Target Detection and Distance Measurement using Software-defined Radio as Radar

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Abstract - *One of the military's most important and old device is RADAR(RAdio Detection & Ranging), which is a device in which the electromagnetic waves of higher frequencies are transmitted into space through the antenna, where the guided waves are made to propagate in an unguided medium(space). This device has diverse applications and various types of requirements to enhance system performance. The development of radar on the Software-defined Radio platform increases the flexibility, reliability and functionality of the device by enabling it to be used as a multi-carrier system using OFDM modulation technique. The device uses a USRP hardware and open-source tool GNU Radio as software. The use of USRP accelerates the wireless aspect of this project. The hardware device used for this project is USRP b-200 mini that has Xilinx Spartan-6 FPGA device as its processor that enables us to develop broadcast, wireless communication automotive and other cost and power-sensitive application that requires transceiver capabilities in one module. This project's main aim is to reduce the size, weight and increase operating range form that of the existing system.*

1.INTRODUCTION

The earth is one of the most unique planets which has the seven layers of atmosphere which allows life. Exploring this enormous space is a matter of utmost importance because this not only represents the vast natural resources but it also helps us understand the complex, unrevealed part of our ecosystem.

There has been a lot of inventions and innovations in space technology that is being developed in the past few decades. One of the cutting-edge technology to serve ATC is RADAR. It was invented during the times of the second world war for detection of the attacking missile from the enemy base camp.

Radar is still being used to serve various Ballistic Missile Defense and space surveillance purposes with a lot more innovation and development. One of the recent on-going innovation is the Phased-array Radar, as the name says it uses a Phased-array of a dipole antenna with phase altering capability to perform the Radar operation. This Radar has a greater range and high power transmission and reception. It also covers are very large range and works at a various range of fixed high frequencies.

The main drawbacks of the Phased-array Radar are its bulkiness, the power required for pumping and absence of dynamic frequency range. Due to these disadvantages, even though there are various inventions and innovations in the Unmanned Aerial Vehicle (UAV), it is not possible to mount it on devices. To overcome this, many other technologies are invented. One such innovation is Software-defined Radar.

In Software-defined Radar, the RF front-end of the entire Radar system is defined by software. Hence, the specification, performance and functions are all achieved only through software. This type of construction makes the Radar more adaptable, flexible and scalable. Furthermore, this technology makes the Radar more customizable making it easily installable in various bodies from a car to a UAV. The MIMO(multiple-inputs/multiple-outputs) makes it a good product for better devices for wireless communication purposes since the data from the various antennas can be fused to minimize the errors as well as increasing the data speed. The advantage of Software-defined Radar over Phased-array Radar is its reduced size, low power consumption, less weight, decreased physical layer, increased usage of channel bandwidth, more accurate signal reception with less noise and greater data recovery and dynamic range of operating frequency.

The project uses multiple frequencies are effectively used using Orthogonal Frequency Division Multiplexing(OFDM), where each carrier is divided into sub-carriers for accurate transmission of the desired frequency at that particular instant using the orthogonality condition. This narrow band transmission and reception of high-frequency electromagnetic wave are deployed to detect and measure the distance of various targets for the military purpose. This model is designed to work at L-band frequencies, as this frequency range is appropriate for stealth detection and it can be transmitted over long distances with less attenuation and more precision.

2. LITERATURE SURVEY

1) COGNITIVE RADIO APPLICATIONS IN SOFTWARE DEFINED RADIO, By John Polson

In this paper, a survey of related cognitive radio topics is reviewed and candidate application architectures are presented. The topic of cognitive radios has been garnering an excellent deal of attention within the past several years. Opinions regarding the extent of sophistication necessary to qualify a system as cognitive vary widely, and discussions are insured regarding this technology. The software-defined radio forum is additionally involved and has working party activity within the area of cognitive radio. Some of the working group results are shown in this paper. Cognitive radio enabling technology, software-defined radio architecture, artificial intelligence technology, sensors and actuators for cognitive radio, etc are widely discussed in this paper.

2) IMAGING OF COMMERCIAL AIRCRAFT BY INVERSE SYNTHETIC APERTURE RADAR AND THEIR CLASSIFICATION IN A NEAR-RANGE RADAR NETWORK, By Th. Sauer, K.H.Bethke, F.Buettner, B.Roede, A.Schroth

In this paper, imaging of a commercial aircraft by ISAR in the near range radar network is explored. The near range radar network is a sensor for the surveillance of the ground traffic at the airport. It localizes targets, evaluates the vectors of velocity, and classifies the targets. For the latter task, microwave images of the moving objects obtained by the principle of ISAR utilized. The most important processing steps are the range alignment and the preface compensation of the measured range profiles, which are accomplished by a huge transform algorithm and an auto-focusing technique, respectively. For the final classification projections of the pixel intensities onto 2 orthogonal axes are extracted and evaluated by a correlator.

