A Modern Approach to MIT's Coffee Can Radar

Initial Proposal

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For Bid Purposes

1 Mission Statement

Yesterday's Tech, Today's Children,
Tomorrow's Breakthroughs

2 Why Focus on Yesterday's Technology

The most ground breaking advancements of last two centuries are now within the grasps of every day people. Allowing today's students to become exposed to what was once ground breaking frees up higher education to continue raising the bar and allows for further breakthroughs. This project aims to allow high school aged students to experiment with topics which were once unavailable to them.

3 History and Introduction

Major investment in Radar started in 1930 for ship and aircraft detection with two major advancements being continuous wave (CW) and pulse radar. The continuous wave radar broadcasts a continuous wave where the interference and doppler-frequency shift effect can be detected on the receiver. This method was able to detect presence of an object but not the position. Pulse radar was then developed that pulsed the transmitted signal and measured the time delay of the echo which allowed for position and velocity [1].

This project will take a step further combining concepts from CW and pulse radar by using a continuous frequency sweep, chirp, instead of a pulse. The frequency shift caused by interference from objects can be observed using modulation techniques between the difference between the transmitted signal and the received signal. This is called Frequency Modulated Continuous Wave or FMCW.

4 Goals

1. Modernize the MIT system with modern components
2. Update learning materials for high school aged students
3. Keep affordable (150 USD)
4. Align project with STEM education and sponsor's missions

5 Function of a FMCW Radar System

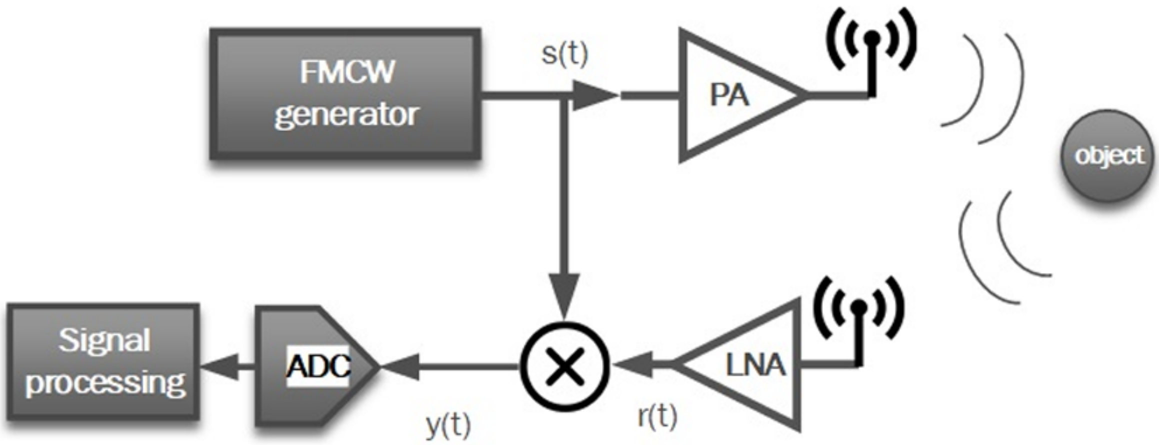

Figure 1: Block diagram of FMCW transmitter and receiver [2]

This block diagram starts with a FMCW generator that produces the frequency modulated continuous waveform called $s(t)$. The signal is then amplified by the power amplifier and transmitted through the antenna. The transmitted signal hits the object, causing interference in the waveform. The receive antenna then receives the interfered signal called $r(t)$. $s(t)$ and $r(t)$ are then mixed together to created the signal $y(t)$. The mixed signal $y(t)$ is then sampled in the Analog to Digital Converter so that the data may be processed to find location and velocity.

6 The MIT System

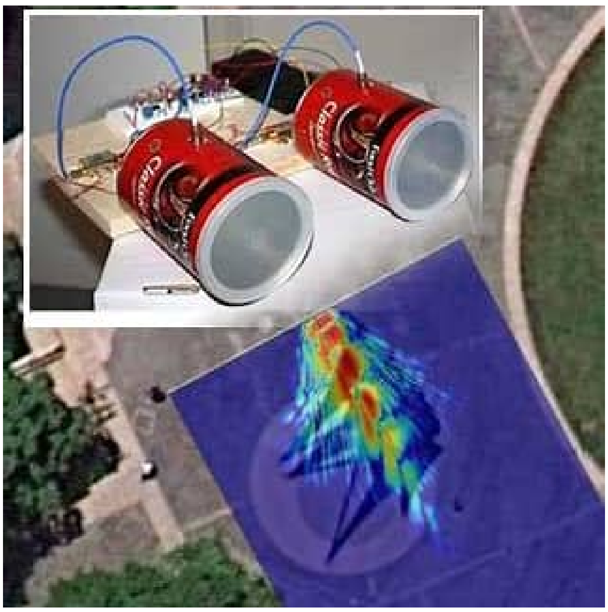

Figure 2: Finalized MIT Coffee Can Radar System with SAR Map [3]

