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FPGA based Solution for the Identification of RADAR Pulse Sequences for Defense Applications

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Abstract

The main objective of this paper is to design a generalized architecture for polyphase code identification used in RADAR signal processing applications. The proposed VLSI architecture will identify the type of a given polyphase code, amount of phase change and number of phase changes. RADAR signal processing applications require a set of sequences with individually peaky autocorrelation and pair wise cross correlation. Obtaining such sequences is a combinatorial problem. This paper aims at implementation of an efficient VLSI system for the design of polyphase codes identification useful for RADAR applications. The VLSI system is implemented on the field programmable gate array as it provides the flexibility of reconfigurability and reprogrammability and it is a real time signal processing solution which identifies the polyphase codes. The simulation results and the FPGA implementation shows the successful code identification, amount of phase, number of phase changes for a given input sequence.

Index terms— code identification, phase identification, frank codes, polyphase codes, RADAR, FPGA, VLSI, LPI.

1 Introduction

olyphase code identification and localization are basic and important problems in RADAR systems. Localizing the received code is an important task in the detection of polyphase codes. Localization of the received signal can leads to incorrect target range measurements. Pulse RADAR that uses pulses as the RADAR signal is being used in aviation control, weather forecasting, and ships. The strength of the received signal by the radar varies with the distance from radar to the target and is also dependent on the target RADAR cross section. The proposed architecture will identify the type of polyphase code, amount of phase change and number of phase changes among the polyphase codes which are present in the Low Probability of Intercept (LPI) RADAR. Identification of these parameters like code, phase, number of phase changes can reguide and retransmit to the transmitter without any effect to our electronic systems. With this system the unwanted signals are retransmitted to the transmitter.

II.

2 Polyphase Codes

The transmitted complex phase coded signal can be expressed in the following form (1) where A is the amplitude, f c is the carrier frequency and is the discrete phase sequence. Each phase has the same time duration. In the following, five different polyphase pulse compression codes are presented. The codes presented are the Frank, P1, P2, P3, and P4 codes.

3 a) Frank Codes

The Frank code is a step approximation to a linear frequency modulation (LFM) waveform using N frequency steps and N samples per frequency. Thus, the total number of samples in a Frank code is N 2 . The phase of the i th sample of the j th frequency of a Frank code is given as (2) Where and.

The pulse compression ratio of the Frank code is N 2 . The Frank code has the highest phase increments from sample to sample in the center of the code, where the numbers represent multiplying coefficients of the basic phase angle .

4 b) P1 Polyphase Codes

The P1 code also consists of elements as

Frank code, that way P1 code signal with N=4 produces a matrix of 16 different phases, if N=8 produces a matrix of 64 phases. In a p1 code, the phase of the i th sample of the j th frequency is given by (3) where and .

5 c) P2 Polyphase Codes

This code is essentially derived in the same way as the P1 code. The P2 code has the same phase increments within each group as the P1 code, except that the starting phase is different. The P2 code is valid P for N even, and each group of the code is symmetric about 0 phases. In a p2 code, the phase of the i th sample of the j th frequency is given by (4) where and .

6 d) P3 Polyphase Codes

This code is derived by converting a linear frequency modulation waveform to baseband using a local oscillator on one end of the frequency sweep and sampling the In phase component I and Quadrature component Q at the Nyquist rate. If the waveform has a pulse length T and frequency

, where k is a constant and the bandwidth of the signal will be approximately.

The bandwidth will support a compressed pulse length of about and the waveform will provide a pulse compression ratio of.

Assuming that the first sample of I and Q is taken at the leading edge of the waveform, the phases of successive samples taking apart are

Where . Substituting and , the equation can be written as (6) e) P4 Polyphase Codes

The P4 code consists of discrete phases of the linear chirp waveform taken at specific time intervals and exhibits the same range Doppler coupling associate with the chirp waveform. Phase code elements of the P4 code are given by (7) where .

