EE318 : Electronics Design Lab I

Project Description – Group B1

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Vehicle speed indicator

(CW radar, with vehicle detection and digital readout)

Problem Statement:

To make a low cost vehicle speed indicator working in the RF range that can measure vehicle speeds in the range of 10-200 km/hr.

Block diagram:

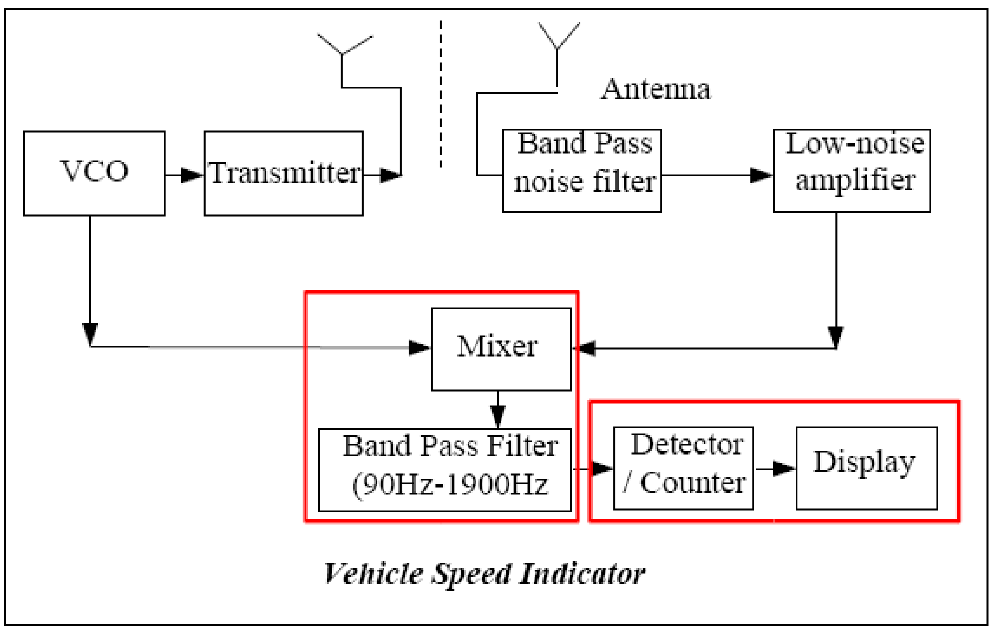

Figure 1 Functional block diagram of a continuous wave RADAR

Approach to design:

The solution consists of using continuous wave RADAR to measure the vehicle speed based on the Doppler shift in frequency. The project would accordingly be in three modules- Transmitter, Receiver, and Processor.

Two alternative designs were considered to start with. One is to use separate antennae isolated from each other for reception and transmission or to use a single antenna with a circulator to isolate the received signal from the transmitted signal.

Currently the circulators available commercially have a typical isolation of about 25 dB. The received signal according to the formula

$$Pr/Pt = Gt*Gr*(\lambda/4\pi R)\hat{}2$$

Where Pr = Power received
Pt = Power transmitted
Gt = Gain of transmitting antenna
Gr = Gain of receiving antenna
λ = wavelength
R = path length

was calculated to be of the order 80 dB lower than the transmitted signal. This was calculated assuming a reflectivity of about 1% to account for the non-normal incidence and a distance of 20m. Keeping in mind the prices of the circulators, the alternative method of using separate transmission and reception antennae was used. As the results of our experiments show (Table 1), this provides a much better isolation between the two signals, especially when we shut off the reception antenna from the transmitting antenna using a metal sheet.

We decided to work in the WLAN band of 2.4 GHz frequency according to practical considerations of availability of components. The VCO generates a signal of 2.4 GHz frequency which is divided into two signals of equal power with one being fed to the mixer and the other pre-amplified before transmission.

The reception module consists of the reception antenna, an amplifier circuit, mixer and a Low pass filter. The response of the antenna is sufficiently narrowband (Table 2) that we found that it performs the function of a very narrow band pass filter. The amplification is done with three LNAs each with an amplification of 25 dB cascaded together, which further reduces the ambient white noise. After the amplification, the signal is expected to be about 5dB lower than the transmitted signal.

