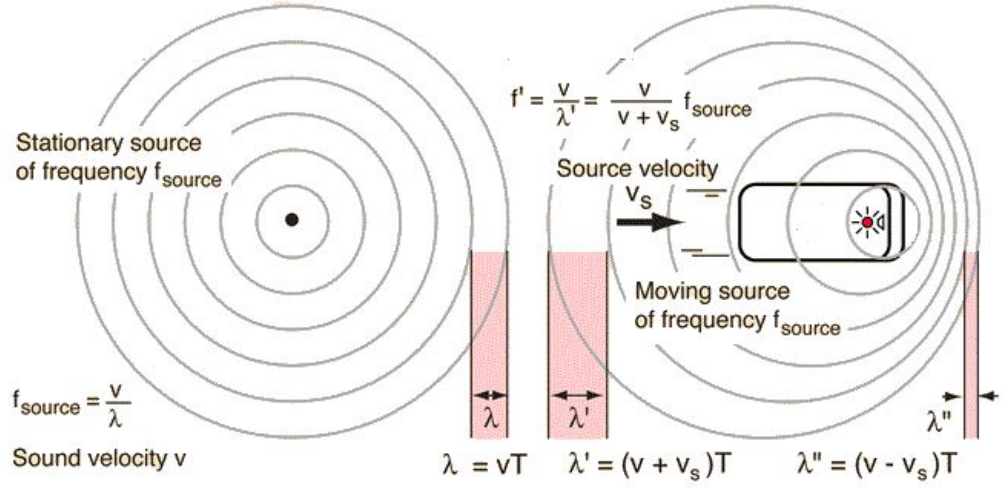


Figure.2 Analyzing two different situations with v_s =0 and v_R =0 respectively[7]

As shown above the received frequency of observer equal to the numbers of full-wave in unit time. Suppose the wave passes through the observer with velocity 'v' then the numbers of full-wave in 't' time unit will be $N = vt/\lambda$.Therefore the numbers of full-wave that passing through the observer in unit time will be $f = v/\lambda$.

There are four situations to explain Doppler effect in detail by discussing the speed of observer and source which are shown as below:[7]

1) Observer and source are relatively static($v_s = 0, v_R = 0$):

$$f_R = u/\lambda = fs. \tag{2.1}$$

2) Source is static but observer moving with speed 'v_R' relative to the wave source:($vs = 0, v_R \neq 0$):

$$\begin{aligned} f_R &= u + V_R/\lambda = u + v_R/(u/f_W) = (1 + v_R/u) f_W, \\ f_W &= fs, f_R = (1 + v_R/u) fs \end{aligned} \tag{2.2}$$

The frequency of observer is larger than the source frequency.

3) Observer is static but source moving with speed ‘ v_s ’ relative to the observer:($v_s \neq 0, v_R = 0$):

$$\lambda = uT_s - v_sT_s = u - v_s / f_s, \quad f_R = f_W = u / \lambda = [1/1-(v_s/u)]f_s \tag{2.3}$$

The frequency of observer increase.

4) Both observer and source have speed ‘ v_s ’, ‘ v_R ’ where ($v_s \neq 0, v_R \neq 0$):

$$f_W = [1/(1-v_s/u)]f_s, \quad f_R = (1+v_R/u)f_W, \quad f_R = [(1+v_R/u)/(1-v_s/u)]fs \tag{2.4}$$

The frequency of observer is much larger than the frequency of full-wave.

2.2.1 Survey of Doppler radar

Doppler radar is a specialized radar which by using Doppler effect for positioning target,test velocity and ranging distance [8]. When radar transmits a fixed frequency pulse to the moving target there is a variation(shift) between transmit wave frequency and received wave frequency.This deviation is called Doppler frequency.Depending on the value of Doppler frequency,the relative speed between radar and target can be measured.According to the time difference between the transmitted pulse and received, the distance of target can be estimated simultaneously.Meanwhile distinguishing the target signal from strong clutter is easy to accomplish by checking the Doppler frequency spectrum.

Suppose the range to the target is “ R ”,then the total number of wavelengths “ λ ” in the two-way path from radar to target and return is “ $2R/\lambda$ ”.Each wavelength corresponds to a phase change of “ 2π ” radians.So the total phase change in two-way propagation path can be represented as below[9]:

$$\phi = 2\pi \times \frac{2R}{\lambda} = 4\pi R / \lambda \qquad (2.5)$$

If the target is in motion relative to the radar, " R " is changing and so will the phase.Differentiating the formula with respect to time gives the rate of change of phase,which is the angular frequency:

$$\omega_d = \frac{d\phi}{dt} = \frac{4\pi}{\lambda}\frac{dR}{dt} = \frac{4\pi v_r}{\lambda} = 2\pi f_d \qquad (2.6)$$

Where $v_r = dR / dt$ is the radial velocity(meters/second),or rate of change of range with time.If the angle between the target's velocity vector and the radar line of sight to the target is " θ ",then $v_r = v\cos\theta$,where " v " is the speed.The rate of change of " ϕ " with time is the angular frequency $\omega_d = 2\pi f_d$,where " f_d " is the Doppler frequency shift.Thus the equation can be written as

$$f_d = \frac{2v_r}{\lambda} = \frac{2 f_t v_r}{c} \qquad (2.6)$$

2.2.2 Simple Continues wave Doppler Radar

Other authors have mentioned the different from a pulse radar,a CW radar transmits while it receives.Without the Doppler shift produced by the movement of the target,the weak CW echo signal would not be detected in the presence of the much stronger signal from the transmitter[10].Filtering in the frequency domain is used to separate the weak Doppler-shifted echo signal from the strong transmitter signal in a CW radar system.The transmitter generates a continuous sinusoidal oscillation at frequency which is radiated by antenna later.On reflection by a moving target,the transmitted signal is shifted by the Doppler effect by an certain amount "$\pm f_d$".The plus sign applies when the distance between radar and target is decreasing.Thus the echo signal from a closing target has a larger frequency than that which was transmitted.The minus sign applies when the distance is increasing.To utilize the Doppler frequency shift a radar must be able to recognize that the received echo signal has a frequency different from that which was transmitted.The transmitter leakage signal acts as a reference to determine that a frequency change has happened.The detector multiplies the echo signal at a frequency with transmitter leakage signal "ft".The Doppler filter allows the difference frequency from the detector to pass and rejects the higher frequencies[11].

2.2.3 Pulse Doppler Radar

Pulse Doppler radar is different from CW Doppler radar which means it cannot simply convert the CW radar to a pulse radar by turning the CW oscillator on and off to generate pluses.Generating pulses in this manner also removes the reference signal at receiver,which is needed to recognize that a Doppler frequency shift has occurred.Therefore as shown in Figure 4 the output of a stable CW oscillator i amplified by a high-power amplifier.The amplifier is turned on and off to generate a series of high-power pulses.The received echo signal is mixed with the output of the CW oscillator which acts as a coherent reference to allow recognition of any change in the received echo-signal frequency.By coherent is meant that the phase of the transmitted pulse is preserved in the reference signal.The change in frequency is detected by the Doppler filter[11].

