Design of a cost effective portable multimode Radar for surveillance application.

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***Abstract*— In the current pandemic situation, there is a shortage of private security guards which has resulted in increased concerns regarding homeland security. To address this issue, an integrated radar module operating at the 2.4 GHz ISM band has been designed in this project. The primary objective is to develop an affordable all-weather sensor for surveillance applications. The radar module operates using frequency-modulated continuous-wave radar technology and has a long-range detection capability. In case of any suspicious activity, the 24 GHz circuit is activated automatically.**

Keywords—continuous-wave radar, Doppler radar, frequency modulated continuous wave (FMCW), microwave circuit, multimode radar.

I. INTRODUCTION

Frequency-modulated continuous-wave (FMCW) radar has become increasingly popular in consumer applications due to its low cost and ease of implementation at microwave frequencies . It can provide information on radar cross-section, range, velocity, and vibration of any target [1], [2]. FMCW radars with specific applications are now readily available in the commercial market, and with the advancements in signal processing, artificial intelligence (AI), and machine learning (ML) techniques, they are being used in a wide range of applications such as automotive [3], security [4], healthcare, biomedical [5], and industrial fields [6].

The project is focused on the 2.4 GHz and 24 GHz ISM bands, it was discovered that there were no commercially available radars at the 2.4 GHz ISM band. Thus, most of the project's time was spent designing and implementing a portable multimode radar at 2.4 GHz. The Infineon Sense to Go radar was used for the 24 GHz ISM band. Finally, both radars were packaged into a single platform with a common processing unit. When the 2.4 GHz radar detects an intrusion, it sends a signal to power the 24 GHz radar, which then performs further analysis. This makes the complete system highly reliable for security-based applications.

II. DESIGN OF RADAR

The proposed radar module's block diagram is presented in Fig. 1, which includes several primary modules such as the RF module containing the transmitter and receiver blocks, baseband block, DC power distribution block, and an Arduino-based module for control, synchronization, and data collection. In the CW mode of operation, the frequency stabilization loop utilizes a voltage-controlled oscillator (VCO), a 1:4 Wilkinson power divider [7], a phased-locked-loop (PLL), a non-inverting amplifier, and a lowpass filter. The PLL is controlled using a stable 10 MHz clock as a reference.

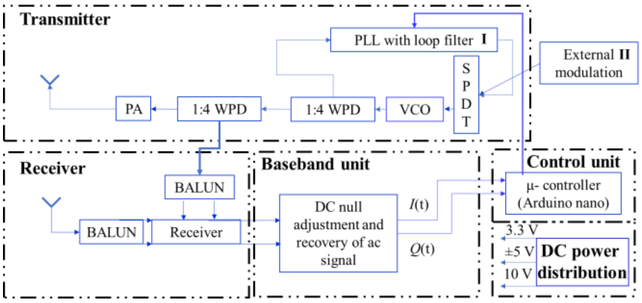


Fig. 1. Basic block diagram of multimode radar arcitecture.

To switch between CW and FMCW modes, a single-pole, double-throw (SPDT) switch is employed to either connect the voltage-controlled oscillator (VCO) to block I or II, respectively. In FMCW mode, the loop is used to calibrate the radar by setting the upper and lower limits of the RF transmitted frequencies. The phase-locked-loop (PLL) is controlled through a serial peripheral interface (SPI) to allow for software-controlled reconfiguration of the RF frequency. The tuning pin of the VCO is directly linked to an external modulation source (II) using the SPDT switch. To increase the peak transmitted power to 10 dBm, a power amplifier AG30286 is connected to the transmitter.

The radar module consists of a transmitter, receiver, DC power distribution, and an Arduino-based module. The transmitter has a voltage-controlled oscillator (VCO) for stabilizing the transmitted frequency. The receiver uses a quadrature demodulator IC AD8347, and the received signals are processed using a baseband circuit [8]. The power management module uses a micro-USB port and provides DC power to all ICs, including a stable 3.3 V and a dual power supply chip. The module has a total power consumption of 0.98 W.