7 f) Barker Codes

Barker sequence is a finite sequence of N values of '+1' and '-1'.The coding scheme used in direct sequence spread spectrum (DSSS) radio systems. Ai for i=1, 2, 3 ?.N. such that the off peak autocorrelation coefficients (8) For all

. Barker codes are used for pulse compression of radar signals. There are Barker codes of lengths 2, 3, 4, 5, 7, 11, and 13, and it is conjectured that no longer Barker codes exist.

III.

8 Proposed Architecture

Figure **??** show the block diagram for code identification, phase identification and number of phase changes identification. An input sequence of N bit length is applied to the proposed system. The first 3 MSB bits X N-1 , X N-2 , X N-3 are useful for code identification and the remaining bits from X N-4 to X 0 bits are used for phase identification. The input code word format is shown in table1.

X N-4 phase identification bits will give the 2 N-4 phase changes. The system will find which type of code it is by comparing the coefficients of those respective codes i.e. whether it is Frank, p1, p2, p3, p4 and Barker Generalized Input Code Word codes that are store in the memory. The system has other inputs of clock and reset signal. The count block will give the number of phase changes in the respective code. The registers fp, pp1, pp2, pp3, pp4 are useful for storing the amount of phase change from the adjacent alphabets of the codes.

9 a) Code Identification

When an input code word shown in table 1 is given by the MSB bits X N-1 , X N-2 , X N-3 are used for code identification where the code identification bits X N-1 , X N-2 , X N-3 are given as inputs. The output is the corresponding identified (frank, p1, p2, p3, p4 and barker) code. Figure 2 shows the generalized block diagram for code identification. The code identification logic and its corresponding input output relationships are shown in the table 2. When the code identification bits are 000 then it will identify as frank code and similarly when the code identification bits are 001,010,011,100 and 101 they correspond to the p1, p2, p3, p4 and barker codes respectively. Code identification output enables the corresponding phase identification units. Based on the identified code, the corresponding state machine will be activated. The counter will identify the number of phase changes in the given sequence. For the N-4 bits it will identify 2 N-4 phase changes. The enable inputs are useful for activating the appropriate state machine for calculating the number of phase changes and amount of phase. The State machine consists of 2 N-4 states and 2 N-4+1 outputs and N-4 inputs. The figure 5 shows the N-4 inputs and N-4 next state outputs and corresponding complements. The reset and clock are given as the other inputs of the phase identification unit. ? ? ? k i i 1 Code Identification Bits Phase Identification Bits X N-1 X N-2 X N-3 X N-4 ? X 1 X 0 Figure 1 :

10 b) Phase Identification

11 P2 Frank P1

The remaining bits from X 0 to X N-4 are used for phase identification. Table 3 gives the phase change identification and amount of phase change from one phase to another phase among the polyphase codes. X N-4 phase identification bits will give the 2 N-4 phase changes. The phases are given as from ? 0 , ? 1 , ?..? 2 N-5 , ? 2 N-4 . From the table 3 the generalized phase changes equations are given below. The phase change can be calculated by using the given equations.

12 Code identification bits

Code X N-1 X N-2 X N-3 0 0 0 Frank 0 0 1 P1 0 1 0 P2 0 1 1 P3 1 0 0 P4 1 0 1 Barker 1 1 0 Used for Future Expansion 1 1 1 X N-4 X N-5 ??? X 1 X 0 Phase 0 0 ??? 0 0 ? 0 0 0 ??? 0 1 ? 1 0 0 ??? 1 0 ? 2 . . . . ??? . . . . . . 1 0 ??? 0 0 ? N-4 1 0 0 1 ? N-3 . . . . ??? . . . . . . 1 1 ??? 1 0 ? 2 N-5 1 1 ??? 1 1 ? 2 N-4

. (9) The number of phase change identification can be identified by using the following equations (10) (11) The phase change is given by (12) if Z=1 then count = count+1; else count = count; IV.