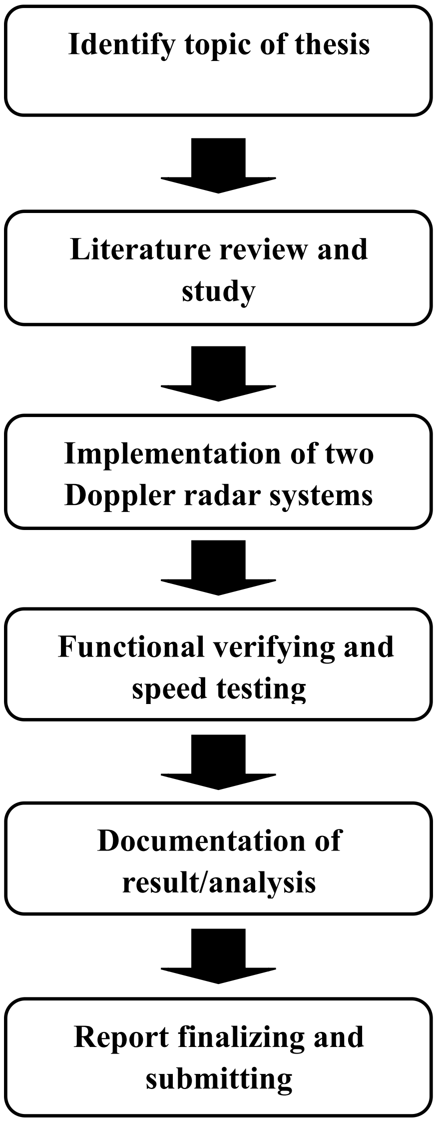
2.2.4 Synthetic aperture radar(SAR)

Many authors have mentioned about synthetic aperture radar(SAR) produces a high-resolution image,or map,of a scene by synthesizing in its processor the equivalent of a large antenna to obtain good resolution in the cross-range direction.High resolution in the range direction is obtained by either a short pulse or pulse compression.A good SAR might have a resolution in range and cross-range of one meter,but it can be much less if desired.A SAR i more complex than normal radar,but it produces much higher resolution images.Meanwhile a conventional SAR is normally designed to image stationary objects.Moving targets are smeared,distorted,and misplaced when seen by a SAR.Moving targets can be detected with SAR if they have a Doppler frequency shift greater than the spectral bandwidth of the stationary ground clutter echo(Clutter in this case is the desired signal for a SAR).This technique has been limited, however ,because it needs a PRF high enough to avoid Doppler fold-over of echo signals.A high PRF,on the other hand,might give rise to range ambiguities.This method for extracting moving targets with a SAR might not be able to detect moving targets with low radial speed[11].

3 Process and Result

This chapter includes the architecture diagram of building two different frequency Doppler Radar systems and its functional testing.

3.1 Flow Chart



3.2 2.4GHz Can System

A low cost Doppler can radar system was implemented by using simple stuffs as using the cans for antennas,and mounting the video amplifier and the radio frequency part on a wooden board.As we can see from the block diagram shown as below,the whole radar was a FMCW system and divided into three parts:The Antenna Part,The Video Amp part and the RF part.The transmit signal was modulated through the modulator and got oscillation in the left channel with a 3dB attenuator.This lead the transmit power was approximately 10mW(13dBm).At the receiver side the received signal was amplified with a low-noise amplifier which is connected with a mixer between transmission and receiving.After comparing the derivation between transmitted signal and received signal the mixed signal was amplified by the Video Amp part to the right channel with 20KHz bandwidth.This radar system operates in ISM band of 2.4GHz with 1km maximin range for 10dBm theoretically.