3) FMCW RADAR IMPLEMENTED WITH GNU RADIO COMPANION, By Zhu Qizhao and Wang Yaqi

In this paper, the FMCW radar is analyzed and simulated in GRC. Continuous-wave frequency modulated radar or FMCW radar is straightforward in design, small in size and weight and uses low transmitting power. The range resolution depends on the bandwidth. FMCW radar is used applications ranging from guided weapons systems 2 vehicle collision avoidance systems. Measuring the distance to the target is the essential feature of FMC W radar. Firstly, this thesis introduced the basic structure of the FMCW radar and the principle for measuring the distance. Secondly, by using software-defined radio, FMCW radar can be implemented and configured with the reduced cost and complexity.

4) SIMULATION OF FMCW RADAR SYSTEMS BASED ON SOFTWARE DEFINED RADIO, By Carlos López-Martinez and Marc Vidal-Morera

This paper addresses the implementation of a frequency modulated continuous wave radar based on software-defined radio. In particular, a USRP device implementing the radar system is simulated to determine the radar performances especially in terms of achievable range and arrange a spatial resolution. The Ettus system X300/X310 equipped with a UBX 10-6000 MHz receiver/transmitter daughterboard is considered. The different simulations demonstrate that the radar would achieve a range of three km with a range resolution in the order of 10 meters. Additional simulations at different carrier frequencies detail the achievable radar performances.

5) DESIGN AND IMPLEMENTATION OF A 24 GHz MULTICHANNEL FMCW SURVEILLANCE RADAR WITH A SOFTWARE-RECONFIGURABLE BASEBAND, By Eugin Hyun, Young-Seok Jin and Jong-Hun Lee

In this paper, a 24 GHz surveillance FMCW radar is designed and developed with the software reconfigurable based band. The developed radar system consists of a transceiver, two selectable transmit antennas, 8 parallel receive antennas, and a back-end module for data logging and to regulate the transceiver. The architecture of the developed radar system can support various waveforms, gain control of receive amplifiers, and allowed the choice of two transmit antennas. To do this, a frequency synthesizer device and a two-step VGA along with switch controlled transmit antennas are implemented in the receiver. To support high-speed implementation features alongside good flexibility, a rear module supported an FPGA is developed with the parallel architecture for the real-time data logging of the beat signals received from a multichannel 24 GHz transceiver. To verify the feasibility of the developed radar system, signal processing algorithms were implemented on a number PC. All measurements were administered in a room to extract a 3D range-Doppler angle map and target detections.

3. PROPOSED SOFTWARE-DEFINED RADAR SYSTEM

The software radar architecture proposed in this work is developed to create a low-cost, compact, and flexible solution for an accurate target detection; potentially, this scheme can be easily adapted in different scenarios without significant hardware modification, thus leading to create a multipurpose radar system.

The complete block diagram of the proposed SDRadar system is reported in Figure1. The USRP B200mini platform is used to transmit and receive data by a linear array antenna with specific bandwidth and directivity features useful for the prescribed application.

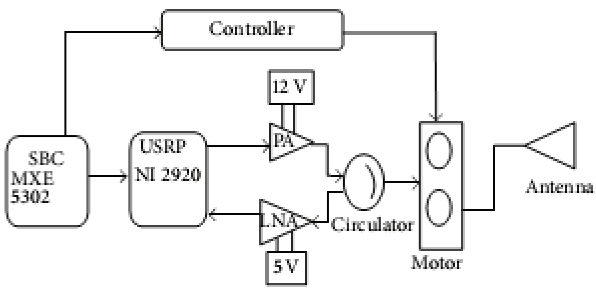

Figure 1: Proposed SDRadar System Block Diagram

The description of the hardware and software used is in the following paragraphs:

A. Hardware

i) USRP B200 mini

The USRP B200mini is a software-defined radio that has a 1x1 mode of the channel for transmission and reception. This device has a wide frequency range from 70MHz to 6GHz. It is having a programmable Spartan-6 FPGA that is from Xilinx and this is flexible and compact for users. This device has a bandwidth of 56MHz. The receiver noise figure is less than 8 dB. This device is powered using a 5V power supply and gives an output power greater than 10 dB. It is very small in size and can be operated in a range of 0-40°C.

ii) Antenna

An antenna is an interface between radio waves propagating through space and electric currents moving in metal conductors, used with a transmitter or receiver. The antenna is omnidirectional which uses 2.5mW to get energized. It has a compact structure which allows it to be mounted on other parent devices.

B. Software

GNU Radio is a free & open-source software development toolkit that provides signal processing blocks to implement software radios. It can be used with readily-available low-cost external RF hardware to create software-defined radios, or without hardware in a simulation-like environment. It is widely used in research, industry, academia, government, and hobbyist environments to support both wireless communications research and real-world radio systems.

