

Implementation and Testing of Low Power FMCW S-Band Radar System Design for Small UAV

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Abstract— The paper importantly discuss about design of low power Frequency Modulated Continuous Wave (FMCW) S-Band (~2.3GHz) radar system, and then the implementation and testing procedure. The main system of FMCW S-Band radar consists of a ramp generator, a Radio Frequency (RF) System, and an audio amplifier. The ramp signal is generated from IC XR-2206 (modulator). This ramp signal is connected to a voltage-controlled oscillator (VCO), one part of RF system, to produce a chirp signal with varying frequencies as a result of inclined voltage signal (ramp signal) generated by modulator. Besides VCO, in RF system there are also signal amplifier (either for transmitting signal or receiving signal), splitter signal (for transmitting purpose) and mixer (for receiving purpose). Audio amplifier consists of a gain stage/amplifier and two-stages 15 KHz active Low-Pass Filter (LPF) which are applied to process the signal from RF mixer's output before being acquired through audio jack. At the front end of the system, two Vivaldi Antennas with 4dBi gain are installed and act as transmitter and receiver. The system is tested to detect simple corner reflectors placed in an area. The future application of this light weight and low power FMCW radar system is able to be mounted on a small Unmanned Aerial Vehicle (UAV) to do myriad tasks such as forest survey, crop monitoring, and reconnaissance.

Keywords— FMCW S-Band radar, Ramp Generator, RF System, Audio Amplifier, Unmanned Aerial Vehicle

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I. INTRODUCTION

NOWADAYS, one of important application of radar is monitoring wide environment because observation can be conducted both in day-night time and all-weather conditions. Furthermore, there are many radar sensors embedded on an Unmanned Aerial Vehicle for easier and wider-coverage in environment monitoring [1]. Because this sensor will be located in a small UAV, the radar sensor should be light weight and also low power [2]. Therefore, we chose Frequency-modulated Continuous-wave (FMCW) S-Band radar. The S-band frequency (~2.3GHz) is chosen because it lies between the longer L-band (1–2 GHz) and the shorter C-band (5–6 GHz)

and has been insufficiently studied for environment monitoring due to limited data availability [3].

The present work is concerned with system design of FMCW S-Band radar and the testing scenario to validate the result. The paper is organized as follows. The RF system design are explained in Section II. The circuit diagram of ramp generator, together with audio amplifier, is presented in Section III. Testing scenario of the whole system is presented in Section IV. Some simulations and results are included in Section V. Finally, the concluding remarks end the paper.

II. RF SYSTEM

The RF system diagram of FMCW radar is shown in Figure 1. Ramp signal from modulator will be passed to voltage-controlled oscillator (OSC1) to be transformed into chirp signal with varying frequencies. This chirp signal has power around 6dB and will be attenuated with ATT1 (-3dB) before passing power amplifier (PA1) since the power amplifier has input limitation about maximum 3dB. Output from PA1 will be splitted equally to two channels. The first channel is transmitter channel connected with Tx Antenna. The signal through this channel will be transmitted by Tx Antenna in the form of electromagnetic wave. The second channel is connected to the mixer MXR1. Signal in this second channel will be used for output reference. After the electromagnetic wave is reflected by the object(s)/land and received by Rx Antenna, the received signal will be passed through to a low noise amplifier (LNA). This LNA specification is similar with PA1 specification. Finally the output signal from LNA will be continued to the audio amplifier block.

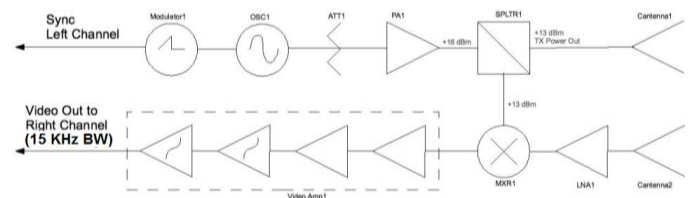


Figure 1 Design of RF system of FMCW S-Band radar [4]

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V. SIMULATION AND RESULT

Simulation

There are two components of radar system which we simulated, ramp generator and audio amplifier. We use software Multisim to conduct these simulation. Figure 8 shows the output simulation of ramp generator (modulator). As the scale in x-Axis is 20 ms/div, so the signal frequency is 50Hz, like what we need. As shown in the Fig. 8 that scale in y-Axis is 2 Volt/div and also that the minimum value in channel A is about 1.3 Volt, so the range voltage of the ramp signal lies between 1.3 Volt up to around 3 Volt.

