Design of Wave Form Generation using Quantum Particle Swarm Optimization with Uniform and Normal Distribution model for MIMO Radar Applications

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Abstract: The State of art of the particle swarm optimization (PSO) performance depends on the behavioral characteristics of quantum, static state and convergence in many radar synthesis applications. Critical factors include: reducing mutual interference and increasing resolution range in generating waveforms for MIMO radars. Majority of the MIMO applications of the radar survey states that the researchers made attempts to explore the orthogonal signal transceiver operational behavior and characteristics performance in synthesis analysis. An effort has been made to find one of the optimized solutions in this research work using Particle swarm optimization to minimize the error metrics like Autocorrelation Side lobe Peak (ASP) and low Cross correlation Peak (CP) and targeted to meet the long range as well as multiple target resolutions. For target detection, MIMO radars transmit multiple linearly independent signals through multiple antennas using both spatial and waveform diversity. By integrating motivational concepts from quantum theory to find performance-based optimum design solution for MIMO radar applications. MIMO Radar feasibility depends on the availability of a collection of low Autocorrelation Side lobe Peak (ASP) and low Cross correlation Peak (CP) orthogonal signals to minimize interference and high range and multiple target resolution. Based on Quantum- particles behavioral analysis, the experimental synthesis results are compared to enroot the optimized solution for orthogonal MIMO radars. In this paper we deploy Quantum PSO (QPSO) technique with normal and uniform distribution with random numbers used in the algorithm for designing optimized orthogonal waveforms. The simulation results of the proposed Quantum Particle Swarm Optimization with Uniform and Normal Distribution model are compared for the improvement of the overall performance in MIMO radars. Differential particle swarm optimization (DPSO) through the collaboration of the two multi-input multi-output (MIMO) radar systems with a new model that can concentrate on population diversity and PSO prematurity.

Keywords – MIMO Radar, Quantum PSO (QPSO), LFM, Side lobes.

I. INTRODUCTION

Multiple Input and Multiple Output (MIMO) Radar [1] uses multiple waveform transmission forms and has the capacity to receive jointly processed signals by multiple receiving antennas. It utilizes broadly spaced transmitters and receivers to simultaneously view the target from several different aspects, resulting in spatial diversity, which can enhance efficiency of radar detection. To enrich the performance of MIMO radar technique while generating the waveforms by justifying orthogonal property that can mitigate the evaluation factors can be improved with low interference and high resolution so that it can increase the detection capabilities. By collaborating the two schemes with multi-input multi-output (MIMO) radar, differential particle swarm optimization (DPSO) in to a new model that can focus on population diversity and PSO prematurity. In this work, random search and optimization techniques were mainly based on evaluating side lobe level and NULL depth to create the best array structure [2, 10]. The signals transmitted must be mutually orthogonal. The primary feature of the MIMO Radar system, therefore, is the use of L orthogonal waveforms, each transmitted from various phase centers and received by N phase centers. It is very important for transmitted signals that need a low auto correlation signal with side lobe peaks to establish radars with high resolution in multiple target detection. In this paper, we develop an algorithm that incorporates QPSO ***with normal and uniform distribution of random numbers*** to generate linear frequency modulation (LFM) orthogonal waveforms. The rest of this paper is structured as follows. We clarify QPSO in Section 2 ***with normal and uniform distribution of random numbers used in the algorithm***. We present LFM Waveform design in **Section 3. In section 4 we articulate cost function and Ambiguity function for MIMO Radar. Section 5 describes the findings of the simulation and the paper is eventually concluded.**

II. PROPOSED ALGORITHM

QUANTUM PSO

Particle Swarm Optimization (PSO) is generally one of the best search algorithms to be modified from iteration to iteration through a swarm of particles. Each particle moves in the direction of its previous best position (pbest) and the global best position (gbest) in the swarm to mitigate the optimal solution [3, 9The relatively recent version of PSO, QPSO [4], was influenced by quantum mechanics and PSO dynamic analysis. In order to increase the global search capability of the particle, QPSO uses a technique based on a quantum delta potential well model to sample around the previous best points and receives assistance from the average best location. QPSO is a sort of probabilistic algorithm, and QPSO's iterative equation is very different from the PSO equation. The component i can be updated by using the equation 1 as

$$X^j_{i,n+1} = p^j_{i,n} \pm |X^j_{i,n} - C^j_n| \ln\left(\frac{1}{u^j_{i,n+1}}\right) \quad (1)$$

