Doppler: Detecting Objects Presence in Space through Perseverance and Learning which Entails R&D Avenues

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Abstract—**The objective is to create a PC based low-cost, low-power rangeDoppler imaging system based on an existing coffee can "cantenna" design. The actual radar hardware consists of microwave components, modulator, ramp generator, and a pair of cantenna. This radar design sends analog data to a PC via the audio line-in port. The data is saved on the PC as a .wav file. The user can then process the data using a MATLAB script to display range and velocity measurements. But thisdata cannot be processed in real time. The user must record data, save the data, then process the data.**

Keywords—**Doppler imaging; MATLAB; coffee can antenna; microwave components; data acqustion.**

I. Radar Theory

Radars are systems that are used for detecting objects. They detect objects by using electromagnetic waves to determine a variety of detection parameters. Such parameters include altitude, speed, range and direction. The project that we choose uses range and Doppler (direction) to detect objects. There are many different configurations in which a radar can exist. Among the many, the few that are most common include Monopoles Radar, Biostatic Radar, Doppler Radar, and Frequency Modulated Continuous Wave (FMCW) Radar. Of the above stated configurations, this RADAR system uses a Frequency Modulated Continuous Wave Radar configuration to determine range and direction of an object.

II. Receive and Transmit Antennas

Fig. 1.represents a simple antenna design of the radar system implemented for the project. It consists of two cantinas (antennas made of coffee cans) one being a receiver and one being a transmitter. The radar transmitter induces a time-varying microwave signal along a coaxial cable to the transmit cantenna. The time-varying signal will induce an electrical current and produce electromagnetic radiation. The microwave photons will flow away at the speed of light and reflect off an object. The reflected energy will illuminate the receiver cantenna and induce an electrical current to the radar receiver.

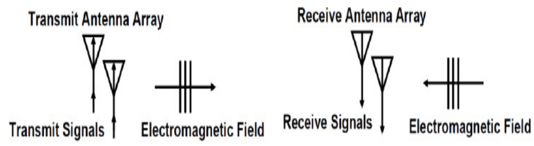

Fig. 1. Receive and Transmit Antennas.

III. Radar Block Diagram

Fig. 2. Shows the basic idea of the accomplished radar. The radar operates in ISM(industrial, scientific and medical) band of 2.4 GHz. It is a Frequency Modulated Continuous WaveRadar. The approximate transmitting power is exactly 10 mW. Maximum range approximately 1 km for 10 dBsm.

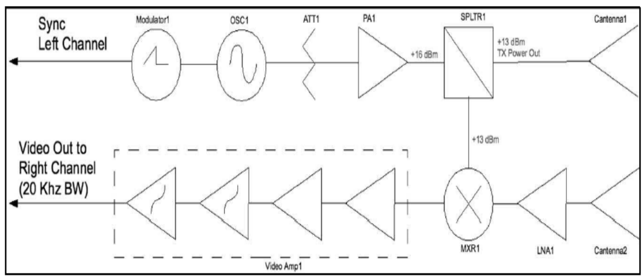

Fig. 2.Radar Block Diagram.

IV. Production of FMCW Signal

The radar system begins at Modulator 1. Modulator 1 is the circuitry that drives our FMCW signal; it uses a XR2206 IC that produces high quality sine, square, triangle, ramp and pulse waveforms. Using this IC is ideal for producing our FMCW signal because FMCW radars are capable of slewing up and down with any of the four different wave configurations capable by the IC. However for this application we'll use a triangle modulated waveform because it will provide us with range and velocity capability. Modulator1 has two functions in this system. First, it produces a linear ramp which modulates OSC1 of figure 13 with a variable called Vtune. The Vtune voltage is proportional to our transmit frequency (between 2.4-2.45 GHz). Modulator 1's linear ramp of Vtune will cause OSC1 to produce a linear FM chirp which is used to transmit and receive the signal. The given ramp up time and triangle wave period is 20ms and 40ms respectively. The magnitude of the ramp is also given; we will set our potentiometers to give us a 100 MHz transmit bandwidth. Secondly, it sends a pulse to our data acquisition device and sends it to the PC to be displayed on our GUI by perform an FFT with it. The Modulator 1 signal is synchronized with the linear ramp.Fig. 3.Shows the schematic and soldered version of the Modulator 1 circuitry.