Figure 9 shows the output simulation of audio amplifier. The blue pointer is located in -3dB and as our target is LPF with frequency cut-off in 15 KHz, we can see that the blue pointer shows y-Axis of the plot in 16.928 KHz. Despite not precisely with our target in 15 KHz, but the result is still tolerable. The plot looks like Band-Pass Filter (BPF) instead of simple Low-Pass Filter (LPF) because the gain stage (first stage of audio amplifier block) actually works also as passive High-Pass Filter (HPF). It is because we put additional resistor and capacitor before the gain stage. This HPF is needed to block 50Hz signal coming from the original signal (ramp signal) so that this 50Hz signal will not make ambiguity with the real raw data that we want to analyze.

Figure 10 shows the antennas which we used, Vivaldi antenna. Figure 10(a) and Figure 10(b) show the result in design and simulation process, while Figure 10(c) and Figure 10(d) show the result after manufacturing the design using PCB material.

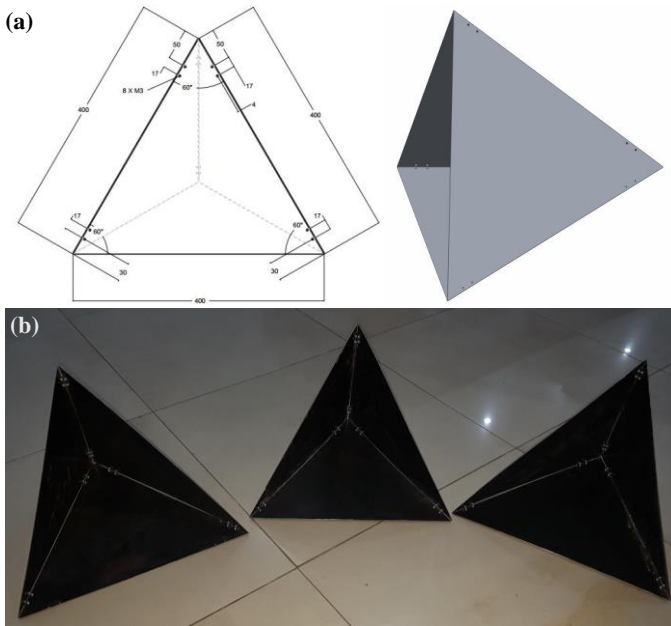


Figure 7 Corner Reflector:
(a) CAD design, (b) after manufacturing

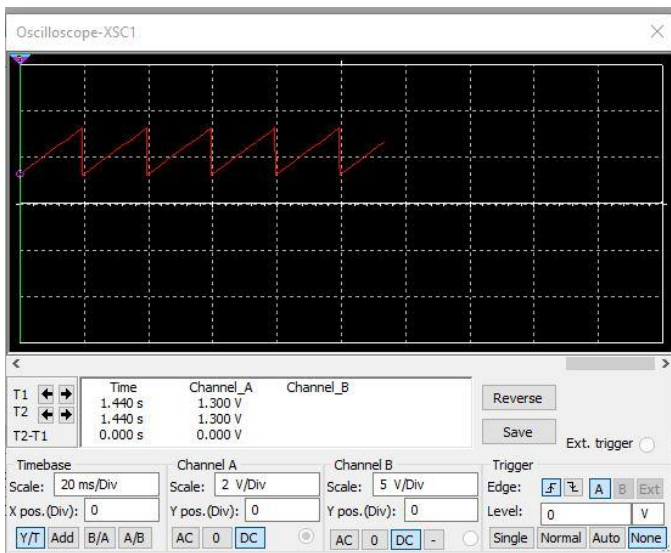


Figure 8 Output simulation of ramp generator

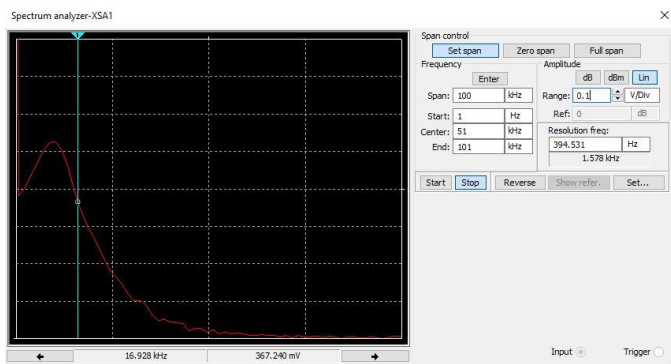


Figure 9 Output simulation of audio amplifier

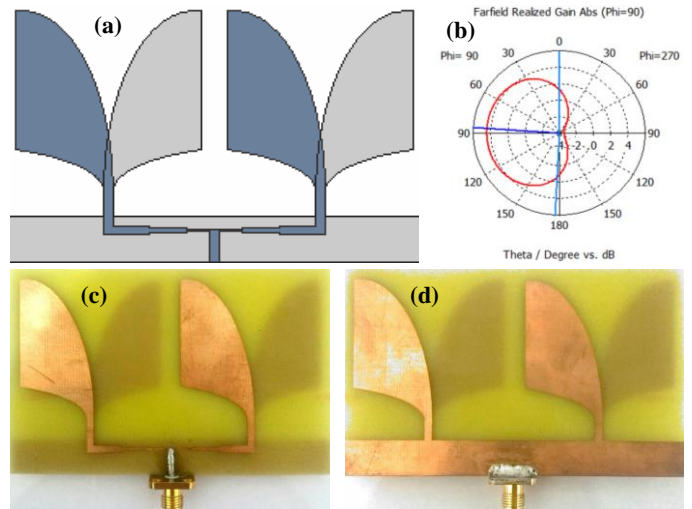


Figure 10 Vivaldi array antenna:
(a) Antenna design, (b) Radiation Pattern Simulation,
(c) Manufacturing result-front side, (d) back side

We conduct the real ground testing in a yard (Figure 11) with common object like car and also corner reflector(s) which have been made by us. We want to compare the result of those different objects. Figure 12 shows the result displayed from laptop. This result is the range detection result yield from post-processing step with software Matlab in our laptop. The data plot in Figure 12 shows two kinds of display result, the first is in frequency domain and the second is in range/distance domain

(for easier reading). From the second plot we can see that our radar detect two objects with different range/distance, in ~ 2.7 meters and in ~ 11.6 meters.



Figure 11 Real ground testing using corner reflector

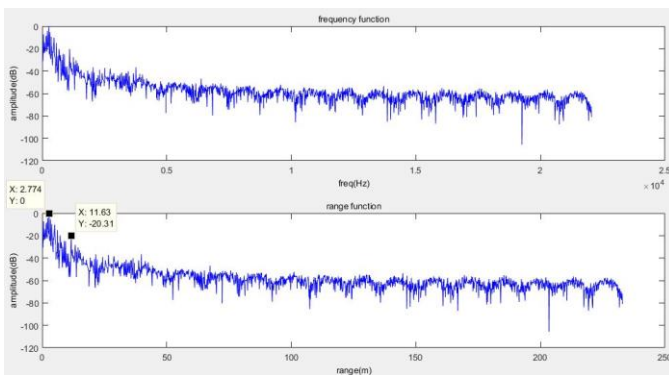


Figure 12 Plot result that shows range detection of object/target(s)

VI. CONCLUDING REMARKS

The design of FMCW S-Band radar has been embodied and also validated with both simulation and real ground testing. However, the testing was still in range detection while our ultimate goal is testing using a small UAV and the result is a map/2D radar image. Therefore, in the next future works we still need to improve the robustness, reliability, and the capability of our radar system to accomplish the ultimate goal.

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