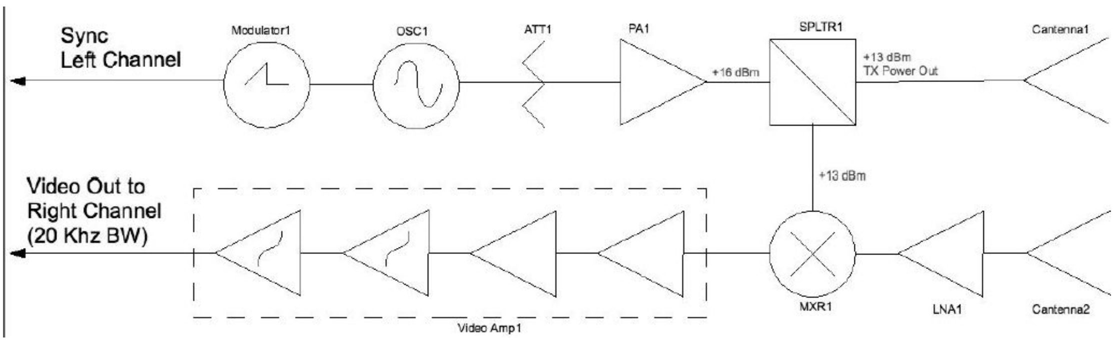


Figure.4 Block diagram of 2.4GHz radar kit

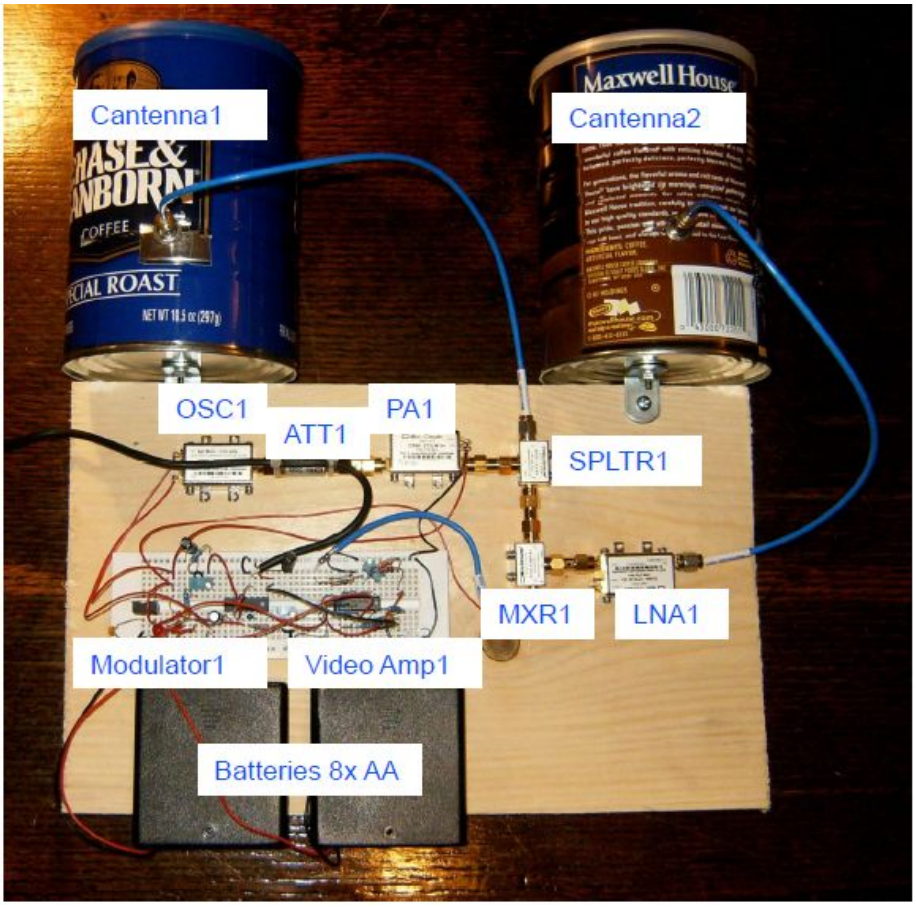


Figure.5 Block diagram of 2.4GHz radar system in practical[10]

3.2.1 Video Amplifier and Modulator Part

The video amplifier uses a quad low-noise op-amp which the DC precision of it eliminates trims in most systems while providing high frequency performance.The quad op-amp MAX414 was single supplied by 5V and 12V but its only required 2.7mA of quiescent supply current per amplifier.It followed by a 4th order 15kHz anti-aliasing filter and the output was fed into the right channel of the laptop audio input.The schematic of modulator and video amplifier is shown as below:

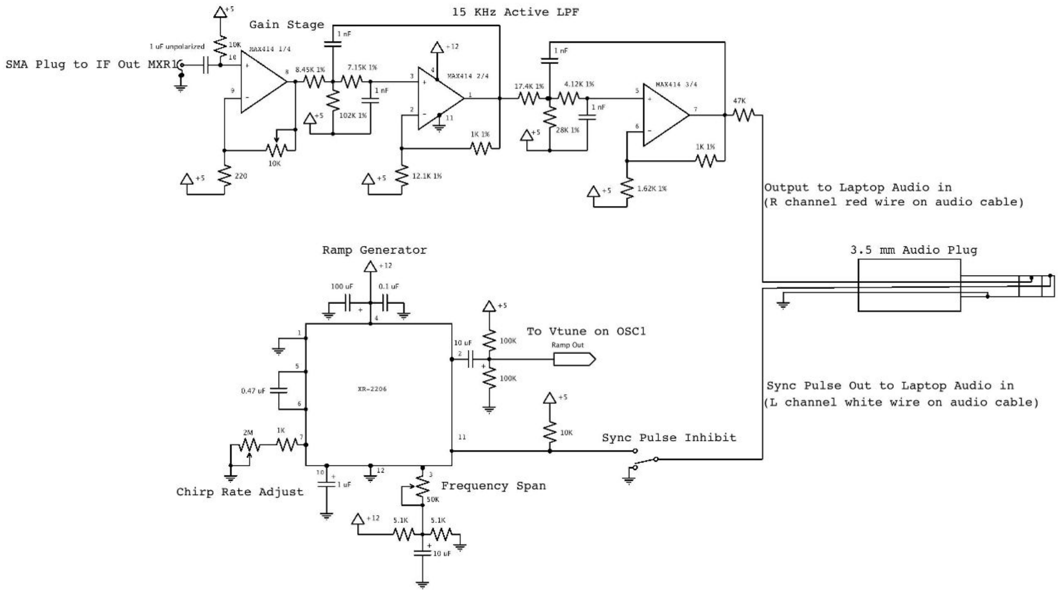


Figure.6 Schematics of video amplifier and modulator

The XR-2206 is a monolithic function generator that integrated circuit capable of producing high quality sine,square and ramp pulse with high-stability and accuracy[10]. In this radar system the 20ms up-ramp time and 2.4V magnitude were used for ISM band chirp.

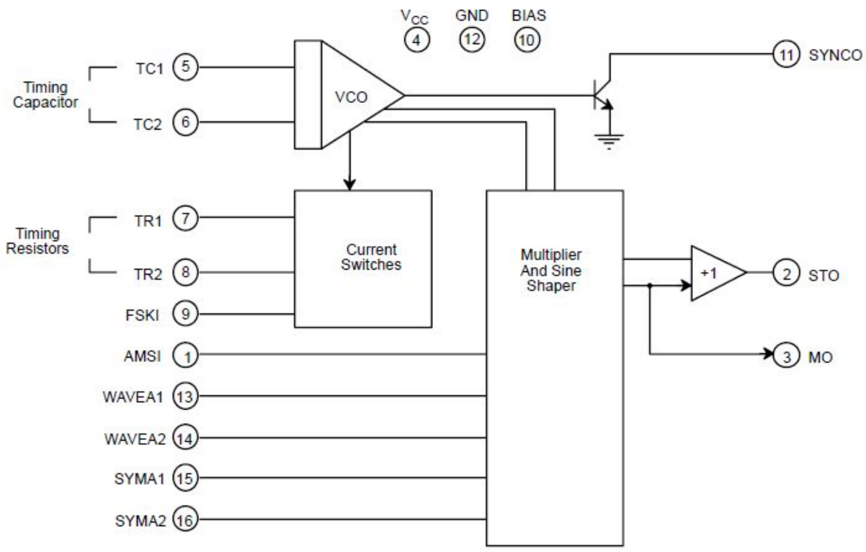


Figure.7 Block diagram of XR-2206 regulator[12]

Eight AA batteries(1.5V per each battery) power the radar kit system which providing a 5-volts voltage for the microwave modules and 12-volts for the modulator by using the LM2490C regulator as shown below:

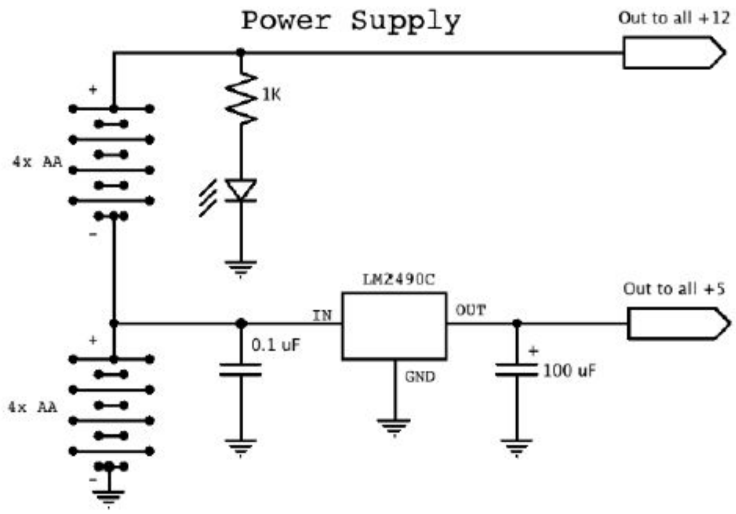


Figure.8 Schematic of Power supply

3.2.2 Modular System RF Design

The RF part is consisting of a voltage controlled oscillator,3dB attenuator,a--mplifier,splitter and the mixer.In the transmit chain the signal is acquired went through the voltage controlled oscillator to get a steady DC voltage with 6dBm RF power.By the action of the attenuator and amplifier the power of signal was changed to 16.7dBm at the end of transmission line.At the receive chain the signal was received by the can antenna with the power of approximately -36.6dBm.With the adjustment of low noise amplifier and mixer the IF power became -28.1dBm with some leakage.Mixer was used for copy the transmitted signal with the received waveform to get the DC level signal at last.The complete RF chain is shown as below:

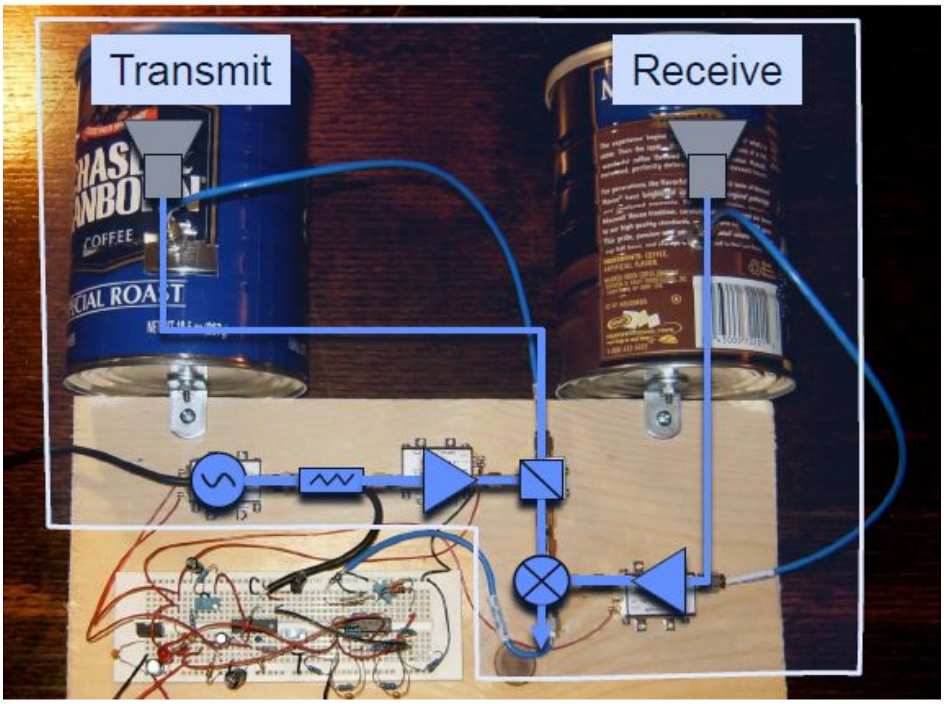


Figure.9 Block diagram for the RF chain[10]

3.2.3 Metal Can Antenna Design

There were two separate antennas used for transmit and receiver to reduce the transmit -to-receive mutual coupling.A simple metal can antenna acting as an opened circular waveguide due to its low cost,easy to build and nice performance in terms of reflection coefficient ,gain,and the beam-width.From the wavelength equation "$\lambda = \frac{c}{f}$" the free space wavelength can be calculated easily with the value of 12.4cm at 2.4GHz.Meanwhile the monopole wire probe is set up into the can as the length of one quarter of the guide wavelength from the bottom of the can. Through analysis and calculation the demission of can antenna is :

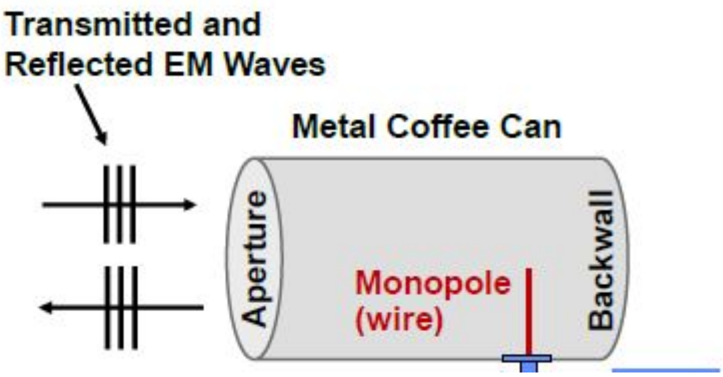


Figure.10 Dimension of can antenna

Metal can length:13.3cm(11cm used in this system);

Metal can diameter:10cm(9.7cm used in this system);

Monopole wire length :3cm(2.6cm used in this system);

Spacing from monopole wire to the bottom:4.6cm(3.9cm used in this system);

3.3 24GHz Chip Radar System

In the second part a 24GHz RF-beam microwave system was introduced.As a low cost Doppler devices which contains a 24GHz K-band miniature transceiver and a RF-beam ST-100 starter-kit chip.The typical application for this system are detecting the purpose movement,security guard protection,object ranging detection and testing the velocity.

3.3.1 K-LC1a Radar Transceiver

K-LC1a is a 8 patch Doppler module with an asymmetrical beam for low-cost short distance applications.Its mainly work in the movement sensors and automatic door domain.The module is extremely small and lightweight with the IF bandwidth from DC level to 50MHz.Due to the unique RF-beam oscillator design its allowed to use for ranging measurement[12].The block diagram and a picture of K-LC1a are shown as below:

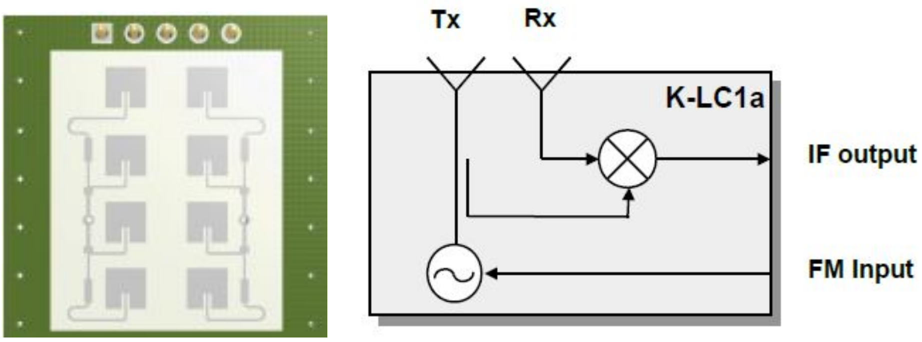


Figure.11 Block diagram of K-LC1a and its actual size[13]

The diagram below shows module sensitivity in both azimuth and elevation directions. It incorporates therefore the transmitter and receiver antenna characteristics[13].

