Development and Performance Evaluation of PSO Based Adaptive Mismatch Filter for Radar Pulse Compression

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Abstract:

The paper proposes two efficient mismatched filters for radar pulse compression using Barker and Barker like sequences. The multi-layer artificial neural network/adaptive linear combiner as the basic structure and PSO and Orthogonal PSO (OPSO) as the training algorithm. Under noisy and noise free conditions the performance of these structures has been obtained through simulation study and compared with those obtained by conventional autocorrelation function(ACF) and least squared (LS) based methods. Exhaustive simulation study demonstrates that proposed pulse compressor out performs two conventional methods reported in the literature.

Key Words: Radar pulse compression, Signal to side lobe ratio, PSO, OPSO

I. INTRODUCTION

The primary object of Pulse Compression is to transmit high energy with a long pulse and simultaneously to obtain resolution corresponding to a sort pulse. To solve the dilemma between the range resolution and the transmitted energy, for long detection and high resolution, it is necessary for Pulse Compression processing to give low range side-lobes in modern high resolution radar system. The main purpose of Pulse Compression is to raise the signal to maximum side-lobe (signal to side-lobe, SSR) ratio and decrease the side-lobe level to improve the detection and range resolution abilities of the radar system.

In practice two different approaches are used to obtain the Pulse Compression. The first one is to use a matched filter, here code with small side- lobes in their auto-correlation function (ACF) are used [1, 2]. The second approach to Pulse Compression is to use inverse filters of two kinds namely non-recursive time invariant filter [3] and recursive time variant filter [4]. These are based on the least square method. Steven Zoraster has utilized linear programming (LP) techniques to determine the optimal filter weights for minimizing the peak range side-lobes of the Barker code [5].

This paper investigates on the development and performance evaluation of novel pulse compressors which is developed employing either a multi-layer perceptron network whose connecting weights are updated using an orthogonal particle swarm optimization (OPSO) algorithm or consists a tap delay adaptive filter whose weights are trained by PSO algorithm. The performance of this new class of hybrid compressor is evaluated through simulation study and is compared with those obtained using standard auto- correlation function (ACF) and least squared based methods.

The performance study includes evaluation of signal to side-lobe ratio (SSR) under both noisy and noiseless condition. The concept of designing an appropriate mismatch filter is based on the principle of changing the weights of adaptive linear combiner or multi-layer perceptron network in such a way that when Barker code is applied the desired main lobe and least side lobes are achieved at the output of the mismatch filter. In the present investigation two novel pulse compressors are proposed: MLP with OPSO based training and adaptive linear combiner with PSO based training.

II. DEVELOPMENT OF PSO BASED COMPRESSOR

A simple block diagram of an adaptive mismatch filter based pulse compressor of Barker code is shown in Fig.1

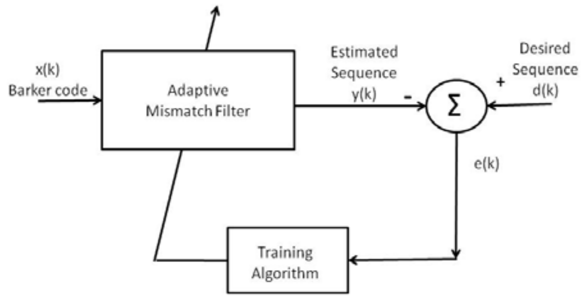

Figure1 Block diagram of adaptive mismatch filter

The input x(k) in Fig.1 Barker code sequence applied serially and the desired signal is zero in all other cases except a one in the middle. The comparison of desired value and the estimated output y(k) produces an error term e(k).The input and error values are used to update the mismatched filter until the desired output is obtained. Conventionally least mean square (LMS) and recursive least square (RLS) algorithms are used to train the weights. But the learning algorithms being derivative in nature, they tend to produce weights which are trapped by local minimum.

III. DEVELOPMENT OF OPSO BASED PULSE COMPRESSOR

Fig. 3 shows another pulse compressor with MLP architecture and orthogonal PSO based training. The objective of choosing the MLP is because of its inherent nonlinearity and selecting OPSO [7] algorithm enables improved training of the mismatched filter.

IV. PERFORMANCE EVALUATION THROUGH SIMULATION STUDY

The simulation study of the proposed models are carried out and are evaluated and compared with those obtained by BP based MLP and ACF pulse compressors. To improve the compression performance an OPSO based algorithm is used for training the weights. Two MLP structures with 13-3-1 and 13-3-1 neurons and two adaptive linear combiners with 35 and 13 taps are chosen for simulation purpose. The parameters used for PSO based training are presented in Table 1

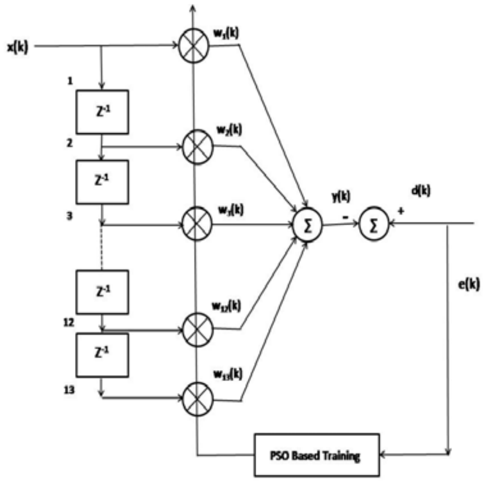

Figure.2 An efficient pulse compressor using adaptive linear combiner with PSO based training of weights

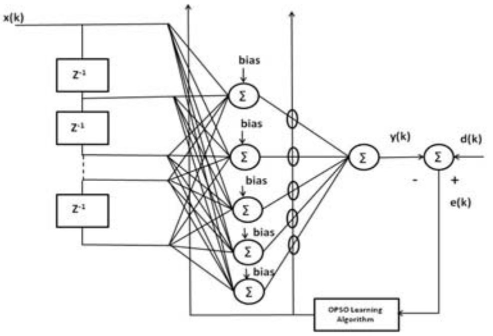

Figure.3 An efficient Pulse compressor using MLP Architecture and OPSO based training of weights

In the first simulation the structure of mismatch filter is chosen as an adaptive linear combiner with 13 and 35 taps. The signal to side lobe level ratio performance is computed both under noisy and noise free conditions.