The MIT coffee can radar system operates using the following key components

1. Operates in the S-band frequency range (2.4GHz)

2. Analog components for signal generation
3. Full MATLAB software package support
4. Uses PC microphone line in for sampling
5. Hand made antennas (coffee cans)

The main downsides of the MIT system is the lack of an easy to use kit version.

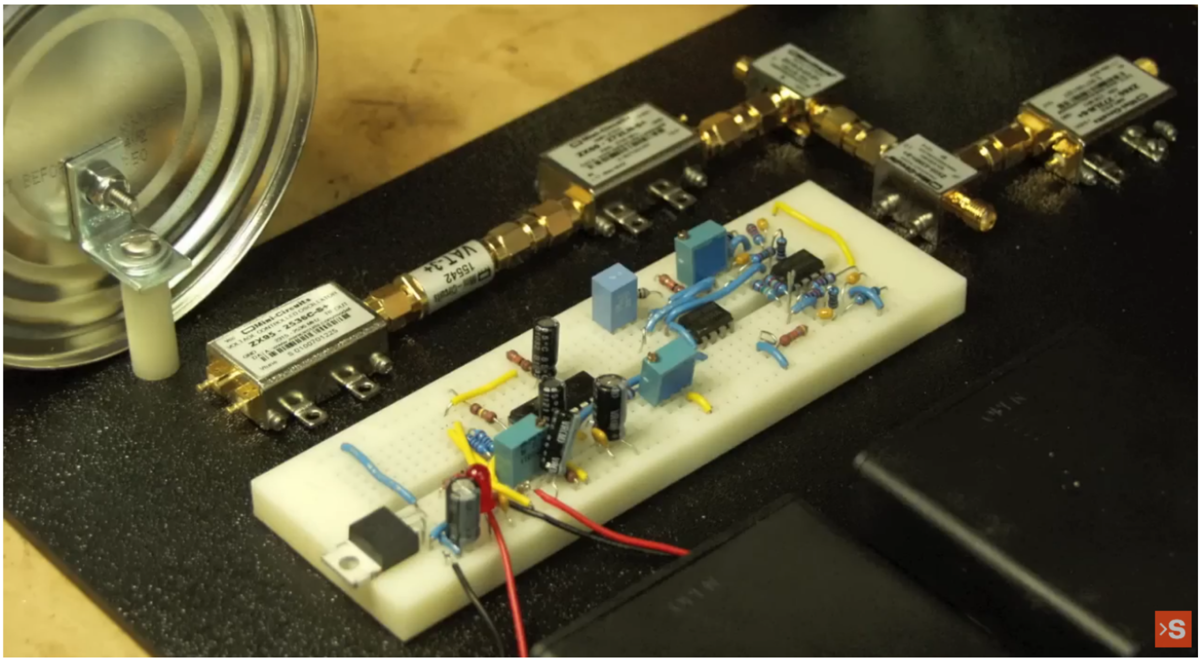

Figure 3: Breadboard circuit of the MIT Coffee Can Radar System [4]

Figure 3 shows the breadboard circuit of a radar system which would prove a challenge to undergraduate level students. This puts the project out of the reach of our target demographic of high school aged students.

In addition, many of the components used are no longer in production or should be replaced with ICs that are more functional and are cheaper.

7 Proposed Updated Radar System

There will be many features that will be the same as the MIT system and some which will be updated this includes the following:

1. Operates in the S-band frequency range (2.4GHz)
2. Modern components for signal generation and processing
3. Full software package support
4. DAQ or PC line in for data acquisition
5. Hand made antennas

The notable differences will be the use of modern components, software package that will derive from the MIT's MATLAB based one but not necessarily be in MATLAB. The potential use of a dedicated data acquisition component which will then be compared to the current line in method. Lastly, moving away from coffee cans for the antennas due to manufacturing moving to plastic.

8 Stage One (Proof of Function)

Stage one will act as a proof of function which will test the mathematical model of the radar system. This includes various simulations on the PC and on a Software Defined Radio.

Figure 4: Libre Software Defined Radio

Above is a software defined radio which allows for various waveforms to be generated. The output can be controlled by a computer and can be combined with mathematical models to output our radar system.

A basic software package that supports range finding and speed detection will be created as well.