Here, u is a uniformly distributed random number within the interval (0, 1) and $C_n = (C^1_n, C^2_n, \ldots\ldots C^N_n)$ is recognized as the best mean position that can be determined by the average of all particles' personal best positions. C^j_n is given by equation 2 as

$$C^j_n = \left(\frac{1}{M}\right) \sum_{i=1}^{M} P^j_{i,n} \;\; (1 \le j \le N) \quad (2)$$

Here, M reflects the number of particles. $p^j_{i,n}$ Can be obtained using equation 3 as

$$p^j_{i,n} = \phi^j_{i,n} P^j_{i,n} + (1 - \phi^j_{i,n}) G^j_n \quad (3)$$

Where, ϕ is a random number. $p^j_{i,n}$ Represents the center of δ potential well for the j^{th} component of i^{th} particle in n^{th} iteration. Due to the mean best location implemented in the QPSO leading to a better particle distribution, a peculiar waiting capacity occurs. The convergence rate would definitely be influenced by this particle distribution, but the concept leads to greater global search potential than the classical PSO.

U and φ are random numbers in QPSO that are distributed uniformly u and ϕ are random numbers in QPSO that are distributed uniformly. In this work, we analyze the QPSO for these random numbers using both uniform distribution and normal distribution properties.

WAVEFORM DESIGN

Linear Frequency Modulation (LFM) waveform is explained as follows

- ***Linear Frequency Modulation***

LFM waveform is expressed by using equation 4 as S_p --

$$S_p = \sum_{n=0}^{N-1} A(t)\, e^{(j2\pi f^p{}_n t)} \cdot e^{(j\pi\kappa t^2)} \quad (4)$$

Where, A(t) is $A(t) = \begin{cases} 1/T, & \text{if } (n-1)T \le t \le nT \\ 0 & \text{elsewhere} \end{cases} \quad (5)$

Where, κ is the slope of frequency, κ=B/T, B is the bandwidth, T is sub pulse width.

III. COST FUNCTION AND AMBIGUITY FUNCTION

The cost function is evaluated in this proposed work as the sum of the total side lobe energy of autocorrelation for each waveform in the set and total cross-correlation energy for all distinct combinations of two waveforms in the set. Therefore, the cost function to be reduced as follows in this work:

$$E = \sum_{l=1}^{L} \int_{\tau} |A(S_l,\tau)|^2 d\tau + \sum_{p=1}^{L-1} \sum_{q=p+1}^{L} \int_{\tau} |C(S_p,S_q,\tau)|^2 d\tau \qquad (6)$$

Where, $A(S_l,\tau)$ the autocorrelation function of coding signal $S_l(t)$ and $C(S_p,S_q,\tau)$ represents the cross-correlation function of coding signals $S_p(t)$ and $S_q(t)$.

Range-Doppler waveform resolution is evaluated using the uncertainty function [7]. For MIMO, the ambiguity function [8] is given by equation 7 as

$$\chi_{m,m'}(\tau,\nu,f_1,f_2) - \sum_{m=0}^{M-1} \sum_{m'=0}^{M-1} \chi_{m,m'}(\tau,\nu)\, e^{(j2\pi(f_1 m - f_2 m')\gamma)} \qquad (7)$$

where $\tau = \tau_1 - \tau_2$ and $\nu = \nu_1 - \nu_2$ denotes the delay and Doppler mismatch at the receiver end, f_1 denotes the true spatial frequency of the target, and f_2 denotes the assumed spatial frequency at the receiver end, M is the number of transmitters, γ represents the ratio of spacing between the consecutive transmitter and receiver. $\chi_{m,m'}(\tau,\nu)$ Is represented by function of cross-ambiguity between any two transmitted waveforms.

IV. EXPERIMENT AND RESULT

The simulation results of LFM waveform set with the different length N=128 and code sets of 3 using QPSO with uniform distribution and QPSO with normal distribution are briefed in this section.

TABLE 1: Max ASP and CP of the designed LFM set at Bandwidth 5MHz using QPSO with uniform distribution

	PW=100µs			PW=150µs		
	Code1	Code2	Code3	Code1	Code2	Code3
Code1	0.9900	0.0417	0.0459	0.9915	0.0982	0.0358
Code2	0.1034	0.9900	0.0968	0.1075	0.9915	0.0951
Code3	0.0385	0.0526	0.9900	0.0326	0.0249	0.9915

TABLE 2: Max ASP and CP of the designed LFM set at Bandwidth 10MHz using QPSO with uniform distributio

Code1	0.9910	0.0382	0.0472	0.9916	0.0951	0.0310
Code2	0.0382	0.9910	0.0968	0.1064	0.9916	0.0942
Code3	0.0385	0.0526	0.9910	0.0326	0.0238	0.9916

