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SIXPHASEOPTIMALSEQUENCEDESIGNFORMIMORADAR

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Six Phase Optimal Sequence Design for MIMO Radar

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Abstract- Radar applications desire a set of sequences with discretely peaky autocorrelation and pair_wise cross correlation. Invade such sequences is a combinal problem. If the autocorrelation and cross correlation are convenient in the a periodic sense then there are hardly any theoretical aids available thus the problem of signal design referred to above is a defying problem for which many global optimization algorithms like ant colony optimization ,artificial bee colony (ABC) algorithm and particle swarm optimization algorithm were reported in the literature. The paper intent at gadget of an efficient optimization algorithm is design to find an optimal pulse compression code useful for radar applications .The proposed optimization algorithm particle swarm optimization algorithm for identifying the optimal pulse compression codes and it is a real-time signal processing solution which identifies optimal sequences.

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I. Introduction

Number of waveforms are used for radars signal. Several properties of radar waveforms are discussed in [10], [9], [7]. An un-modulated or modulated continuous signal is used in continuous wave radar. Such a system can detect targets using Doppler offset, but range measurements become difficult. Since the radar transmits continuous waves, the requirement for secondary antenna for reception arises which is considered as another short coming of such a system. Pulsed radar transmits signals at regular time intervals of time unlike the CW radar. pulsed radars could give range measurements. But the selection of pulse width is a co-operation among the required resolution of the system and the detectable maximum Range. Number of characteristics of the radar system such as the Range resolution, range accuracy, target detection, radar range and Doppler shift. are decided by the radar waveforms. For example, the shorter the pulse width, the more accurate rang resolution the system has. But at the similar instance of time, short pulse will not support a good detection range.

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The above problem solved by the Pulse Compression. Pulse compression shares the inkling of transmitting a long-range pulse with some modulation embedded which spreads the energy over the bandwidth necessary for the required resolution. Pulse compressed Wave forms have larger time bandwidth (BT) product compared to uncompressed pulses whose BT=1.The pulse compression technique in the waveforms is employed either in the Frequency coding or Phase coding. An LFM signal is a waveform of frequency modulated whose carrier frequency varies linearly with time, over a specific period. This is one of the oldest and frequently used waveforms. It finds application in CW and pulsed radars. Since an LFM waveform serves as a constant amplitude waveform, it makes sure that the amplifier works efficiently. Also, this waveform spreads the energy widely in frequency domain.

A long pulse is divide in to a number of sub pulses of equal duration and the phase of each sub pulse is modulated with the different phases. This can be merely divided into binary and poly-phaser phase coding. In binary technique, the phase of any sub pulse takes any of the two values, either 1 or -1, in harmony with the sequence. In poly phase coding or Non-Binary coding , the phase of the sub pulse takes any of the M arbitrary values. The poly phase codes are Frank codes,p1 codes,p2 codes , P3 codes and p4 coded waveform are some of the commonly used sequences in Polyphase coding. The range side lobes for polyphase coded waveforms are lower than that of binary-coded waveform of same length, but the Doppler performance gets debilitated.

II. Orthogonal Wave forms

Orthogonal poly phase code consists of Length of the sequence (N_c),set size of the (L) and Phase of the sequence (M). Signals which probably containing N sub pulses represented by a complex number sequence, the set of the sequence is given by

$$s_l(n) = e^{j\emptyset_l(n)} \tag{1}$$

Where n=1,2, …., N_c and l=1, 2, …., L Where Øl (n), ($0 \le \emptyset_l(n) < 2\pi$) is the phase of sub pulse n of signal.

$$\emptyset_l(n)\epsilon\left\{0, \frac{2\pi}{M_c}, 2.\frac{2\pi}{M_c}, \ldots, (M_c - 1).\frac{2\pi}{M_c}\right\} \tag{2}$$

$$\phi_l(n) = \{\psi_1, \psi_2, \ldots, \psi_{M_c}\} \tag{3}$$

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Assume a set a poly phase codes with contains the set as Nc whose set size is L, one can briefly signify the phase values of S with following L× N_c phase matrix.