4. WORKING

- The USRP Source block is associated with the receiving antenna of the USRP module used. The noise in the surroundings is initially received as input signal and further sent to digital processing modules of the process.
- The input noise signal is then given to an OFDM modulator block which performs OFDM modulation on the signal for low ISI and better efficiency.
- The throttle block is used to combat CPU congestion and also to act as a buffer between the different modules in the process.
- This signal is then observed using FFT sink and scope sink which show the FFT plot of the signal respectively.
- This signal is then given to a Multiply Const block which multiplies a uniform signal with a set amplitude to the input noise signal.
- A Signal Source block is used to generate a cosine waveform of high frequency.
- The cosine and waveform and the product waveform are then given to an Add block which performs addition on the two signals mimicking an ADC operation.
- This meta output waveform is then observed using FFT sink and Scope sink to check for similarities or differences between the input and meta output waveforms.
- Virtual Source and Sink blocks are used to achieve a null connection for convenience.
- The Virtual Source block is connected to output sinks as well as the USRP Sink which is associated with the transmitting antenna of the USRP module.
- The output waveform is observed using the FFT sink and Scope sink. The output waveform is converted to a wave file format using File Sink and Wav File Sink blocks.
- Now the output wave transmitted is received as an input signal by the USRP Source block due to orthogonal placing of the transmitting and receiving antennas of the USRP module.
- The whole process is applied to that input signal and it is transmitted again. This feedback like cycle achieves the Active Radar on a single module.
- In the process, appropriate conversion blocks are used to connect blocks that have different input type.

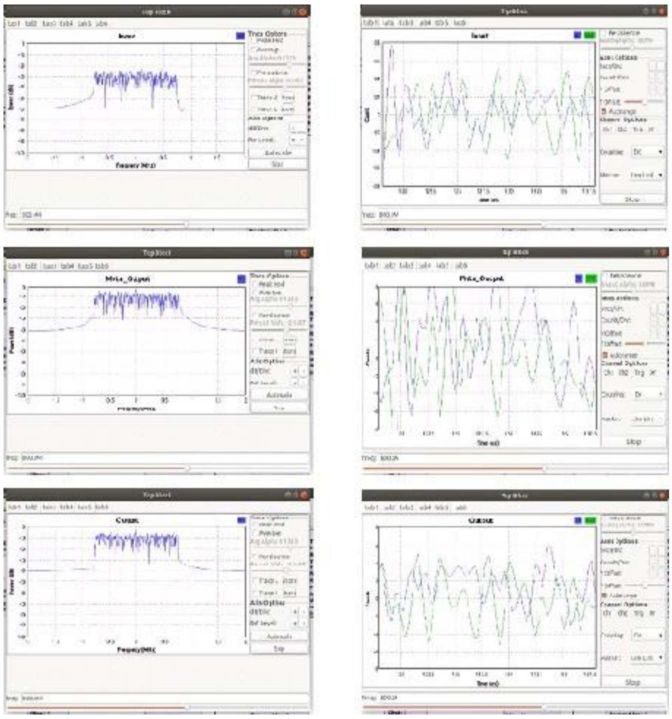

Figure 2: Inputs and Outputs

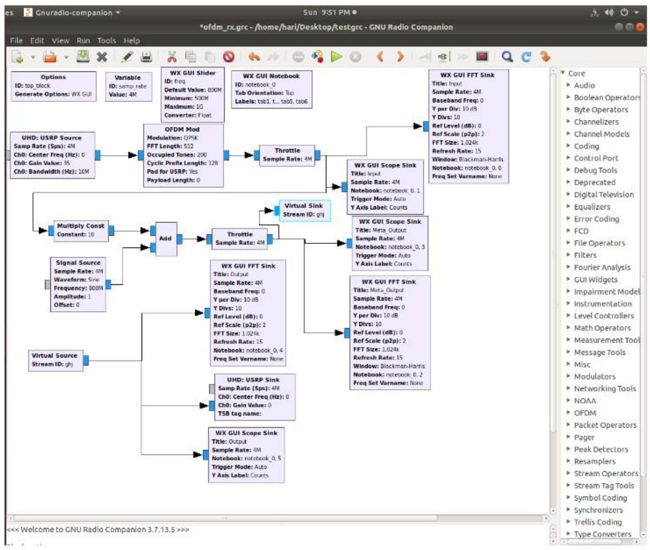

Figure 3: Basic Block Diagram

5. CONCLUSION

The project generates L-band Electromagnetic signals to detect the target and determine the distance. The use of highly sophisticated hardware and software with the Graphical User Interface using GNU-Radio open software tool reduces the computation complexity and increases the functionality of the existing radar device.

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