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Hdl Implementation of Algorithm To Detect The Proximity of A Moving Target

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Abstract: Radar Signal Processors heavily possess the capabilities of traditional microprocessors based signal processing systems. Higher performance systems using custom-made silicon, cost too much for the typically small production volumes and are not flexible enough for research applications. The performance of custom-made silicon while maintaining the economies, the Field Programmable Gate Arrays offer too much flexibility in comparison to traditional microprocessor-based solutions. The recent device possess the density and performance to realize a complete radar signal processor in a single FPGA, including complex down conversion of the IF to baseband. The commercially available FPGA boards eliminated the specific chips required for the down conversion and matched filtering. Thus, the use of FPGA has been increased extensively.
In the field of motion detection, the researchers have shown various deviation detection methods for efficient detection of small moving targets. These algorithms can detect moving objects deviation in a properly defined attribute space. The deviation is defined as an object distinct from the objects in its neighbourhood. In this work, we are going to increase the proximity range for the moving targets. The BPSK Modulation is going to be used in this for getting the correct and enhanced input signals.
The work completely relates to a Radar system where speed and accuracy could not be ignored. In this work, an algorithm has been implemented to detect the proximity of a target. The major challenges in developing this algorithm are to detect the target when it is coming towards Radar within a specified range (0 to 55 meters) with a range resolution of 3.4 meters.
Index Terms: Background Subtraction Algorithm, Correlation, Doppler Effect,FPGA, Moving Target Detection, RADAR, VLSI.

I. INTRODUCTION

The devices that use radio waves to determine the range, angle or velocity of objects is called Radio Detection and Ranging (Radar). Radar is an object-detection system. It can be used in Avionics, Aeronautical, Marine systems, naval operations, Weather forecasting and in transportation too. Every radar-based system contains the transmitter that is producing the electromagnetic waves, a transmitting and receiving antenna sometimes also referred as Transceiver and a receiver and signal processor unit to determine the properties of the object(s)[1]. To get the information about the object's location and speed the transmitter used to send the radio waves (pulsed or continuous) and the reflection from the object goes to the receiver. The radio waves emitted by the transmitter side called radar signals are always in predetermined directions. After hitting the object, these waves generally get reflected or scattered in almost all directions.

The radar signals when comes into contact with the target which are made of materials of electrical conductivity especially by most metals, seawater and by wet ground, are getting reflected properly. Some of these objects make possible the use of radar as an altimeter. The reflected radar signals towards the transmitter complete the working of a radar system. Now to identify that if the object is moving either towards or away from the transmitter, there is always a slender change in the frequency of the radio waves, due to the Doppler Effect. The frequency shift is caused by motion that changes the number of wavelengths between the reflector and the radar. These changes can intensify or decrease the radar performance depending upon how that affects the detection process.

The use of this particular algorithm[2] could be used in many types of object's motion detection. The special device that detects moving objects, particularly people. Such devices are often embedded in a system that automatically performs a specific task or notifies the motion in an area. These devices can be a vital component of security, automated lighting control, home control, energy efficiency, and other useful systems. Nowadays, Motion detection is an extensive area of research. Because of niche technologies, the interest in the uses of motion detection in everyday life is increased e.g. automated traffic monitoring, homeland security without the guard, video surveillance for remote monitoring. There are different approaches for identifying locations of the moving objects, some of them are based on the background subtraction, multimodal Gaussian distributions, the statistical models[3].

A. Basics Of Radar System

Radio detection and ranging are usually known as Radar. It is an electromagnetic system used for the detection and location of objects or targets. The detection and ranging of an object or target can be achieved by sending electromagnetic waves towards the object and extract the information about the target from the returned echo[4]. This information is drawn from the changes observed in the signal parameters. The time taken by the radar signal to traverse to and fro from radar to target is used to determine the range or distance. Or in other words, it is calculated from the travel time measurement by the radar signal in forward and returned direction from the target. The properties of the radiated electromagnetic energy made it possible for the measurement of range, or distance.