$$(L, N_c, M_c) = \begin{bmatrix} \phi_1(1) & \phi_2(2) & \cdots & \phi_1(N_c) \\ \phi_2(1) & \phi_2(2) & \cdots & \phi_2(N_c) \\ \vdots & \vdots & & \vdots \\ \phi_L(1) & \phi_L(2) & \cdots & \phi_L(N_c) \end{bmatrix} \quad (4)$$

Here the phase sequence in row (1≤ l ≤ L) is the sequence of polyphase signal, and complete elements in the matrix can be elected from the set of phases. From the cross correlation and autocorrelation distinguishing of orthogonal polyphase codes, we get.

$$A(\phi_l, k) = \begin{cases} \frac{1}{N_c}\sum_{n=1}^{N_c-1} \exp j[\phi_l(n) - \phi_l(n+k)] = 0 & 0 < k < N_c \\ \frac{1}{N_c}\sum_{n=-k+1}^{N_c} \exp j[\phi_l(n) - \phi_l(n+k)] = 0 & -N_c < k < 0 \end{cases}$$

For l=1, 2, ... L (5)

$$C(\phi_l, k) \approx \begin{cases} \frac{1}{N_c}\sum_{n=1}^{N_c-k} \exp j[\phi_q(n) - \phi_p(n+k)] = 0 & 0 < k < N_c \\ \frac{1}{N_c}\sum_{n=-k+1}^{N_c} \exp j[\phi_q(n) - \phi_p(n+k)] = 0 & -N_c < k < 0 \end{cases}$$

or p≠q and p, q=1, 2, … L (6)

where $A(\varphi_l.k)$ and $C(\varphi_p.\varphi_q.k)$ are the aperiodic function of autocorrelation polyphase sequence S_l and the function of cross correlation sequences S_p and S_q .Where k defined as the discrete time index. Therefore, crafting of an orthogonal polyphase code made corresponding to the building of a polyphase matrix in equation 6 with $A(\varphi_l.k)$ and $C(\varphi_p.\varphi_q.k)$ constraints in equation 5 and equation 6.For the scheme of code sets of orthogonal polyphase used in MIMO radar systems, an the process of optimization is used not only to suppress the auto correlation side lobe peaks and the cross correlation peak but also to suppress the the total autocorrelation sidelobe energy and cross correlation energy in equation 7. Here λ is the weight factor if it is less than one means more weightage is given to auto-correlation and less weightage is given to cross-correlation.

$$E = \sum_{l=1}^{L}\sum_{k=1}^{N_c}|A(\phi_l, k)|^2 + \lambda\sum_{p=1}^{L-1}\sum_{q=p+1}^{L}\sum_{k=-(N_c-1)}^{N_c-1}\left|C(\phi_p, \phi_q, k)\right|^2 \quad (7)$$

III. Mimo Radar Signal Model

A pure MIMO system is one that operates incoherently where as netted radar (NR) Systems operate Coherently and decentralized radar networks (DRNs) operate incoherently with a two stage processing [12].The basic form of the received signal in a MIMO network is the signal arriving at the k^{th} receiver can be modeled as

$$r_k(t) = \sum_{m=1}^{M}[(H_{\frac{0}{1}} \propto_{m,k} (\sigma)s_m(t - \tau_{m.k}) + c_{m,k}(t - T_{m.k})] + J_k(t) + z_k(t) \quad (8)$$

Where $H_{o/1}$ is 0 or 1 depending the absence or presence of target respectively; s_m is the m^{th} transmitted signal, $c_{m,k}$ is the clutter, z_k is the thermal noise, J_k is an external disturbance (such as jamming), $\tau_{m,k}$ and $T_{m,k}$ are the delays occurring during the path between the m^{th} transmitter and the target/clutter respectively and the k_{th} receiver and $\alpha_{k,m}(\sigma)$ is a coefficient that accounts for the parameters of the mono/bisatic radar equations, the phase shift ,and the RCS-distribution, specifically .