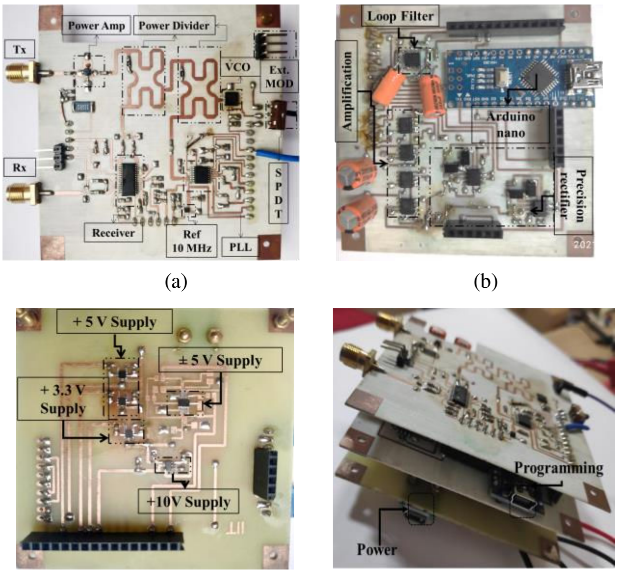
III. FABRICATION AND MESUREMENTS

The image in Fig. 2 displays the physical boards that have been manufactured for the radar system, with the RF layer using a Rogers 4003C substrate and the baseband and power modules using low-cost FR4 All measurements are carried out in laboratory environment Fig 3. The data is recorded using the 10-bit inbuilt ADC of the Arduino, with a baud rate of 11500.

A subject is positioned 5 meters away from the radar and performs different movements, which are recorded using the Arduino. Short time Fourier transform is taken in MATLAB and time domain and spectrogram data are obtained for I and Q channels. The results indicate that the radar can analyze human movements and provide a unique signature Fig 4 and 5, which could be useful for security purposes.

The FMCW radar is calibrated and a triangular wave with 1 kHz modulation frequency is applied to the VCO. Beat frequencies are measured for a person at 1.5 m and 1.0 m distance. The beat frequencies shown in Fig 6 are used to calculate the range of the person using the equation $f_b = 4BR_o/T_s c$ [1] where B is the bandwidth for the RF modulated signal, R_o is the distance, T_s is the time period of modulation and c is the speed of light.

This information in turn is used in order to power up the 24 GHz module [9]. The baseband signal form the module is used to enhance the resolution and prevent false alarm. Thus making the design efficient and compact.



(a) (b)

(c) (d)

Fig. 2. Photographs of the fabricated radar boards, (a) RF, (b) baseband and control, (c) power management boards, and (d) a 3D view before final integration. Total size after final integration is 8 cm × 8 cm × 1.5 cm.

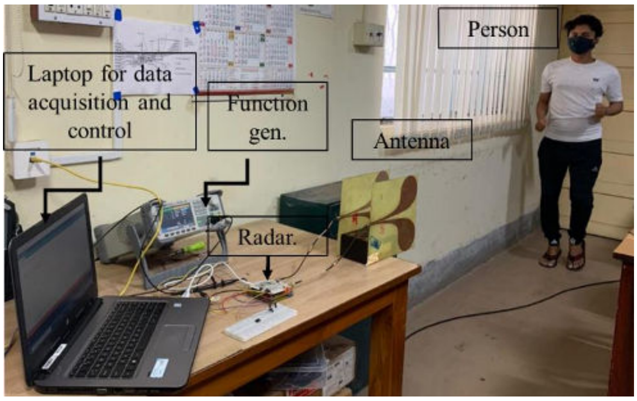
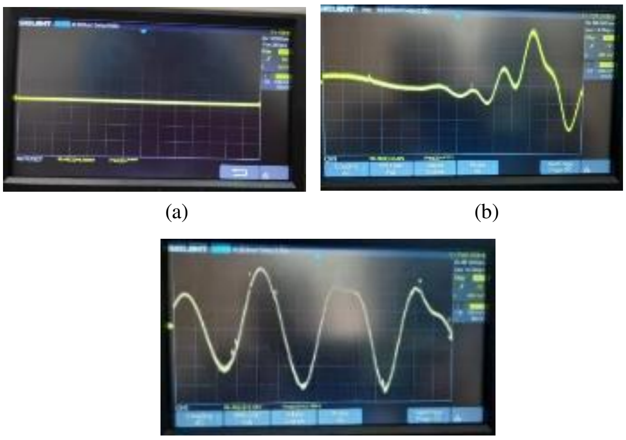