13 Example for Four Phase Identification

For a five input sequence the first three MSB bits are used for the code identification and the remaining two bits are used for the phase identification. The two phase identification bits will give four phases. The clock and reset signals are given to the buffer register. The buffer register is used to split the code identification bits and phase identification bits. The code identification block is used to identify which type of code whether frank, barker, and polyphase code i.e. p1, p2, p3, p4.The level detection unit will give the phases for the corresponding inputs bits. The z phase will give the phase change among the phases. The phase display unit will give the phase angle corresponding to the four phases. The counter block will give the number of phase changes among the four phases. The internal block diagram of the system is given below figure 6.

Figure **??** shows the code identification unit for the five input sequences. The three MSB bits X in [4], X in [3], X in [2] are the code identification bits. These are the inputs given to the code identification unit. The corresponding codes frank, p1, p2, p3, p4 and barker are the outputs of the code identification unit. The clock and reset are the other inputs of the code identification unit.

The code identification logic is shown in table **??** Table **??** 0, 0 1, 1 2,1 2 N-5 , 1 2 N-4 , 1 0, 1 0, 1 0, 1 0, 1 1, 1 1, 1 1, 0 1, 1 2, 1 2 N-5 , 1 2 N-5 , 1 2, 0 2 N-4 ,1 2 N-4 , 1 2 N-4 , 1 2 N-5 , 1 2 N-5 , 0 2 N-4 , 0 2, 1 2, 1 ENABLE='1' DFF 2 N-5 Reset Clock XN-4 XN-5 X1 X0 AN-4 AN-5 A1 A0 DFF 2 N-4 DFF 2 N-5 DFF 1 DFF 0 X(n)={ XN-4, XN-5,??..,X1,X0} X(n-1)={AN-4,AN-5,??..,A1,A0} Z=X(n) X(n-1)

The count value depends on the number of phases. The number of phases is equal to ? 2 N-4 then the count value2 count ? ? 2 ??4 . Xi n [4] Xi n [3] Xi n [2] F R A N K P1 P2 P3 P4 BA RK ER 0 0 0 1 0 0 0 0 0 0 0 1 0 1 0 0 0 0 0 1 0 0 0 1 0 0 0 0 1 1 0 0 0 1 0 0 1 0 0 0 0 0 0 1 0 1 0 1 0 0 0 0 0 1

If the three MSB bits shows 000 then it will identify the frank code similarly for 001,010,011,100.101 it will give p1, p2, p3, p4, barker codes and the bits 110, 111 are reserved for the future expansion. Figure **??** shows the level detection unit. X in [0], X in [1] are the inputs and Z1, Z2, Z3, Z4 and Z phase are the outputs of the level detection unit. Clock and reset are given as the other inputs of the level detection unit. Table **??** shows the level detection. For the phase identification bits shows 00 then it will give the output z1 similarly for 01, 10, 11 it gives z2, z3, z4 respectively. Table **??** : Level Detection Logic Figure **??** shows the phase display unit where Z1, Z2, Z3 and Z4 are the inputs and phase out is the output of the phase display unit. Xin [1] Xin [2] Xin [3] Xin Xin [2] Xin [3] Xin [4] BarkerLEVEL DETECTION UNIT CLK RESET Z1 Z2 Z3 Z4 Xin[1] Xin[0] ZPHASE Xin [1] Xin [0] Z1 Z2 Z3 Z4 0 0 1 0 0 0 0 1 0 1 0 0 1 0 0 0 1 0 1 1 0 0 0 1 Z1 Z2 Z3 Z4 PHASE DESPLAY UNIT CLK RESET PHASEO UT

Figure **??** : Phase Display Unit Table **??** will give the phase display for the corresponding to the level detection output. For the output z1 it will give 0 similarly for z2, z3, z4 it will give 90,180,270 respectively.