$$\alpha_{k,m}(\sigma) = \sqrt{\frac{P_t}{M}}\sqrt{\frac{G_{tx}G_{rx}\lambda^2\sigma}{(4\pi)^3 {R_m}^2 {R_k}^2}exp\left\{-j\frac{2\pi R_{m.k}}{\lambda}\right\}} \quad (9)$$

Where G_{tx} and G_{rx} are respectively the gains of the transmitting and receiving antennas, σ is the RCS of the target, P_t is the transmitting power, R_m and R_k are the transmitter-target and target-transmitter distances respectively and $R_{m.k}$ is the distance covered by the signal.

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$$r_k(t) = H_{\frac{0}{1}} \sum_{m=1}^{M} (\propto_{m,k} (\sigma) s_m (t - \tau_{m.k}) + J_k(t) + z_k(t) \quad (10)$$

The effects of the clutter are not considered, and hence this leads to the following expression for the received signal.

The received output may be expressed as the result of the cross correlation of the received signal with the transmitted waveforms as follows.

$$\begin{aligned} x_{h,k} &= (r_k) \; t \; \otimes s_h(t) \\ &= H_{\frac{0}{1}} \sum_{m=1}^{M} (\propto_{m,k} (\sigma) s_m (t - \tau_{m.k}) \otimes s_h(t) + [J_k(t) + z_k(t)] \otimes s_h(t) \\ &= H_{\frac{0}{1}} \propto_{h,k} (\sigma) R_h (t - \tau_{h.k}) + H_{\frac{0}{1}} \sum_{\substack{m=1 \\ m \neq h}}^{M} (\propto_{m,k} (\sigma) R_{m.k} (t - \tau_{m.k}) + [J_k(t) + z_k(t)] \otimes s_h(t) \\ &= H_{\frac{0}{1}} \propto_{h,k} (\sigma) R_h (t - \tau_{h.k}) + H_{\frac{0}{1}} \sum_{\substack{m=1 \\ m \neq h}}^{M} (\propto_{m,k} (\sigma) R_{m.h} (t - \tau_{h.k}) + n_{h.k}(t) \end{aligned} \quad (11)$$

Where $R_h(t)$ is the autocorrelation function of sm and $R_{m,h}$ is the cross-correlation function between s_m and s_h and $n_{h,k}$ is the component of the overall disturbance incoming in the k^{th} receiver after the h^{th} matched filter. Consequently a matrix M_x signals from the same area may be written as follows.

$$M_X = \begin{bmatrix} x_{11} & x_{12} \dots & x_{1N} \\ x_{21} & x_{22} \dots & x_{2N} \\ \vdots & \ddots & \vdots \\ x_{M1} & x_{M2} & x_{MN} \end{bmatrix} \quad (12)$$

Alternatively, this equation may be rearranged into vector X as follows

$$X = [x_{11}, \dots x_{1M}, x_{21}, \dots \dots x_{2M}, x_{N1}, \dots . x_{1N}]^T \quad (13)$$

Where T is the transpose operator.

IV. Optimization Algorithms for MIMO Radar

Many optimization methods have been developed for solving various types of engineering problems. Popular optimization algorithms include particle swarm optimization, neural networks, genetic algorithms, artificial immune systems, and fuzzy optimization. The particle Swarm concept originated as a simulation of simplified social systems. The Particle Swarm Optimization algorithm is basically a population-based stochastic search algorithm and provides solutions to the complex non-linear optimization problems. PSO has the benefits of being more efficient when compared to most other optimization algorithms.