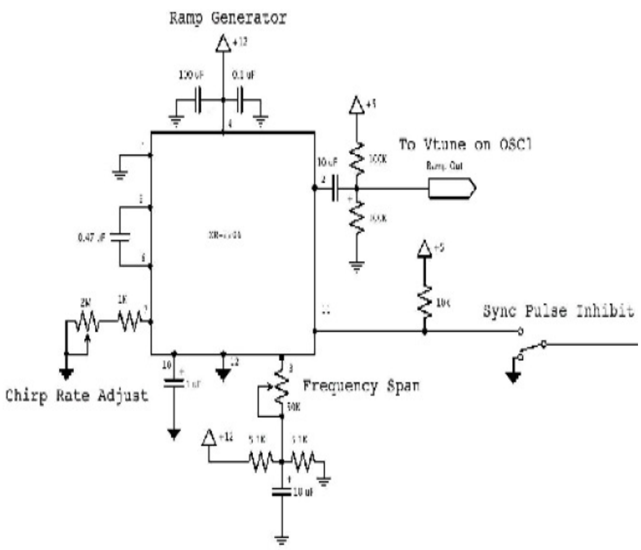

Fig. 3.Shows the schematic and soldered version of the Modulator 1 circuitry.

V. VIDEO AMPLIFIER

After the transmit receiver illuminates a target and receives the reflected signal, it is then passed into the op-amp circuitry, which amplifies the signal. The block diagram of Fig. 2.represents the video amplifier (Fig. 4.). The signal will first enter the gain stage op-amp circuit and amplify the signal about 28dB. The output of our amplified circuit will then be inputted into the 4th order Low Pass Filter. The Low Pass filter configuration is called a Sallen-Kelly LPF. This type of configuration is easy to implement and will not load the circuit like a passive filter would. After the gain and filtering stages, the output is sent to the data acquisition circuitry and processed on the PC. A MAX414 quad op-amp with a single-supply configuration to suit the given design requirements, this particular IC is ideal because both the gain stage and LPF can be implemented using active op-amp components.

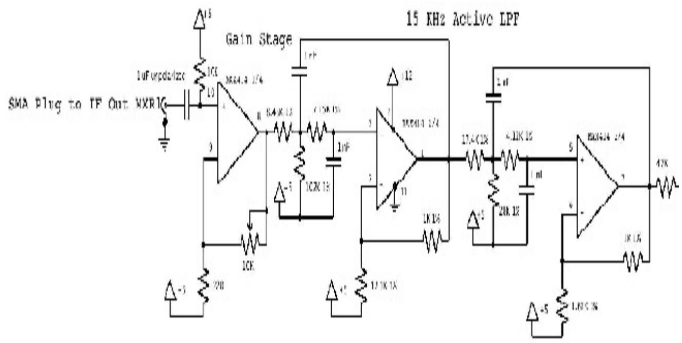

Fig. 4.The block diagram of video amplifier.

VI. POWER SUPPLY CIRCUIT

Two battery packs which hold 4 AA batteries each are used to produce the 6v and 12v dc outputs needed. However, for our circuitry, 12V, 10V, and 5V are needed. This can be accomplished by implementing 2 voltage regulators in the power supply. The RF components are fed by a 5V DC low-dropout regulator. The regulator is fed by 6V from the battery pack. The 10V DC output will power the MAX414 IC and the 12V DC will be used to power the FMCW circuit.Fig. 5. Shows the block Diagram of the power supply.

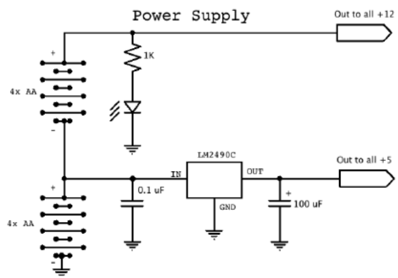

Fig. 5. Block diagram of Power Supply

VII. TRANSMIT POWER DENSITY, RECEIVE POWER AND GAIN CALCULATION

The gain G (relative to an isotropic radiator) of an antenna aperture of arbitrary shape is given by the following expression: $G= 4\pi\ Ae/\lambda^2$------[1]

Where Ae is the antenna effective aperture area and λ is the wavelength.