1) The electromagnetic waves are reflected if they meet an electrically leading surface. If these reflected waves are received again at the place of their origin, then this means that the target is moving.
2) Electromagnetic energy travels through air at a constant speed, at approximately 300,000 kilometers per second or 186,000 statute miles per second or 162,000 nautical miles per second like a speed of light. This constant speed makes possible the measurement of the distance between the reflecting targets and the radar site by calculating the change of time of the transmitted pulses and reflected pulse[5]. By implementing these principles in the radar system, makes it possible for the system to calculate the distance, the direction and the height of the reflecting object. The ability to determine range by measuring the time for the radar signal to propagate to the target and back is probably the distinguishing and most important characteristic of conventional radar. This work describes a new algorithm to detect the closeness of a target within specified range within a short period of time. The proposed method uses Binary Phase Shift Keying (BPSK) Modulation Scheme using Pseudo Random Binary Sequence[6]. The principal of Doppler radar is used to detect motion, and are very much similar to a radar speed gun. A continuous wave of microwave radiation is transmitted, and the continuous change in phase in the reflected microwaves results in a heterodyne signal at a low audio frequency. This phase shifts occurs due to the motion of an object towards or away from the receiver.

B. Radar Digital Signal Processing Architecture

Figure 1 shows the Radar based Digital Processing Architecture. Most of the signals are reflected by the objects or to the objects are propagates and received through the analog antenna or antenna elements. And for processing these analog signals it has to convert into the digital domain. The receiver typically includes down conversion and beam forming elements, as shown in Figure 2. The emitter includes pulse generation, beamforming, and digital upconversion. The processing elements in radar processes information to enhance the signal capacity, to remove environmental effects, to detect target location and the velocity, and hence perform other tasks such as system control.

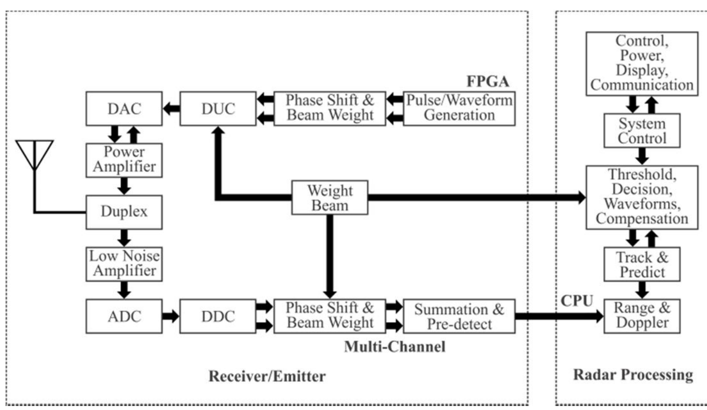

Fig.1 RADAR Digital Processing

II. PROPOSED BLOCK DIAGRAM

The complete system has been divided into two sections one is the transmitter section and receiver section. The transmitter section contains the Pseudo Random Binary Sequence (PRBS) generator block, an optional Signal catcher circuit from moving target, BPSK modulator and a DAC circuit

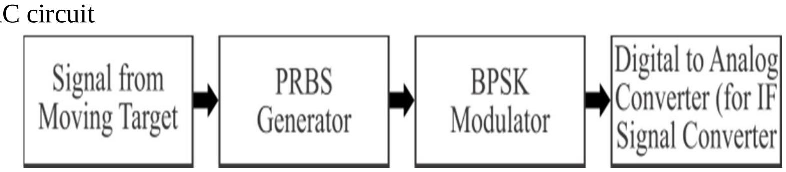

Fig. 2: Transmitter Section

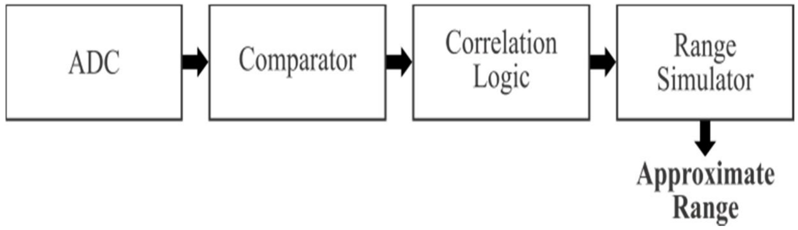

Fig. 3: Receiver Section

While the receiver block contains the ADC block followed by the comparator, digital correlator, and range simulator block.