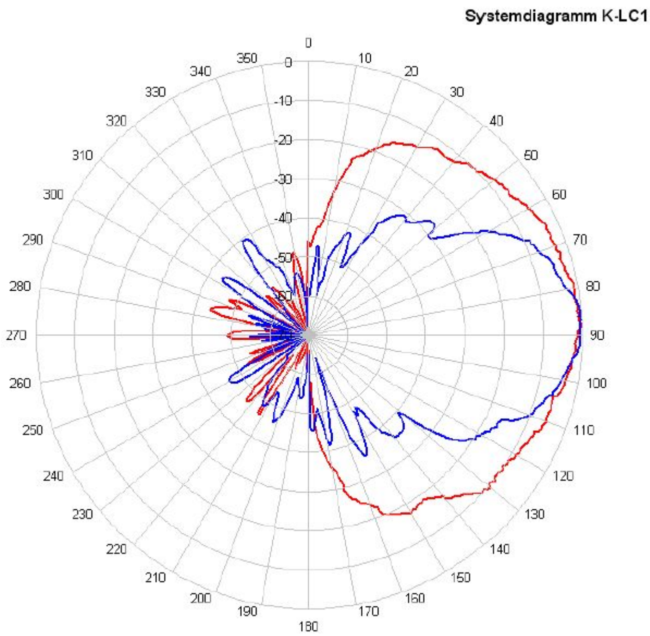


Figure.12 Antenna system diagram for K-CL1a [13]

For this K-CL1a module the sensitivity and the maximum testing range depend on many parameters.But according to the equation of RCS(radar cross section) it can be calculated approximately.Because of the maximum range of Doppler movement depends mainly on module sensitivity 'S'(-114dBc)carrier frequency 'f_0'(24.15GHz) and the radar cross section 'σ' (1m^2 approx. for a moving person and 50m^2 for a moving car normally).So the radar equation according to the K-band module is the following[13]:

$$r = 0.0167 * 10^{\frac{-s}{40}} * \sqrt[4]{\sigma} \tag{3.1}$$

From the formula its get the indicative detection range of :

-12meters for a moving person;

-30meters for a moving car.

3.3.2 ST100 Starter kit

RF-beam ST100 starter kit consist of a PCB motherboard ,a K-CL1 radar module and a flexible acquisition software.In the hardware part,ST-100 consists of two dual-channel low noise amplifiers,a duel 16Bit ADC,a dual 16Bits DAC and a USB interface as well.ADC and DAC are parts of an audio codec,that behaves like an USB sound device.

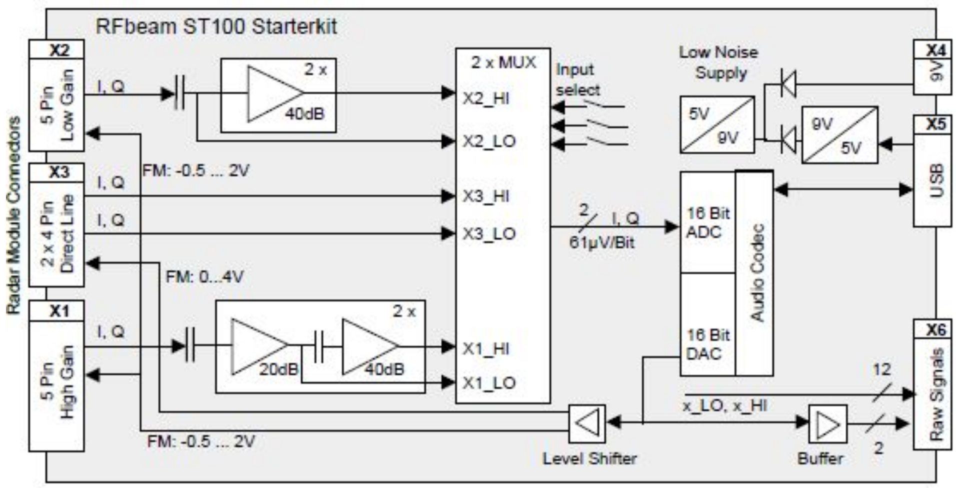


Figure.13 Block diagram for RF-beam ST100 Stater-kit [14]

As shown above from the figure:ST-100 provides 3 inputs (X1...X3) for radar front -ends. The inputs differ in sensitivity and physical outline.Input signals may be selected by a DIP switch and routed via a multiplexer to the ADC codec. As for the

DAC outputs used for generating VCO control voltages for FMCW or FSK operation of RF-beam radar modules.Power supply is normally derived from the USB port and convert to low noise supply voltage[14].

3.4 Synthetic Aperture Radar Imaging

To provide SAR imaging it is better find a location with a straight rail approximately 3.2 meters. Connect the can radar system to a laptop with audio out. After that recording the target which in front of radar continuously.It acquire range profiles at 0.5 meters increments over 2.5-3 meters of aperture length.Meanwhile using toggle switch to blank L synchronization channel,indicating change in radar position for each range 2.5-3 meters..Collect the data and making the SAR imaging figure by using Matlab.

4 Result

This chapter includes the function verifying of two Doppler radar systems and speed testing,ranging testing and SAR imaging.

4.1 Video amplifier verify

4.1.1 Modulator module verify

Test if the ramp-generator working by using the oscilloscope adjust Modulator to 20 ms up-ramp time and 2.4V magnitude for ISM band chirp.Synchronization output test as well in the following figures:

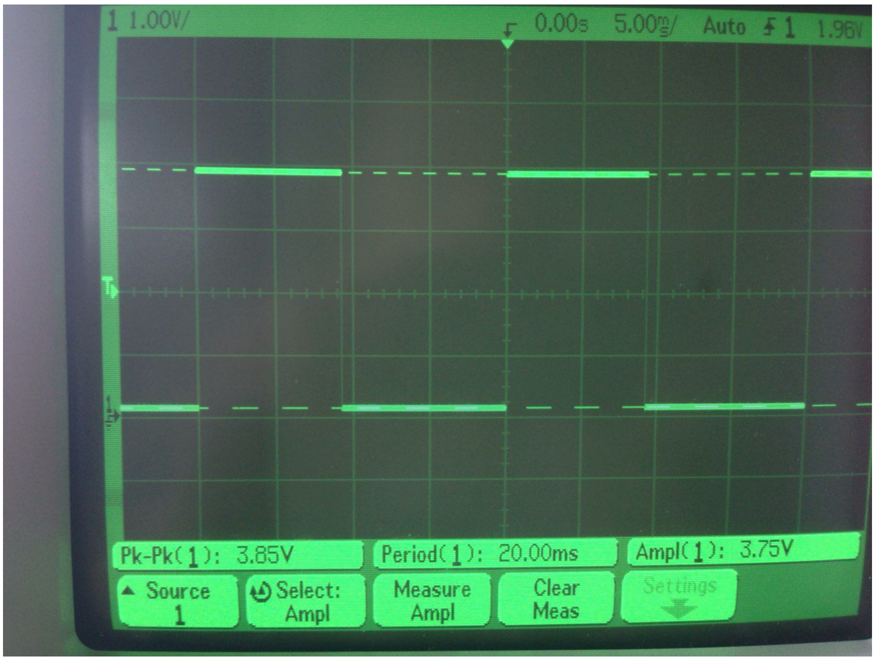


Figure.14 Synchronization output at 20ms period

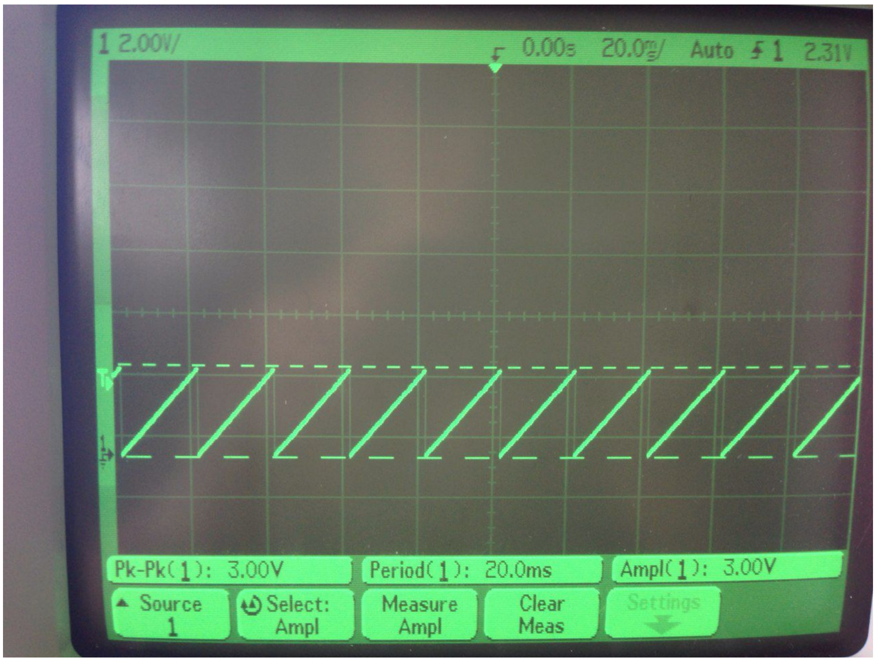


Figure.15 Ramp generator with 20ms

4.1.2 15KHz active low-pass filter verify

Test if the 15 KHz active low-pass filter working by connecting a sin wave generator to the input and a two channel scope to the output and input respectively.Verify -3dB roll-off at 15 KHz and steeper roll-off above 15 KHz is shown as below:

	Vin(V)	Vout(V)	Gain
1KHz	2.06	1.91	-0.65
2KHz	2.06	1.88	-0.79
3KHz	2.06	1.78	-1.27
4KHz	2.06	1.66	-1.88
5KHz	2.06	1.60	-2.19
6KHz	2.06	1.47	-2.93
7KHz	2.06	1.35	-3.67
8KHz	2.06	1.25	-4.34

9KHz	2.06	1.16	-4.99
10KHz	2.06	1.10	-5.45
11KHz	2.06	0.97	-6.54
12KHz	2.06	0.93	-6.91
13KHz	2.06	0.81	-8.11
14KHz	2.06	0.75	-8.77
15KHz	2.06	0.66	-9.89
16KHz	2.06	0.6	-10.7
17KHz	2.06	0.53	-11.8
18KHz	2.06	0.50	-12.3
19KHz	2.06	0.47	-12.8
20KHz	2.06	0.41	-14.1
21KHz	2.06	0.38	-14.7
22KHz	2.06	0.35	-15.4
23KHz	2.06	0.31	-16.5
24KHz	2.06	0.28	-17.3
25KHz	2.06	Low signal	

Table 4.1 15KHz active low-pass filter verify

4.2 Antenna Verify

Reflection coefficient(Return loss) is an important parameter in radio signal transmitting and receiving.Therefore verify the reflection coefficient is necessary for 2.4 GHz can radar system.By trimming the length of the monopole wire in small amounts the return loss is controlled around -10dB over the ISM band (2.4GHz to 2.5GHz).As shown from the figure below both can antennas demonstrate good performance over the required band.