An antenna with circular aperture (diameter D) has a maximum gain value in dBi (relative to isotropic) equal to $G_{m,dBi}= 10\log10(\pi D/\lambda)^2$------[2]

Antenna half-power beam width is approximately:

$HPBW = 58°\lambda/D$------[3]

Effective isotropic radiated power (EIRP) is a function of the transmitted power Pt times the gain of the transmit antenna $Gt(\theta,\phi)$. $EIRP(\theta,\phi)= PtGt(\theta,\phi)$------[4]

Radiated power density Pd at a distance r from the transmit aperture is $Pd(\theta,\phi)= EIRP/4\pi r^2 = PtGt(\theta,\phi)/4\pi r^2$------[5]

Power received Pr by an aperture is the product of the incident power density Pdiand the effective aperture area Ae, referring to equation $Pr= PdiA$------[6]

Relative power coupled between two antennas (transmit and receive)$Pr(\theta,\phi)/Pt = Gt(\theta,\phi)\ Gr(\theta,\phi)\ \lambda^2/(4\pi r)^2$------[7]

If the relative power coupled between two identical antennas (Gr= Gt= G) is measured, the antenna gain iscalculated.

$Pr(\theta,\phi)/Pt = G2\lambda^2/(4\pi r)^2$------[8]

$G2= Pr(\theta,\phi)/Pt\ (4\pi r/\lambda)^2$------[9]

$GdBi= ½[10\log10(Pr(\theta,\phi)/Pt)+20\log10(4\pi r/\lambda)]$------[10]

Equation [10] gives the Antennae gain.

VIII. DATA PROCESSIN AND RESULTS

Fig. 6.Shows theBasic Flowchart for MATLAB code.

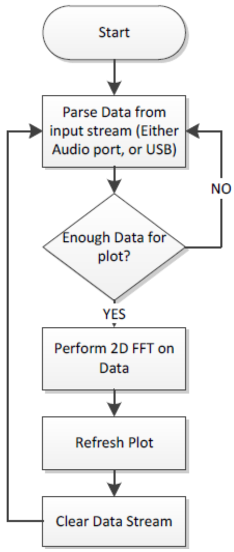

Fig. 7.Basic Flowchart for MATLAB code.

The entire radar system was tested using MATLAB scripts for the Radar hardware. A team member with a metal trashcan stood at the end of a long auditorium and walked towards the radar. The metal coffee can has a higher reflection coefficient than a human and thus will allow for a stronger signal to be received by the radar. Raw data from the radar was sent to a PC via audio line-in, recorded using Audacity then saved as a .wav file so that a MATLAB range vs. time plot could be constructed. Fig. 7.Shows theMATLAB ranging data test.

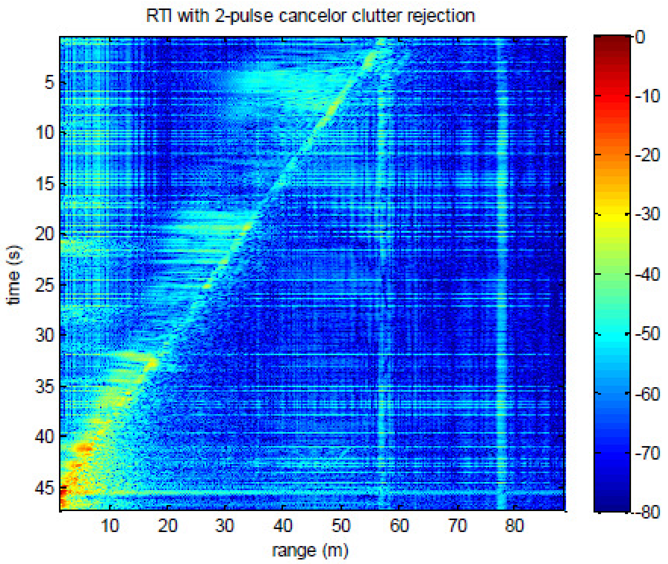

Fig. 7. MATLAB ranging data test.