V. Simulation Results

In this paper Optimization of Orthogonal Polyphase Coded Waveform for MIMO Radar using Particle Swarm Optimization Algorithm is carried out. In the present work, Particle Swarm Optimization Algorithm is to optimize the six phase polyphase coded sequence to achieve good auto correlation properties and cross-correlation properties. On the basis of projected algorithm the polyphase six phase coded sequences are set with lengths varying from 7 to 128 and number of transmitting ,receiving antennas L=3 and L=4. The Maximum autocorrelation side lobe peak (ASP) and Maximum cross correlation peak (CP) values obtained using proposed algorithm is compared with literature values. The results shows an advance in Autocorrelation Side lobe Peak (ASP)s and Cross Correlation Peak (CP)s. It infers that sequences generated by Particle Swarm Optimization Algorithm have good correlation properties.

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Table 1: Auto Correlation side lobe peaks of Six phase synthesized sequence sets with L=3, and Sequence length N= 40 to 128.

S.No	Length of Sequence	Max(ASP) Reported	Max(ASP) Literature
1	40	0.0044	0.079
2	48	0.0035	0.0751
3	51	0.0031	0.0808
4	60	0.0032	0.0745
5	65	0.003	0.0769
6	70	0.0019	0.0769
7	75	0.0021	0.0777
8	80	0.002	0.076
9	85	0.0022	0.0704
10	100	0.0019	0.067
11	110	0.0016	0.0692
12	120	0.001	0.0671
13	128	0.0015	0.0662

The auto correlation side lobe peak values obtained for different length of the sequences. the average value of ASPs is 0.0023 it is better than the literature values.

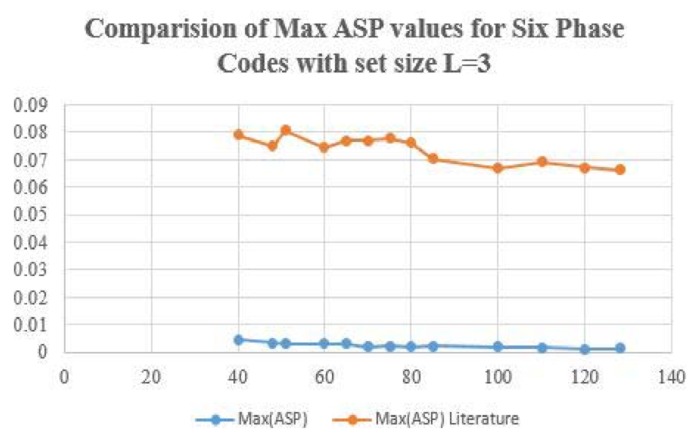

Fig. 1: Max (ASP) values of six phase sequence set L=3 designed using PSO compared with literature values

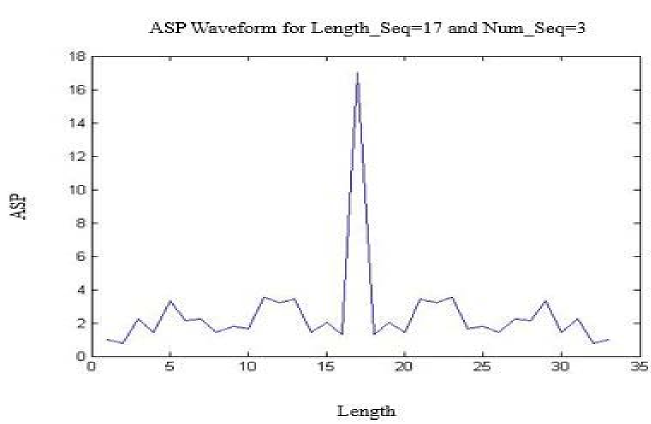

Fig. 2: Minimum Auto correlation Side lobe Peak values of six phase sequence set L=3

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Table 2: Auto Correlation side lobe peaks of Six phase synthesized sequence sets with L=4, and Sequence length N= 7 to 117

S.No	Length of Sequence	Max(ASP) Reported	Max(ASP) Literature
1	7	0.0327	0.079
2	13	0.0179	0.0751
3	17	0.0169	0.0720
4	21	0.0126	0.0731
5	29	0.0061	0.0721
6	31	0.0062	0.0769
7	37	0.0041	0.0777
8	45	0.0036	0.0762
9	49	0.0033	0.0744
10	53	0.0026	0.0731
11	61	0.0017	0.0792
12	87	0.0015	0.0771
13	95	0.0017	0.0762
14	103	0.0011	0.0741
15	113	0.0012	0.0734
16	117	0.0011	0.0733

The auto correlation side lobe peak values obtained for different length of the sequences the average value of ASPs is 0.0069 it is better than the literature values.