This is down converted to the find out the difference between the transmitted and the received signals to find the Doppler shift from which the velocity of the vehicle in question would be given by the equation

$$\Delta f = 0.926 \times v \times F_0$$

Where Δf = Doppler shift
v = Velocity of the vehicle in km/hr
Fo = Frequency of operation

This processing is handled by the processor module which involves a micro controller, an LCD display, power supply to all components. The microcontroller also controls the frequency of waves generated in the VCO.

Circuit Design and working algorithm:

According to our requirement of a central frequency of operation of 2.4 GHz, we obtained samples of ADF 4360-0 which also comes with an inbuilt PLL which is essential for precision in the output frequency and is compatible with 89C52 series of microcontrollers. The circuit diagram is as shown in the following figure.2

At a substrate thickness of 1mm, we calculated that for 50 ohm matched impedance, the track thickness is 1.875 mm and accordingly designed the PCB circuit matching impedances on all the lines involving RF signals. This is very important in order to minimize losses and avoid damage to the ics because of power reflection.

The VCO requires a high precision TCXO oscillator of operating frequency 16 MHz. A 3.3 V DC regulated power supply would be required for this purpose by the oscillator and we obtained a sample of TPS 7333 which satisfies the criteria.

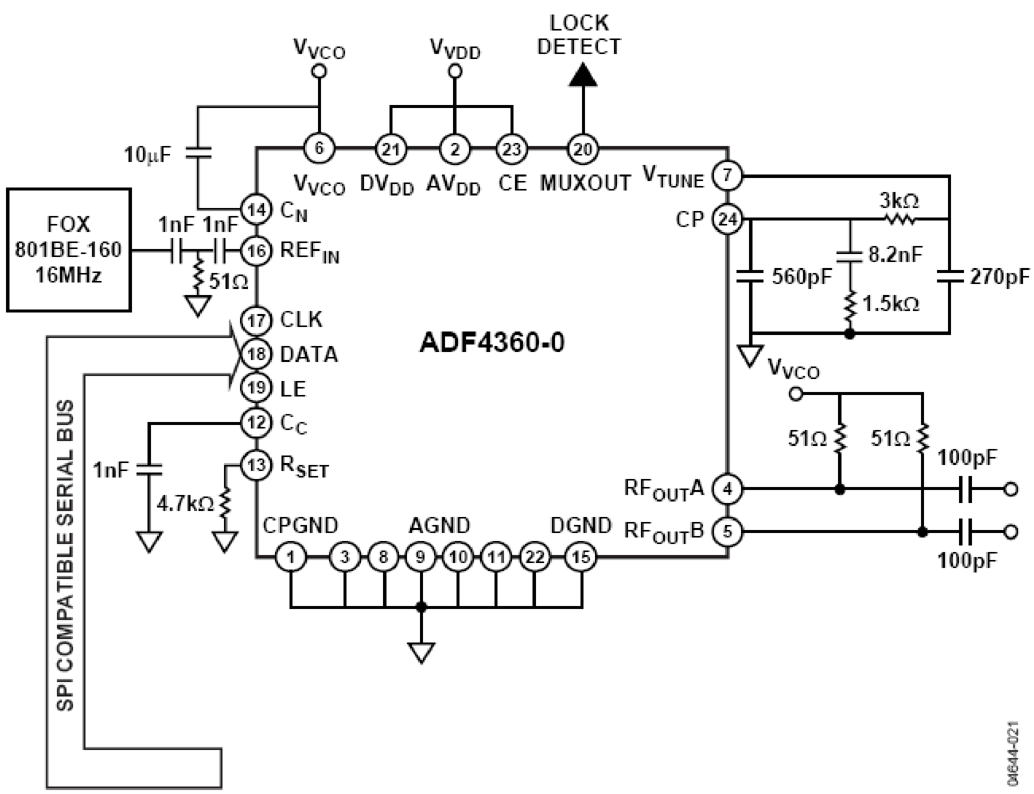

Figure 2 Fixed Frequency interfacing

The interface between the VCO and the controller consists of a serial SPI compatible bus for writing the control word. Firstly the chip is enabled. Then 3 sets of 24 bit words are to be sent called the control latch, n counter latch and r counter latch. We set the words that control 4 parameters a, b, p and r. where the frequency is given by

$$F = (a*p + b) * \text{crystal frequency} / r$$

Where the values used for p,b,r, and a are as follows

pb + a = 2400/16 * r

r = 54 = 00 0000 0011 0110
p = 16

16b + a = 150*54 = 8100

b = 505 = 0 0001 1111 1001
a = 20 = 1 0100

LNAs used in the circuit were BGA 430s from Infineon Pvt Ltd. as they had an internal impedance matching circuitry as well as a central operation frequency of 2.4 GHz. The output from the VCO is of the order -13 to -6.5 dBm. And this is further split into two signals of equal power using a Wilkinson's divider. One signal is fed to the mixer for downconversion, and the other signal is amplified by one LNA and then transmitted. The antennae used were designed by Prof. Girish Kumar with a central frequency of 2.4 GHz and a very narrow passband of around 200 MHz.