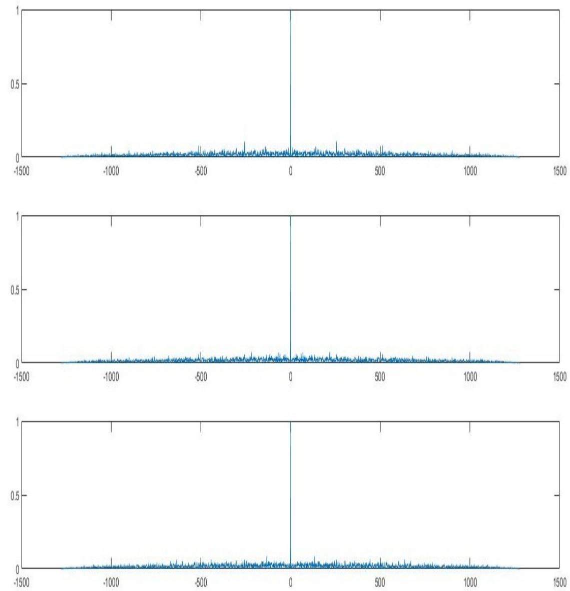

Figure 1: Autocorrelation plots of Code 1, Code 2 and Code 3 at BW=5MHz and PW=150µs of LFM set using QPSO with uniform distribution

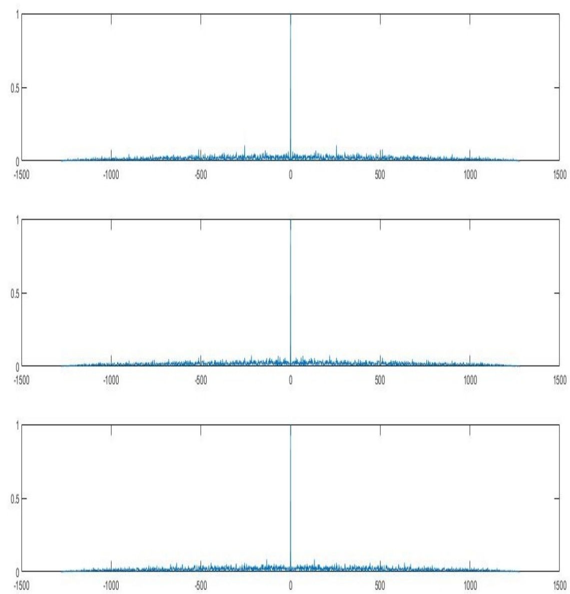

Figure 2: Autocorrelation plots of Code 1, Code 2 and Code 3 at BW=10MHz and PW=150µs of LFM set using QPSO with uniform distribution

TABLE 3: Max ASP and CP of the designed LFM set at Bandwidth 5MHz using QPSO with normal distribution

	PW=100µs			PW=150µs		
	Code1	Code2	Code3	Code1	Code2	Code3
Code1	0.9900	0.0459	0.0459	0.9915	0.3262	0.3262
Code2	0.1434	0.9900	0.1178	0.0723	0.9915	0.1491
Code3	0.0607	0.0411	0.9900	0.3262	0.0300	0.9915

TABLE 4: Max ASP and CP of the designed LFM set at Bandwidth 10MHz using QPSO with normal distribution

	PW=100µs			PW=150µs		
	Code1	Code2	Code3	Code1	Code2	Code3
Code1	0.9900	0.1342	0.0459	0.9915	0.0326	0.0326
Code2	0.0407	0.9900	0.1042	0.1610	0.9915	0.0772
Code3	0.0459	0.0435	0.9900	0.0326	0.0243	0.9915

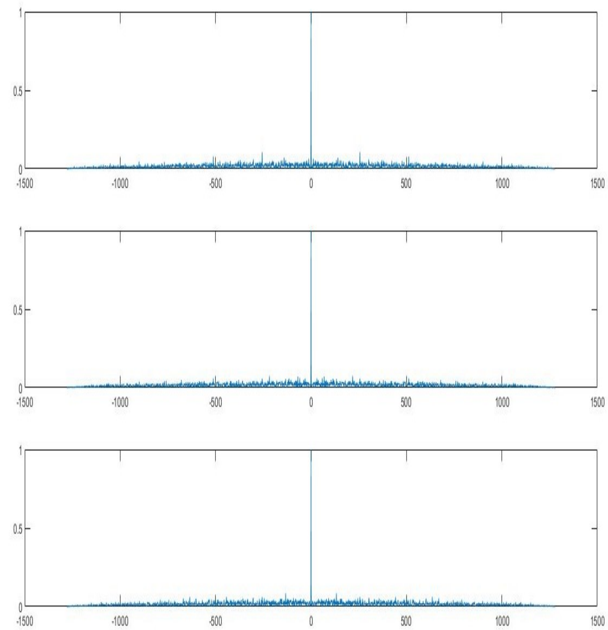

Figure 3: Autocorrelation plots of Code 1, Code 2 and Code 3 at BW=5MHz and PW=150µs of LFM set using QPSO with normal distribution