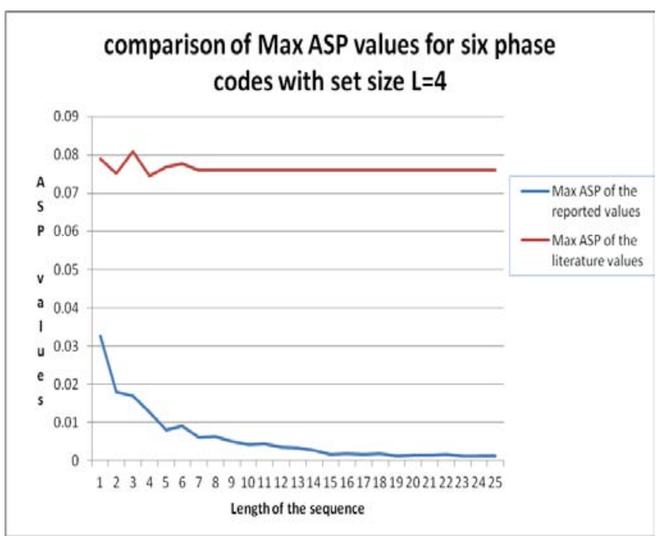

Fig. 3: Max (ASP) values of six phase sequence set L=4 designed using PSO compared with literature values.

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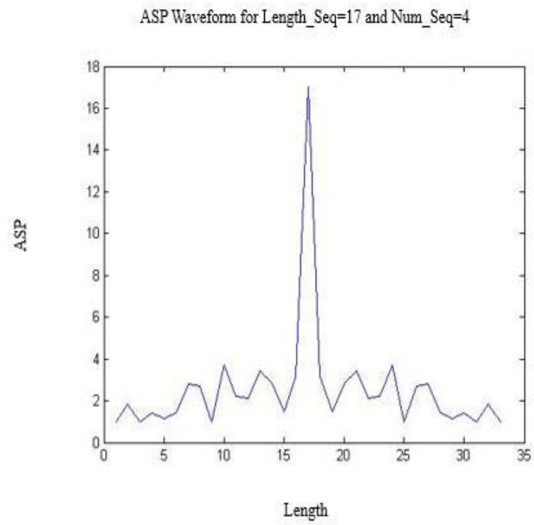

Fig. 4: Minimum Auto correlation Side lobe Peak values of six phase sequence set L=4

Table 1 compares the obtained values of ASPs with literature values. ASPs of Six phase synthesized sequence sets with three transmitting antennas (L=3), and Sequence length varying from N= 40 to 128 are tabularized and Table 2 compares the obtained values of ASPs with literature values. Auto correlation side lobe peaks of four transmitting antennas (L=4) synthesized sequence sets, and Sequence length various from N= 7 to 117. Fig. 1 and Fig.3 illustrates the Max (ASP) values of L=3 and L=4 designed using Particle swarm optimization algorithm compared with literature values.

VI. Conclusion

Properties of Auto correlation side lobe peaks of Six phase produced order sets with three and four transmitting antennas for Sequence length N= 40 to 128 is obtained and compared with the literature values. From the design result, it conclude that the results obtained have great improvement in ASPs things of all the sequence lengths. In order to carry out the implementation of particle swarm optimization algorithm for the optimization of orthogonal poly phase sequences is developed for MIMO radar.

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