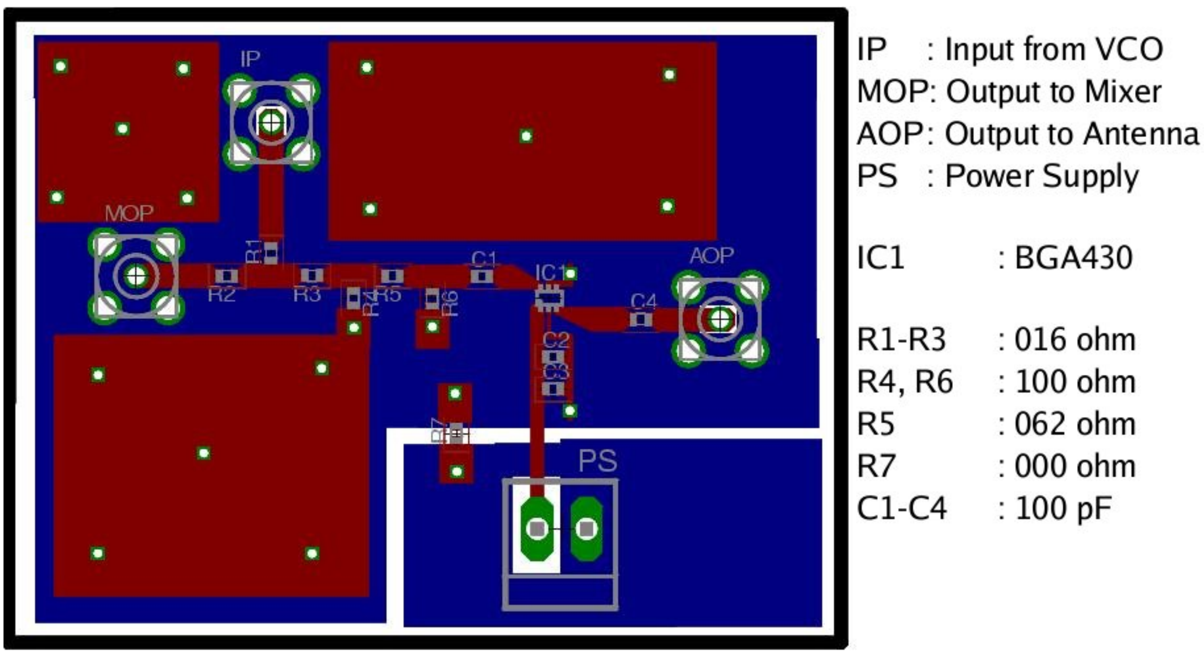

Figure 3LNA VCO and wilkinson

The received signal is expected to be about 80dB lower in power than the transmitted signal. This is put through a three stage cascaded amplification by BGA-430s. This greatly reduces the ambient white noise as well as amplifies the signal back to a power level of the order -10 dBm.

We obtained samples of AD 8343 from Analog Devices, India, Pvt Ltd. an active mixer with a gain of 7.1 dB and a broadband of operation from DC to 2.5GHz. With a provision to accept single ended input signals. After passing through the mixer, the Downconverted signal is passed through a low pass filter and fed to the processor module for further analysis.

. Calculations done according to the formula

$$\Delta f = 0.926 \times v \times F_0$$

give us an estimate of 10-500 Hz as the Downconverted signal frequency for a speed range of 10-200 Km/hr. This signal is then amplified by an op amp and converted to a digital signal using a Schmidt trigger. The microcontroller measures the period of this positive pulse by using timer 1 in gated mode, calculates the speed and displays it on the LCD. The trigger to the microcontroller is enabled and it awaits the next trigger.