A. Pseudo Random Binary Sequence

To generate any random binary sequence(s) a circuit designer employes Pseudo Random Binary Sequence (PRBS). This circuit or structure provides the next value of an element in any sequence, this value is independent of values of any other elements. The term pseudo tells that the particular sequence is deterministic and after N elements it starts to repeat itself unlike any other real random numbers like random sequence are radioactive decay and white noise. A binary sequence is pseudo-random if their autocorrelations function:

$$C(v) = \sum_{j=0}^{N-1}(a_j a_{j+v})$$

Which has only two values i.e.,

C (v) = m if v = 0 (mod N)

C (v) = mc if v ≠ 0 (mod N)

Where c = (m –1)/ (N –1) which is called as the duty cycle of PRBS.

The Linear Feed Back Shift Register (LFSR) PRBS can be used to generate PRBS[7]. The feature of the period of maximal length tap sequence is the length of the output stream of an LFSR before it repeats itself. Besides being non-repetitive, a period of maximal length stream has other features that are characteristics of random streams.

1. In a period of a maximal length sequence data, the sum of all zeroes will always be less than the sum of all ones by one.
2. The length (N) of the maximal length sequence is maximum when N = 2^m–1, where m is a number of shift register stages.
3. In the maximal sequence length, the runs of ones and zeros in a pattern will be of equal values in the bit stream. One period of an n bit LFSR with a maximal length tap sequence will have 2^n –1 runs. For example, a 5-bit device yields 16 runs in one period. 1/2 the runs will be one bit long, 1/4 the runs will be 2-bits long,1/8 the runs will be 3-bits long; up to a single run of zeros that is n –1 bits long and a single run of ones that is n bits long.
4. In one period of an LFSR, the shifted stream take the stream of bits with a maximal length tap sequence and also circularly shift it any number of bits less than the total length. By performing a bitwise XOR with the previous one. It is another replica of same with a shift different from either one. In this sequence is generated with a period of 3.1 microseconds at 10 MHz frequency.

B. Binary Phase Shift Keying (Bpsk Modulation)

In Binary phase shift keying modulation, the binary data are represented by two signals with different phases. Typically these two phases are 0 and π, the signals are

S1 (t) = A cos2πfct, 0 ≤ t ≤ T, for 1

S2 (t) = –A cos2πfct, 0 ≤ t ≤ T, for 0

These signals are called antipodal. Due to the minimum error probability and having correlation coefficient -1, the BPSK modulation preferred. The transmitted radio frequency Signal undergoes BPSK modulation with respect to the PRBS generated and returned back once it hits the target[8]. As the signal travels some distance, the received signal will be exactly the same as the delayed version of the transmitted PN sequence. The received signal is down converted to IF signal in the mixer The IF signal has purely the information about range.

C. Received Signal

The received signal is the IF signal which we get from the BPSK modulation with the PRBS. This signal undergoes time delay and Doppler shift. Since the signal goes through the Doppler shift, so it is hard to get the PRBS sequence. As the Doppler amplitude appears at maximum whenever received code patterned with delayed transmitted code. In order to extract the PRBS, the received signal has to pass through Analog to Digital Convertor.

D. Range Simulator

The range simulator is been designed to store the delayed versions of the transmitted PRBS. The correlator circuit will use the input from the output of the range simulator. The output is used as a reference input into the correlator circuit. The Serial in Parallel out Shift Register circuit has been used for implementing the range simulator. The generated PRBS are having a 10ns delay.