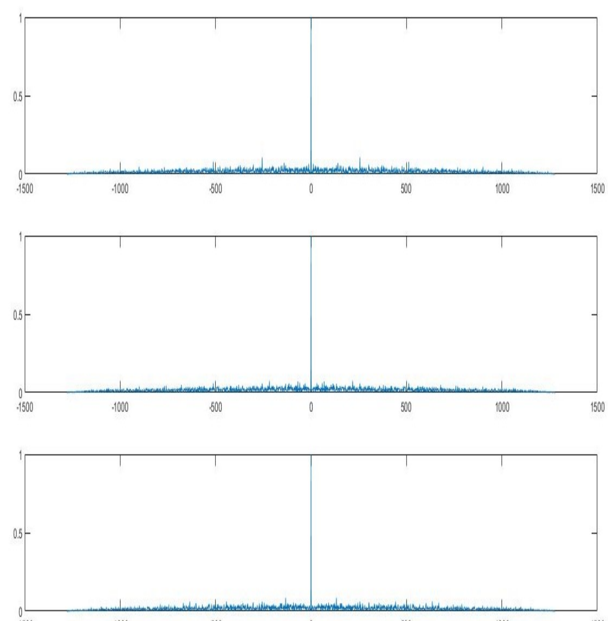

Figure 4: Autocorrelation plots of Code 1, Code 2 and Code 3 at BW=10MHz and PW=150µs of LFM set using QPSO with normal distribution

To confirm Range-Doppler resolution of the designed waveform sequences Figures 5 and Figure 6, respectively, display the partial ambiguity function for one designed sequence for LFM waveform. Both figures have a thumbtack ambiguity function that ensures better resolution of the Range Doppler.

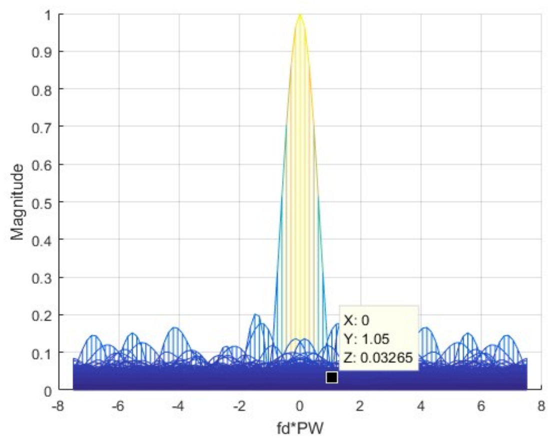

Figure 7: Delay cut of the MIMO radar Partial Ambiguity function of LFM for one designed sequence with code N=128, BW=5MHz and PW=150µs using QPSO with normal distribution

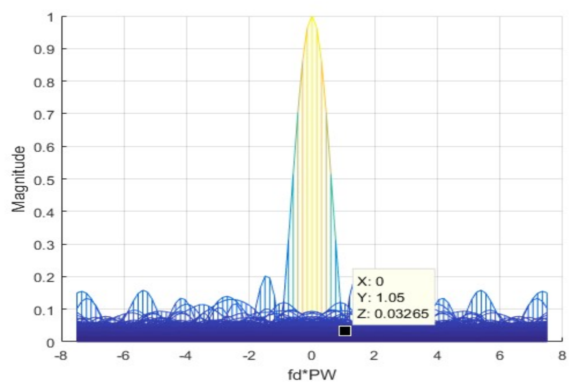

Figure 8: Delay cut of the MIMO radar Partial Ambiguity function of LFM for one designed sequence with code N=128, BW=5MHz and PW=150µs using QPSO with normal distribution

V.CONCLUSION

This paper presents Quantum PSO (QPSO) ***with normal and uniform distribution of random numbers used in this algorithm*** to develop an optimized orthogonal LFM waveform code sets for MIMO Radar. Range-Doppler resolution of the designed waveform is also verified. Both the Quantum PSO (QPSO) ***with normal and*** Quantum PSO (QPSO) with ***uniform distribution of random numbers gives the better results.***

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