14 Z1 Z2 Z3 Z4

Phase out 1 0 0 0 0 0 1 0 0 90 0 0 1 0 180 0 0 0 1 270

15 Table 6 : Phase Display Logic

Figure 10 shows the counter unit. For the counter unit Z phase is the input and the count out is the output. The counter unit will give the number of phase changes among the phases. The below table shows the logic for identifying the number of phase changes.

(13) V.

16 Results and Discussions

Figure 11 gives the output for the code, amount of phase change and number of phase changes identification. The identified code enabled as logic '1'. It also gives the number of phase changes. The output will give the four phases 0 0 , 90 0 , 180 0 , 270 0 . The count block will give the number of phase changes among the codes. The code is identified as p2 code and it is represented in figure 11.the amount of phase change and numbers of phase changes are also shown in figure11.

17 Conclusion and Future Scope

An algorithm is proposed for the identification of radar codes. The proposed algorithm is able to identify the code type, amount of phase and number of phase changes also the algorithm is implemented using FPGA. Using such a system in electromagnetic wave radar lead to a reduction on the required microwave power supplied to the radar or extending the detection range of the radar. By knowing the coded signal parameters like code, phase, number of phase changes we can reguide and retransmit those signals to the transmitter without effecting our systems. [1] [2]

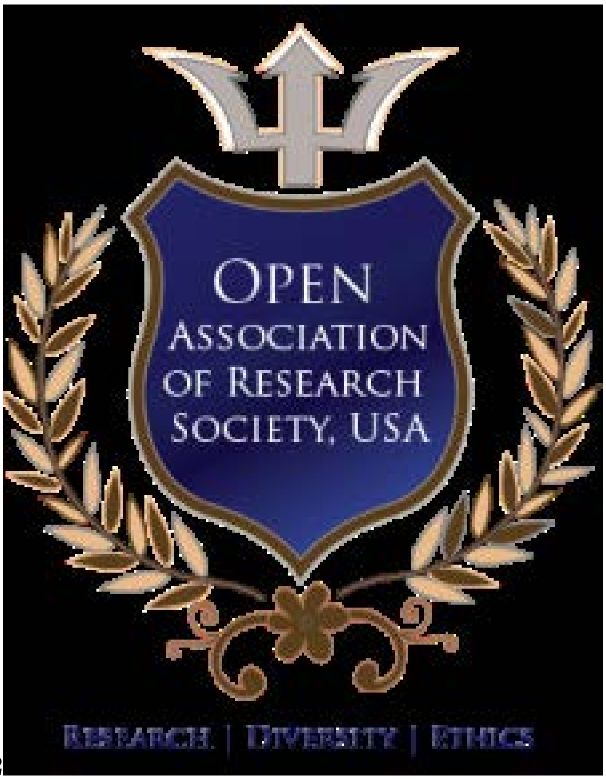
2


Figure 1: Figure 2 :

3


Figure 2: Figure 3

Figure 3:

434 $\Phi_{ij} = \frac{2\pi}{N}(i-1)(j-1)$

Figure 4: 4 Figure 3 :Figure 4 :

5 $i = 1, 2, \ldots, N$

Figure 5: Figure 5 :

6 $j = 1, 2, \ldots, N$

Figure 6: Figure 6 :

78 $2\pi/N$

Figure 7: Figure 7 :Figure 8 :

N^2

Figure 8:

10 $\Phi_{ij} = \frac{\pi}{N}[N-(2j-1)][(j-1)N+(i-1)]$

Figure 9: Figure 10

11 $i = 1, 2, \ldots, N$

Figure 10: Figure 11 :

12 $j = 1, 2, \ldots, N$

Figure 11: Figure 12 :

1

Figure 12: Table 1 :

2

Figure 13: Table 2 :

3

Figure 14: Table 3 :

7

If Z	ph ase =1 then Count=count+1
else	
Z phase =0 then Count=count.	

Figure 15: Table 7 :

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