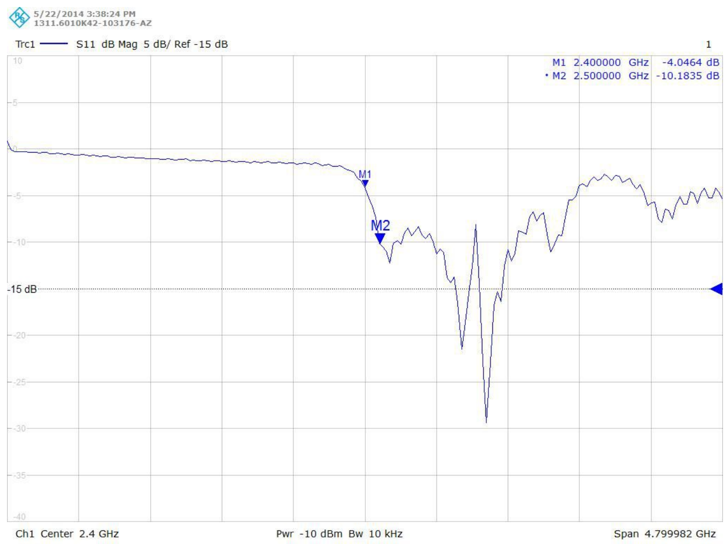


Figure.14 Reflection coefficient of Cant antenna1 for S11

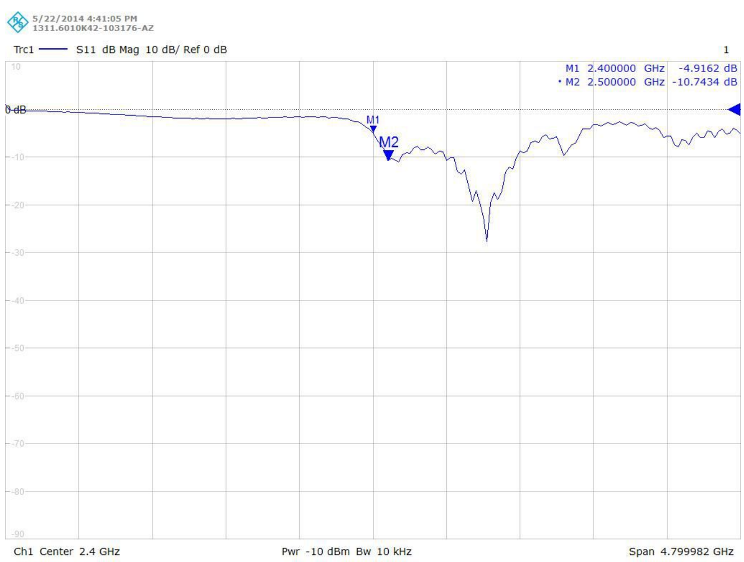


Figure.15 Reflection coefficient of Cant antenna2 for S11

4.3 Doppler Time Intensity

24GHz RF-beam radar system

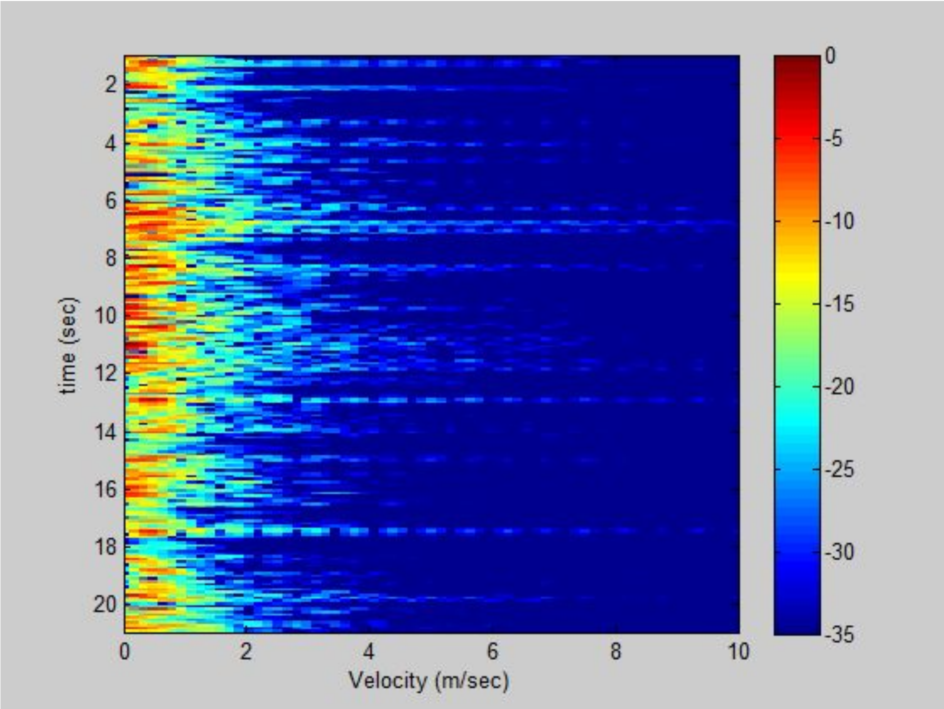


Figure.16 24GHz Doppler-Time Intensity of passing car

Figure.16 shows the Doppler-Time Intensity of passing cars at a crossroad.It present the time versus velocity for the vehicles with different speed.Seen from the figure the average speed of cars is around 3m/s that is because of the driver was about to slow down and observe the situation at the crossroad in case of collision.At 7s.13s and 17s the speed were increasing rapidly with passing through.With the changing of colors provides the intensity of speed distinctly. Overall according to the DTI plot the speed of moving objects can be easily detected.

2.4GHz Can radar system

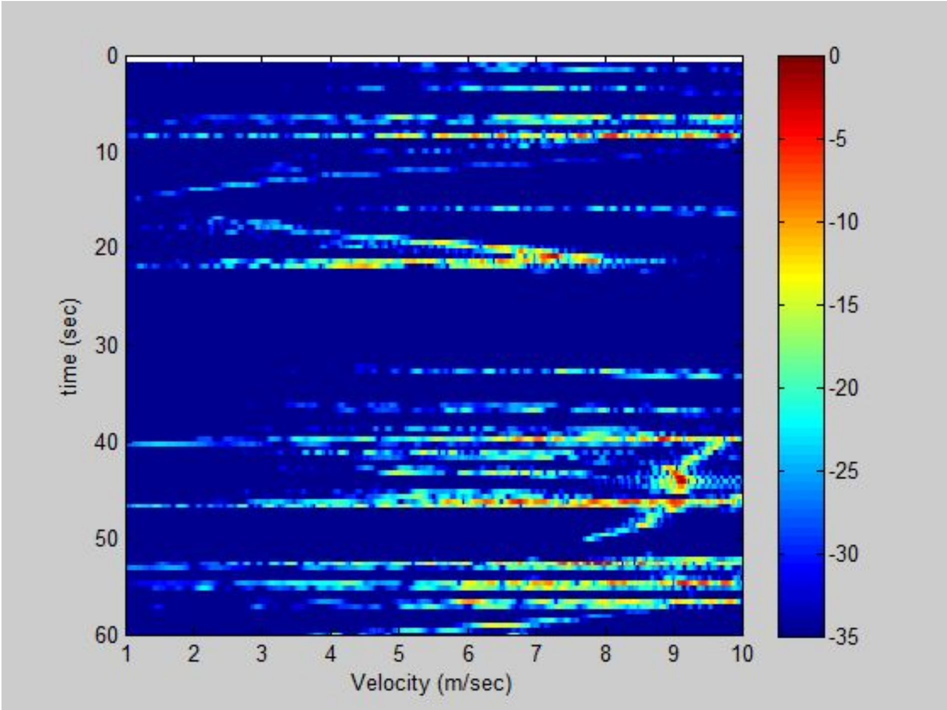


Figure.17 2.4GHz Doppler Time Intensity of passing vehicles plot

Figure.17 shows the vehicles passing through a straight road with the normal speed which is about 7m/s.Unlike previous system the can radar was implemented with a higher sensitive.As we can seen from the figure it record the variation of speed continuously.These images present a small sample of testing objects speed in a simple way for analyzing.