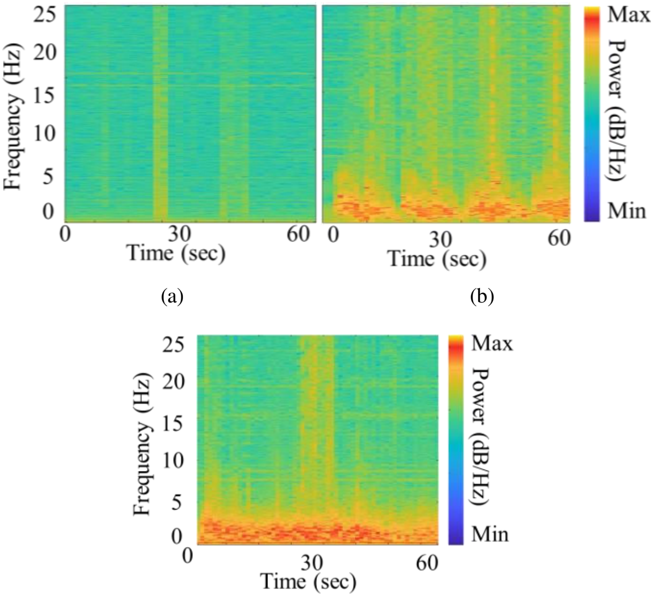
Fig. 3. Experimental setup during labrotary enviroment.



(a) (b)

(c)

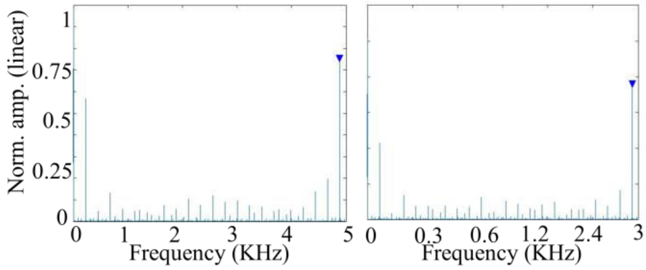
Fig. 4. Time doomain I-channel data displayed in oscilloscope, when a person is (a) standing still, (b) spot-jogging facing towards the radar, (b) and walking slowly towards the radar.



(a) (b)

(c)

Fig. 5. Spectrograms under different conditions, when a person is (a) standing still, (b) spot-jogging, (b) and walking towards the radar.



(a) (b)

Fig. 6. FFT of the beat signals showing (a) 4.87 KHz (b) 2.93 KHz.

IV. CONCLUSONI

A integrated radar module for security applications, capable of operating in CW and FMCW modes with selectable frequencies in the 2.25-2.50 GHz range is designed. This radar can be further used to power up the 24 GHz radar. It provides both I- and Q-components to avoid blind spots, and all hardware blocks are integrated except for the audio signal generator. The system has been fabricated and tested, and can be used as a standalone unit with a more powerful processing unit than the Arduino Nano.

V. ACKNOWLEDGMENT AND CARRER PLANS

The scholarship encouraged me to pursue my PhD in the field of Microwave Engineering. This research was also presented at the Wireless, Antenna & Microwave Symposium-2022 in India, where I received the best paper award in the Master's Category. I would like to express my sincere appreciation to my supervisor, Prof Mandal, for providing invaluable guidance and support throughout the project. His expertise in the field has been critical in shaping this research, and his constructive feedback has been essential in improving its quality. I am also grateful to the MTT community for their inspiration and to Mr. Jagannath Mukhi of the Department of E&ECE, IIT Kharagpur for fabricating the structure. I also thank my friend Biswadeb Dey for volunteering as a subject for the experiment..

VI. REFERENCES

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