Stage one will also determine the new antenna design where a suitable replacement to the coffee cans will be determined.

9 Stage Two (Discrete Components)

Stage two will build upon the mathematic model in stage one, using discrete components instead of running the model on the SDR. These components will be dedicated integrated circuits on their own breakout boards.

Figure 5: Voltage Controlled Oscillator Breakout Board

The figure above is a voltage controlled oscillator or VCO. This devices outputs the desired signal with a 2.4 GHz center frequency. This frequency can be adjusted using an inputted voltage which will act as our chirp.

Various other components such as filters, operational amplifiers, and various other passive components such as resistors, capacitors, and inductors will be used as needed.

Stage two will also act as our final kit ready package where each breakout board can be purchased independently and assembled via wires, cables, or by other methods. This kit will meet cost goal of $150. A bill of materials will be created where all components can be readily found on various suppliers. A 3D printable enclosure will also be created to hold all components.

Lastly, the software package will be fully flushed out with range and speed detection fully supported.

10 Stage Three (Wrap Up)

Stage three is an extension of stage two and will be considered a stretch goal. This means if there is time left over stage three will be started.

The goal of stage three is to integrate all components onto a PCB package. This will allow for a more streamlined kit with all interconnections already being made. This stage will not meet the $150 due to the low volume production of the PCB. This is intended to give the option for advanced users to build an all in one solution or for an instructor to have access to a more complete product to make it easier to teach younger students.

At this stage the goals are as follows:

1. FCC compliant PCB
2. Small footprint
3. Fully compatible with stage two (electrically and software support)
4. Creation of a course catalog

11 Timeline

December 2025

- Formulate mathematic models for the system
- Obtain all hardware for stage one

January to February 2026

- Complete stage one
- Ensure basic software package with range and speed detection

March to April 2026

- Start stage two
- Refine software package
- Presentation and report at MICS in Minneapolis [5]

May to June 2026

- Finalize stage two

July to August 2026

- Extra time for house keeping
- Start and finish stage three (if time permits)

12 Cost Analysis

Time is calculated at a rate of $20 per hour with 10 hours a week.

- Stage one: $2400
- Stage two: $3200
- Stage three: $1600

Testing equipment cost is an estimate allowing for at least two of each to be purchased

- Software Defined Radio: $500
- Vector Network Analyzer: $240

Software cost is an estimate allowing for at least one user for a time period of at least one year

- MATLAB: $100
- Simulink: $50
- DSP toolbox: $50
- Communications toolbox: $50

Component cost is an estimate allowing for at least two copies of each to be purchased

- VCO: $40
- Function generator IC: $10
- Various Active components: $100
- Various passive components: $20
- Cables and wires: $20
- Printed Circuit Board: $70

13 Information for the Sponsors and Supporters

Supporting this project can include monetary contribution however there are other ways to support the mission. The following are potential avenues for supporting the project.

Capital support methods

- Monetary
- Equipment or parts
- Software license(s)
- Expertise and time
- Publication and file hosting

Indirect support methods

- Posting on social media
- Connect potential users, high schools, JROTC, CAP, etc
- Your support through email, calls, and other communication methods

I encourage anyone to contact me at MilesBourassa@outlook.com, please include RADAR in the subject line. Potential sponsor for this project I would be interested in partnering with includes:

- Universities: Expertise and software license(s)
- Military supported youth organizations such as JROTC, CAP, etc
- High schools including their faculty and students
- Companies and organizations aligned with the project goals
- Private individuals who wish to contribute

There will be biweekly newsletters that will be emailed to all sponsors and interested parties that will contain all major milestones and other information pertaining to the status of the project.

References

[1] M. I. Skolnik, *Introduction to Radar Systems*, 2nd ed. New York, NY, USA: McGraw-Hill, 1980.

[2] M. Alizadeh, *Fmcw radar system*, Jul. 2019.

[3] Massachusetts Institute of Technology OpenCourseWare. "Coffee-can radar." Build a Small Radar System: Capable of Sensing Range, Doppler, and Synthetic Aperture Radar Imaging, January IAP 2011. [Online]. Available: https://ocw.mit.edu/courses/res-ll-003-build-a-small-radar-system-capable-of-sensing-range-doppler-and-synthetic-aperture-radar-imaging-january-iap-2011/resources/coffee-can-radar/.

[4] IEEE Spectrum. "Build a coffee-can radar." YouTube video. [Online]. Available: https://www.youtube.com/watch?v=Zr78A6cJDa4.

[5] M. Instruction and C. Symposium. "Mics — midwest instruction and computing symposium." Online resource. [Online]. Available: https://www.micsymposium.org/.