Range Time Intensity(RTI)

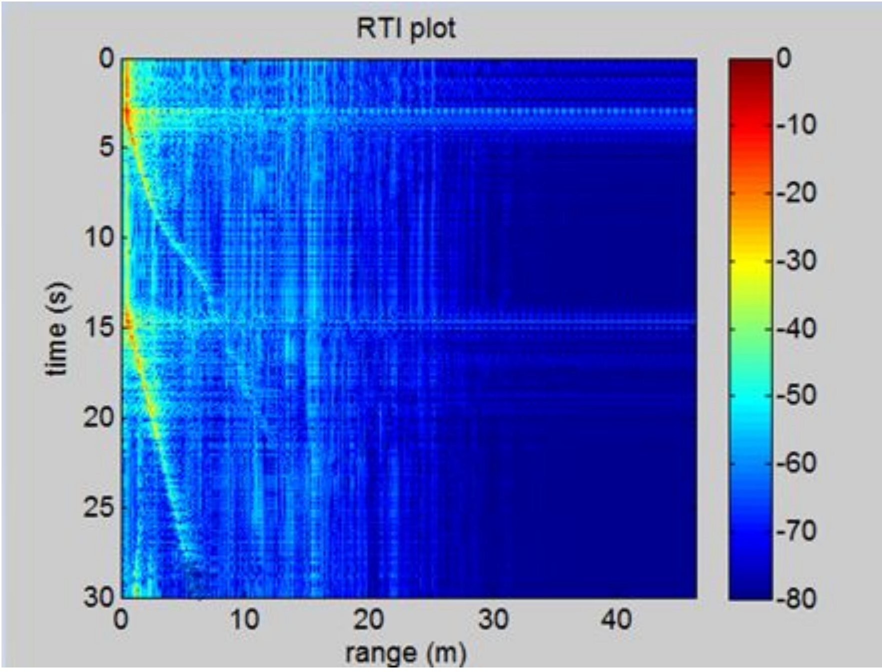


Figure.18 Range Time Intensity of two people walk away

Figure.18 shows the Range Time Intensity of two people walking away from the radar system with different time interval.This experiment shows a person who first walking away at start-point.After 14 second another person start to walk in the same direction but with short distance.Both of them stopped at 25 seconds after nearly.With range versus time the distance can be measured accurately in a direct way and easy to follow for analyzing.

Synthetic Aperture Radar(SAR)

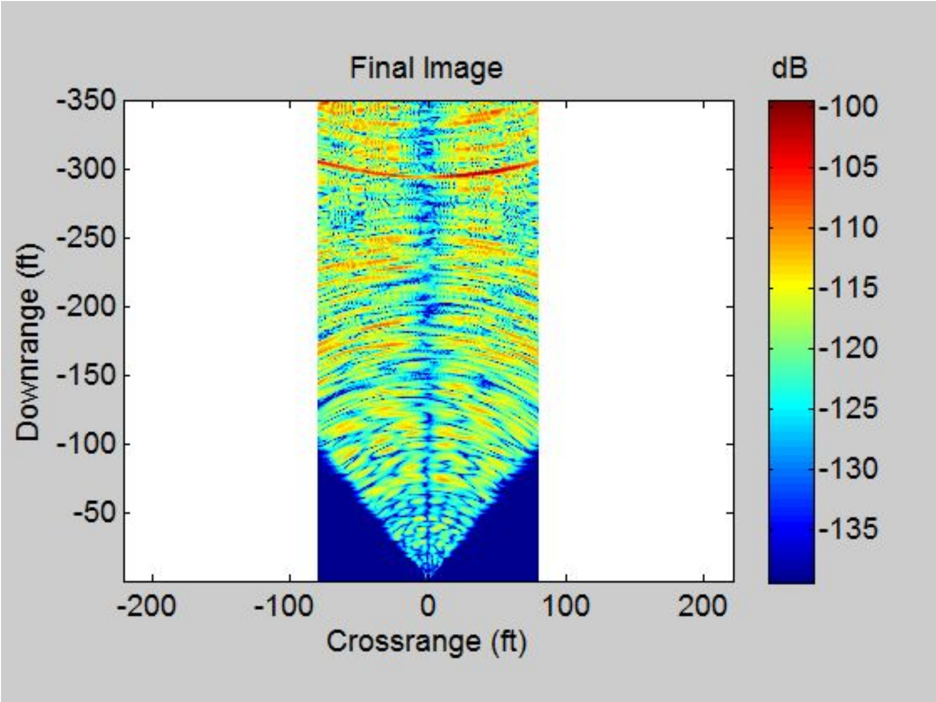


Figure.19 SAR imaging for the crowded corridor

Figure.19 shows the SAR imaging for a crowded corridor with chairs and bookcases inside campus.As can be seen from the graph the intensity present the space of objects which cover from different angle.The power level in dB of objects is shown as different colors corresponding to different positions of objects.By verifying the aperture length with switching on and off L synchronization channel the polt can be adjust.

5 Discussion

For this thesis project two designs working in different frequency ranges (24 GHz and 2.4 GHz) were implemented.One is based on an ‘all-in-one’ chip from RF-beam Microwave and the other is based on components from Mini-Circuits.According to the radar and antenna theory two systems were build by different settings but reached the same goal which is Doppler radar evaluation and proximity sensing with verifying the speed and range of objects.However the system still needs to be improved.For instance in the 2.4GHz radar kit system,two can antennas were unstable because the monopole wire inside was hard to reach in a very accuracy level which leading to the return loss and the radiation pattern cant reach in a desired level as well.As for the 24GHz RF-beam system,the resolution of image is not very good due to the limitation of sensing and maximum detective range.There is a trouble which is about the Ramp Generator fabrication.The microwave chip was quite small for soldering with 16 pins on the mini-board precisely.Therefore an advanced signal generator using 220V power supply was used in indoor experiments to replace the XR-2206 microchip which providing a stable 20ms and 2.4 volts pulse for the can radar system.As for the SAR imaging experiment,the best time for imaging is often taken during the night without too much interference and best place is outside the building with a low activity campus.Due to the Ramp Generator is not portable for this experiment,the imaging have limitation.These will be improved in the future time.

6 Conclusion

The purpose of this thesis is evaluating of two Doppler radar systems for their speed testing,distance detecting and building image of objects.According to the experiments of two Doppler radar systems the theory of Doppler effect was achieved.Students could use these systems to get a deeper comprehend on applied electromagnetic, antennas building and strengthen the concept of modular RF radar design.In the result the Doppler Time Intensity(DTI) which contains time versus velocity and the Doppler Range Intensity(RTI) that contains time versus range are implemented.These two polts present the most commonly used parameters in Doppler theory which is speed and distance of objects.It is quite direct seen the speed variation and the changing of distance.Synthetic Aperture Radar(SAR) imaging was implemented as detecting and giving a image of objects in a certain time period.For the low cost advantage RF-beam Doppler radar is widely used in all over the world for short distance sensing.In addition Doppler radar is also used for weather observation.By detecting the speed of meteorological echo with Doppler radar the distribution that obtained at different heights in the atmosphere of various air turbulence is available to get. Therefore this thesis design an initial platform which leads people improving in the future for more applications by using Doppler radar system.

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