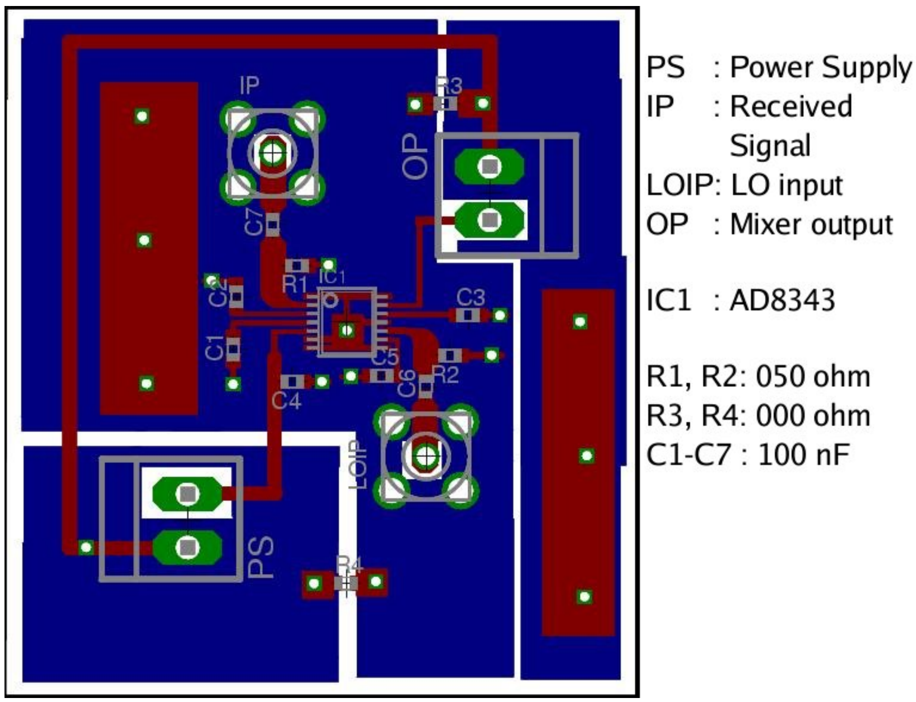

Figure 4 Mixer Circuit

The power supply to all the PCBs is handled by the IC 7805, which gives a regulated power supply of 5V.

The microcontroller algorithm requires a trigger to start off the circuit, (in order to save battery life). Once it has been started, the digital signal is counted for half a cycle, and the time period of the signal is estimated as value A. the signal is checked again so that another value B of the frequency is obtained. Until the two values match, the device will keep polling for the signal. This is a self –consistency is required to eliminate spurious results. If values A and B don't match, the value A is replaced by current value B and cycle is re-executed.

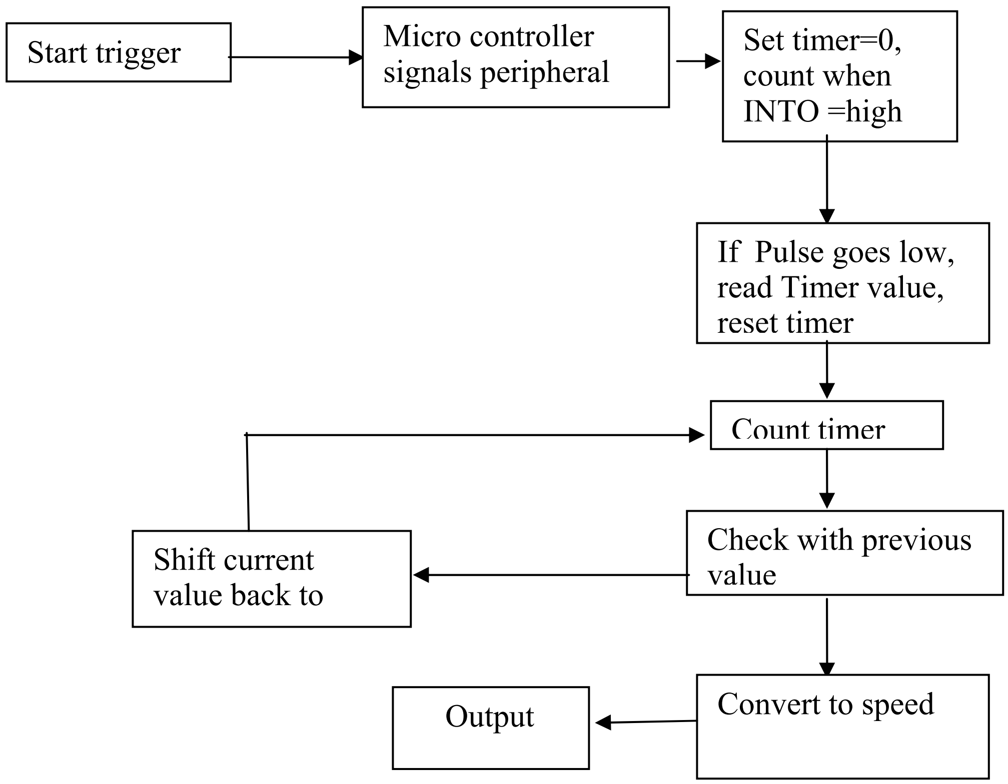

Figure 5:L Micro controller algorithm:

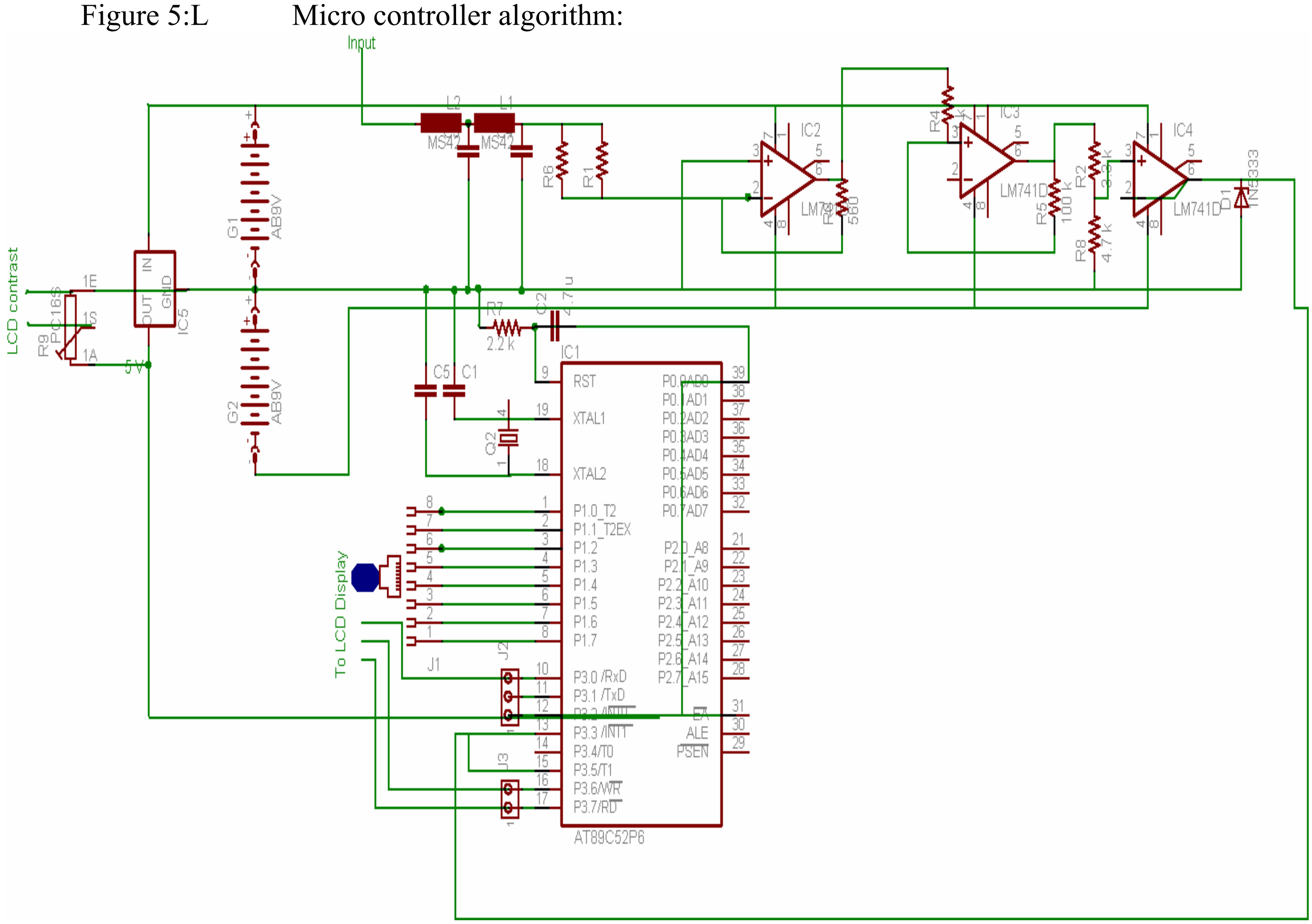

Figure 5 Processor Module

Experimentation:

We tested the processor module feeding it a signal over the range 10-1000 Hz for checking the velocity measured and the output display. The results were obtained to within 0.5% of the accurate measurement for the speed.