As shown in Fig. 7, the target started at a distance just less than 60m away from the radar. 45 seconds later, the target was at a distance of around 1m from the radar. The starting and ending positions of the target were measured with a tape measure and were found to match the results of the MATLAB ranging test. The MATLAB Code is given below;

```
clear all;
close all;
%read the raw data .wave file here
[Y,FS,NBITS] = wavread('running_outside_20ms.wav');
%constants
c = 3E8; %(m/s) speed of light
%radar parameters
Tp = 20E-3; %(s) pulse time
N = Tp*FS; %# of samples per pulse
fstart = 2260E6; %(Hz) LFM start frequency
fstop = 2590E6; %(Hz) LFM stop frequency
BW = fstop-fstart; %(Hz) transmti bandwidth
f = linspace(fstart, fstop, N/2); %instantaneous
transmit frequency
%range resolution
rr = c/(2*BW);
max_range = rr*N/2;
%the input appears to be inverted
trig = -1*Y(:,1);
s = -1*Y(:,2);
clear Y;
%parse the data here by triggering off rising edge
count = 0;
thresh = 0;
start = (trig > thresh);
for ii = 100:(size(start,1)-N)
if start(ii) == 1 & mean(start(ii-11:ii-1)) == 0
%start2(ii) = 1;
count = count + 1;
sif(count,:) = s(ii:ii+N-1);
time(count) = ii*1/FS;
end
end
%check to see if triggering works
% plot(trig,'.b');
% hold on;si
% plot(start2,'.r');
% hold off;
% grid on;
%subtract the average
ave = mean(sif,1);
for ii = 1:size(sif,1);
sif(ii,:) = sif(ii,:) - ave;
end
zpad = 8*N/2;
%RTI plot
figure(10);
v = dbv(ifft(sif,zpad,2));
S = v(:,1:size(v,2)/2);
m = max(max(v));
imagesc(linspace(0,max_range,zpad),time,S-m,[-80,
0]);
colorbar;
ylabel('time (s)');
xlabel('range (m)');
title('RTI without clutter rejection');
figure(20);
sif2 = sif(2:size(sif,1),:)-sif(1:size(sif,1)-1,:);
v = ifft(sif2,zpad,2);
S=v;
R = linspace(0,max_range,zpad);
for ii = 1:size(S,1)
%S(ii,:) = S(ii,:).*R.^(3/2); %Optional: magnitude
scale to range
end
S = dbv(S(:,1:size(v,2)/2));
m = max(max(S));
imagesc(R,time,S-m,[-80, 0]);
colorbar;
ylabel('time (s)');
```

```
xlabel('range (m)');
```

Fig. 8.Shows the entire hardware of the Radar setup.

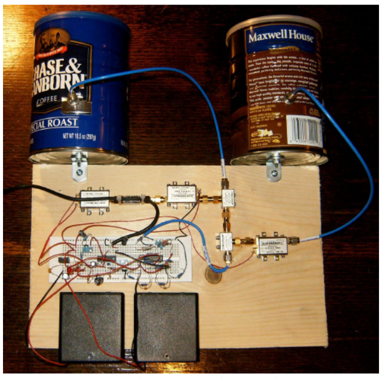

Fig. 8. Hardware of the Radar setup

REFERENCES

[1] Dr. Gregory L. Charvat, Mr. Jonathan H. Williams, Dr. Alan J. Fenn, Dr. Steve Kogon, Dr. Jeffrey S. Herd, "]. Build a Small Radar System Capable of Sensing Range, Doppler, and Synthetic Aperture Radar Imaging".

[2] C. A. Wiley, "Synthetic Aperture Radars: A Paradigm for Technology Evolution," IEEE Transactions on Aerospace and Electronic Systems, vol. AES-21, pp.440–443, May 1985.

[3] Gart, Jason H. "Electronics and Aerospace Industry in Cold War Arizona, 1945–1968: Motorola, Hughes Aircraft, Goodyear Aircraft." Phd diss., Arizona State University, 2006.

[4] L. J. Cutrona,"Synthetic Aperture Radar",The McGraw Hill "Radar Handbook",Chapter 23, pp.25, 1970.

[5] G. L. Charvat, " A Low-Power Radar Imaging System," Ph.D.dissertation,Deptartment of Electrical and Computer Engineering, MichiganState University, East Lansing, MI, 2007.

[6] B. Lovell," Echoes of War: The Story of H2S Radar", Taylor & Francis Group, New York, NY, 1999.

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