Design and Implementation of Quadri phase Sequences with Good Merit Factor Values

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Abstract

Objective: Design of quadriphase codes with superior merit factor in basically a nonlinear multivariable optimization problem. Quadriphase transformation is applied to low side lobes in bi phase generation of binary sequence. In order to provide real time hardware for identification and generation of quadriphase pulse compression sequences. Methods/Statistical Analysis: An efficient VLSI architecture has been proposed. The objectives to achieve high main lobe and low side lobes by poly phase codes. Findings: Initially pulse compression techniques are applied followed by binary quadriphase transformation. By applying a transformation to the biphase code using of sub pulses consequently results in the generation of codes. Near constant envelopes are created. Improvements/Applications: The systematic quadriphase sequences are useful for application to radar and continuation. There is scope for further development of merit factor.

Keywords: Merit Factor (MF), Pseudo Random Binary Sequence (PRBS) Generator, Pulse Compression, Quadriphase Sequence

1. Introduction

Usages of quadriphase wave shape in radar applications are existing. There is a necessity to reduce side lobe of biphase counterpart keeping the time domain characteristics intact. T & B suggested a novel transformation for obtaining decimated side lobe pattern. Interestingly such formulation manifest autocorrelation function identical to that of binary coding. For generation of random numbers many researchers have used the underlying uncertainly. Some researchers have used the underlying uncertainty on FPGA.

In biphase radar, the response of match filter is associated with undesirable side lobes. The endeavor of this paper is to explore polyphase codes which are likely to minimize the side lobe being Doppler tolerant.

Implementation of quadriphase pattern especially form binary sequence in spreaded spectrum communication has been highlighted.

2. Compression Techniques

In, radars pulse are compressed such that aver rage transmitted power pulse can be achieved without sacrificing the range advantage of short pulse. These pulse compression methods are particularly relevant in case of constraint of peak power. Long pulse gives the advantage of higher detection ability observed in Figure 1 where as short pulse has greater resolution accuracy. Both these need to be combined. Number of methods on these combinations has been suggested earlier.

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Figure 1. Envelope of complex signal.

Phase code signals form Barker to quadriphase and various frequency coded signals have been proposed by many researchers\textsuperscript{11,12}. It may be assumed that no particular waveforms have all the merit for target resolution. Moreover a salient feature of concern is the centrally placed spike in the ambiguity surface. There exists a need for optimizing the reduction in interference factor when the enlargement of peak is shifted from the rest.

3. Binary To Quadriphase (BTQ) Transformation

Mismatch loss in the receiver coupled with distorted radial spectrum result from usage of rectangular sub pulses in binary code. Quadriphase does not suffer from these problems. For generating optimum quadriphase pattern are shown in Figure 2 and Figure 3. Barker sequences are preferable\textsuperscript{13}. The chief merit of the BTQ transformation is manifest desirable range of side lobe spectrum. The biphase code can be converted to quadriphase by

\begin{equation}
q_k = j^{s(k-1)}c_k \quad k = 1,2,3,..K-1
\end{equation}

The shape of above signal is of

\begin{equation}
y(t) = \sum_{k=1}^{K} j^{s(k-1)} c_k A(t - k\tau_c)
\end{equation}

13 bit biphase code transformed to quadriphase. It may be noted that shape remains constant except at the terminal points. Usually from probability distributed methods are shown in Figure 4, PRBS can be designed using physical or computational techniques. Computer method is adopted in the paper to create random bit strings of PRBS\textsuperscript{14}. There numbers are is repeatable. Quadriphase can be achieved by any two binary sequences having period K.

\begin{equation}
q_k = \frac{1}{2} (1 + j) x_k + \frac{1}{2(1 - j)} y_k
\end{equation}

Figure 2. LFSR quadriphase generator.

Figure 3. 5 RTL Schematic for TOP module for quadriphase codes.

Here n is the length of biphase code, scan factor is ± 1.