Lots of experiments on the antennae isolation had been done. With a thin aluminum foil between the receiving and the transmitting antennae, we observed a signal of -49 dBm when the signal fed was 13 dBm. Without the foil though, the signal was -40 dBm. One suggestion included a wet towel as a substitute for an absorber of microwave radiation, which when tried gave an improvement in isolation by 2 dB.

The antennae were tested for their performance at 2.4 GHz and we found that the response of the antennae was fairly narrowband with a 3 dB point at 200 MHz on either side thus eliminating the need for a bandpass filter. The results also show a good isolation between the transmitter and the receiver.

The data for these experiments is as shown in the tables below.

Table 1: Frequency response of antenna

Frequency(in GHz)	*Power(in dBm)*
2.65	-55
2.55	-44
2.5	-40
2.45	-46
2.42	-41
2.4	-39
2.38	-36
2.35	-38
2.30	-43
2.25	-52
2.2	-46

Setup for the experiments

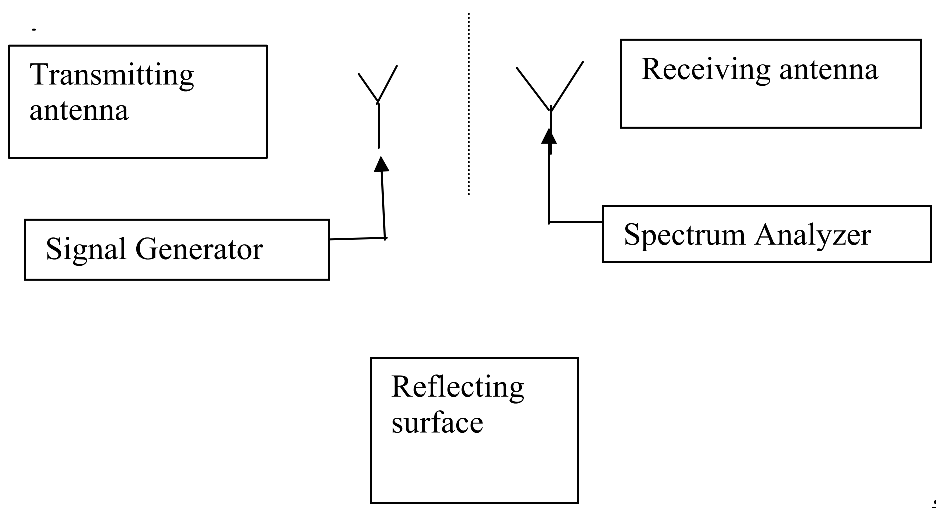

Table 2: Power at receiver antenna
Transmitted power = 0dBm

Distance of reflecting surface	Power without reflecting sheet	With metal sheet as reflector
60 cm	-41 dBm	-30 dBm
90 cm	-41 dBm	-35 dBm
120 cm	-37 dBm	-41 dBm
140 cm	-38.5 dBm	-41.5 dBm

We also did a lot of experiments on the individual sub modules and found that the vco produces an output of ~ 2.45 GHz though steady. This is because the TCXO crystal used was not able to give it a signal of 16.0 MHz accurately enough.

The LNA at the vco end with the Wilkinson's divider for power division works fine but is extremely sensitive to mechanical orientation. This suggests that there is a problem with the SMA connectors- RF cable in interface. (but due to high costs involved, we could not try out a different connector) The same problem persists with the other boards also.(the project in all comprises of 5 PCBs with 4 for the RF and 1 for the analog modules)

Conclusion:

Due to strong dependence of experimental data on the experimental conditions, there was low reproducibility in experimental results. Hence, we could not proceed beyond testing individual modules and the integration of these modules is yet incomplete.

References:

1. Electronic Distance Measurement, J.M.Rueger, Third edition, Springer-Verlag Berlin, Heidelberg 1990.
2. Introduction to Radar Systems, Merrill. I. Skolnik, Second Edition, McGraw Hill International editions, Singapore 1981.

Acknowledgements:

We would like to thank Prof. Girish Kumar for his invaluable guidance throughout the project and for designing the antennae required for the project.