E. Correlation Logic

The Correlation process has been carried out by the Pseudo Random Binary Sequence. This PRBS is extracted from the delayed versions of the reference sequences generated by the range simulator. Here the equivalence checking has been carried by performing XNOR operation of the inputs of the correlator(s) and then accumulate the number of matches. For peak detection, the count value must be greater than the threshold. The threshold is set by the maximum number of matches, also called the loopback testing, just by transmitting and receiving the PRBS alone and by performing the correlation. The peak detected is valid when 3 peaks are continuously detected. Then the delay is noted down and the closeness of the target to Radar is calculated.

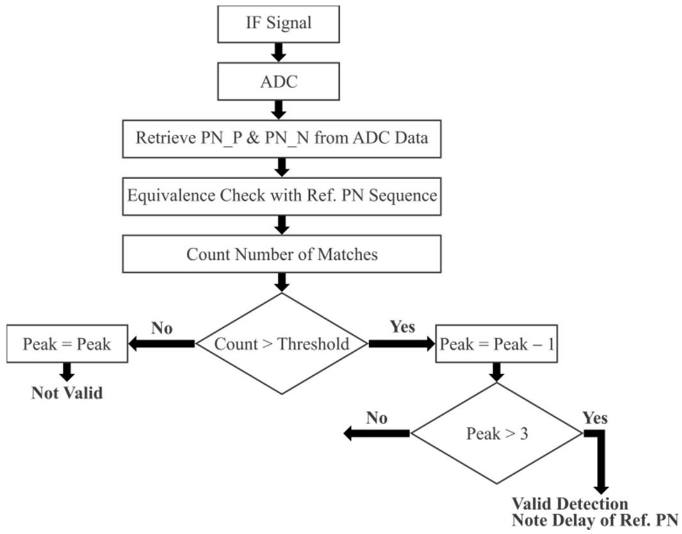

Fig.4: Correlation Logic - Flow Chart

1) Explanation

After applying DAC at the transmitter side the transmitted signal is passed through ADC. This received signal is the IF signal. To extract the PRBS we need to notice the IF signal amplitude. The PRBS bit of the received signal is ‘1’ only when the IF signal amplitude is maximum otherwise ‘0’. This extracted PRBS is digitally compared with the transmitted PRBS and its delayed versions. This process continues for one period and considered as a valid detection, only when the count value exceeds the threshold value. And if this valid detection is observed more than 3 times then the delay of the reference PRBS is noted down to calculate the range.

The above process is implemented through the given algorithm:

Step 1: Input the IF signal amplitude

Step 2: Retreive Pseudo random binary sequence bit

Step 3 : If PRBS_ bit == 0 , IF amplitude = max, else 0

Step 4: Compare PRBS bit with transmitted PRBS

Step 5: If count value > threshold value ,increment valid detection count

Step 6: If valid detection count < 3, repeat

Step 7: else end

F. Digital Correlator

The equivalence of the received PRBS with the delayed versions of the transmitted PRBS has been carried out in the digital correlated/equivalence checker circuit. This circuit has the capability of detecting the target within the range of 55 meters with 3.4 meters resolution[9]. Thus 16 correlation logics have been incorporated into the design. All correlation logics are processing in parallel. To calculate the range, the correlation logic with valid peak detection is taken and the delay of the reference PRBS of the respective logic is noticed[10].

III. RESULTS

Table 1 depicts the simulated results and draws a comparison between the previous result and those obtained through our algorithm.the results are increasing and show a significant improvement over the previous result.All the results are been extracted from the XILINX ISIM tool.

Parameters	Present work	Previous work
Minimum Period (ns)	3.479	5.304
Max. Freq.(MHz)	287.480	188.541
Number of Slices	517	1145
No. of Slice FFs	542	846
No. of 4- Input LUTs	941	2095
No. of GCLKs	3	3

Table1: Comparison Table

IV. CONCLUSION

We designed the algorithm by using VHDL coding and implemented in Xilinx Vertex-4 SLX-35. By implementing this proposed technique, the location of any object within 55mts can be found with a range resolution of 3.4mts. The closeness of the target can be detected if the target is in 55 meters radius in any direction. We can even extend the algorithm for estimating the direction of the target by considering angle resolution, implementing same design in different channels with respective angle resolution.

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