Figure 4. Technology Schematic for TOP module for quadriphase codes.
In reverse computation, quadriphase can be dissolved into two binary and chains. The cross correlation of quadri phase is related to that of binary by a factor $\sqrt{2}$ giving 3db improvement in interference\cite{15,16}.

$$K = 2^r - 1$$  \hspace{1cm} \text{(5)}$$

$$q_k = j^{q_k} \text{ where } j = \sqrt{-1}$$  \hspace{1cm} \text{(6)}$$

Utilizing binary (mod 2) quaternary (mod 4) sequences. PRBS can be developed with the proper results. LFSR, consisting of r shift register, depends on the basic sequence and the type of feedback. So that errors are minimized. For r=5 and best value 1000, the generated sequences is of length 31. When LFSR\cite{17,18} is bought to initial condition the binary sequences are produced Table 1.

### Table 1. Conversion of 13 bit baker code into quadriphase code

| 13 bit Baker code into quadriphase code |
|-----------------------------------------|
| 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1 |
| 1, j, -j, -j, 1, -j, -j, 1, j, -j, 1, j, -j |

13002302113332002301221110001

The desired sequence is obtained using Equation 5.5

$$\{q_n\} = j, -j, 1, 1, -1, -j, 1, j, j, -j, -j, -1, 1, 1, -1, -j, 1, j, -1, -j, j, j, 1, 1, 1, j.$$  \hspace{1cm} \text{(5.5)}$$

$$\{q_n\} = \frac{\pi}{2}, \frac{3\pi}{2}, 0, 0, \pi, \frac{3\pi}{2}, 0, \pi, \frac{\pi}{2}, \frac{\pi}{2}, \frac{\pi}{2}, \frac{3\pi}{2}, \frac{3\pi}{2}, \frac{3\pi}{2}, \pi, 0, \pi, \frac{3\pi}{2}, 0, \frac{\pi}{2}, \pi, \frac{\pi}{2}, \frac{\pi}{2}, \frac{\pi}{2}, \pi, 0, 0, \frac{\pi}{2}.$$  \hspace{1cm} \text{(5.5)}$$

### 4. Experimental Verification

Quadriphase nodes are generated and tested on FPGA kits Xilinx Spartan-II synthesized the sequence. SESP2BRD having 100 k gates, ten thousand logic blocks, SRAM were chosen for this purpose. The successful implementation was indicated by visual signal. An architecture for design (observed in Figures 6 and 7) of ternary codes based on SKH (Simon Kronecker Hamming) has been suggested. In this work, architecture for quadriphase is based on PRBS with phase indication as shown.

### Figure 6. Design summary of quadriphase top module.

### Figure 7. Merit factor vs. length of sequence.

**5. Results**

The synthesized quadriphase has high MF. Language features are avoided or that the design can cover many devices.
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These sequences have many useful application areas in radar signal communication. The MF has been noticed to be high for longer length in Figure and in Table 2.

| S. No. | Length of the Sequence (Quadriphase) | Merit Factor(MF) |
|--------|--------------------------------------|------------------|
| 1      | 5                                    | 5                |
| 2      | 7                                    | 4.667            |
| 3      | 10                                   | 3.03             |
| 4      | 13                                   | 5.12             |
| 5      | 15                                   | 4.28             |
| 6      | 16                                   | 6.16             |
| 7      | 18                                   | 4.23             |
| 8      | 21                                   | 5.15             |
| 9      | 23                                   | 7.7794           |
| 10     | 25                                   | 5.2826           |
| 11     | 30                                   | 5.1              |
| 12     | 31                                   | 5.08             |

**6. Conclusion**

In comparison with conventional phase code based on rectangular sub pulses, the quadriphase codes synthesized in this paper achieve lower side lobes. In this case quadriphase codes are transformed biphasic type using Cosine sub pulses which are overlapped to create a constant shape. The performance measure can be computed on MATLAB for VHDL code. The architecture selected for the purpose has given excellent MF.

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