Table 1: Parameters in PSO based simulation

Sl.No.	Parameter	Value
01	Population	200
02	Maximum Iteration	1000
03	C_1	0.7
04	C_2	0.7
05	W_{start}	0.4
06	W_{end}	0.9

1. *Noise free condition:*

The SSR is defined as the ratio of the peak signal amplitude to maximum side lobe amplitude. The results of simulation are depicted in Table 2. It shows that the proposed mismatch filter based approach exhibits higher output SSR compared to conventional ACF and LS based approaches.

2. *Noisy Condition:*

The 13-element Barker code and 35-element combined barker code are perturbed by additive white Gaussian noise (AWGN) with different SNRs. The SSR performance of the proposed mismatched filter under noise free and noisy conditions are evaluated through simulation and are listed in Tables 2-4.

Table 2: Comparison of SSR under noise free condition.

Algorithms	SSR in dB	
	13-element Barker Code	35-element Barker Code
ACF	22.27	13.97
LS	24.00	16.61
PSO	25.46	18.05

Table 3: Comparison under noisy condition for 13-element Barker code

Algorithm	SSR in dB for varying SNR values				
	5(dB)	20(dB)	40(dB)	60(dB)	80(dB)
ACF	12.25	19.39	22.03	22.24	22.27
LS	14.18	20.61	23.94	23.99	24.00
PSO	14.87	20.89	25.28	25.44	25.45

Table 4: Comparison under noisy condition for 35-element Barker code

Algorithms	SSR in dB for varying SNR values				
	5(dB)	20(dB)	40(dB)	60(dB)	80(dB)
ACF	10.22	13.36	14.00	13.97	13.98
LS	11.67	16.34	16.68	16.60	16.61
PSO	12.76	16.91	17.79	18.03	18.05

Comparison of results in Table 2 indicate that under no noise condition the PSO based linear combiner based mismatched filter method provides 3dB and 5dB improvements over ACF method in case 13- element and 35-element combined barker code respectively. How- ever compared to LS method the same improvement is observed to be 1.5dB in both cases.

In the second experiment the compressor structure is chosen to be an MLP of 13-3-1 configuration and other parameters of BP and OPSO are given in Table 5. The simulation study computes the SSR in various SNR conditions of ACF, MLP-BP and MLP-OPSO based pulse compression methods. The results obtained by these methods are displayed in Table 6. It reveals that there is an improvement in SSR of 38 to 52 dB and 22 to 25 dB for ACF and MLP based methods respectively.

This observation is also shown in form of convergence characteristics of Fig.4, which exhibits both the rate of convergence and mini- mum mean square error (MSE). It is observed that the MLP-OPSO offered the improved convergence performance.

Table 5: Parameters used MLP-BP and MLP-OPSO

Sl.No.	Parameters used in MLP-BP	Parameters used in MLP-OPSO
01	13:3:1 structure	13-3-1 Structure W=0.9 and C1=C2=2
02	'logsig' activation function	'logsig' activation function
03	Iterations=100	Iterations=100

Table 6: Comparison of SSR between MLP-BP and MLP-OPSO under noisy condition for 13-element Barker code

Algorithms	SNR (dB)					
SSR(dB)	No Noise	20 dB	10 dB	5 dB	3 dB	2 dB
ACF	22.27	20.48	17.07	12.65	9.71	8.09
MLP-BP	41.82	42.09	42.48	39.27	35.67	31.88
MLP-OPSO	64.35	64.35	64.34	64.31	60.42	46.18

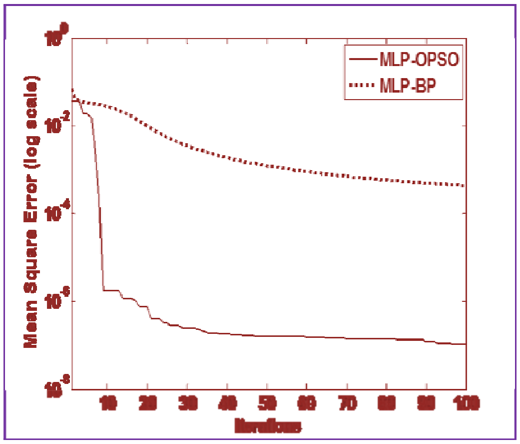

Fig. 4 Comparison of mean square error of MLP-OPSO and MLP-BP based filters

V. CONCLUSION

This paper introduces novel mismatch hybrid filter with MLP as its core structure whose weights are updated by the OPSO algorithm. Similarly another mismatch filter using tap delay line filter as the structure with its weights updated by the PSO are also proposed to assess the SSR performance under noisy condition. In all situations the proposed method mismatch filter outperforms other conventional ACF and LS based methods.

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