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Reduction of side lobes of Radar signals for Complementary Code using LMS

D. Tirumala Rao[1], P. Rajesh Kumar[2], K. Raja Rajeswari[3]
[1](*Associate professor, Department of ECE, GMRIT, Rajam-532127, AP, India)*
[2](*Professor, Department of ECE,AU College of Engineering, Visakhapatnam, AP, India)*
[3](*Professor, Department of ECE,GVP College of Engineering for Women, Visakhapatnam, AP, India)*

Abstract: *Range resolution is the ability of the radar receiver to discriminate nearby targets whereas the Doppler resolution is the ability to determine the relative speed of the target along the line of sight from the radar to the target. The performance of range and Doppler resolutions of radar would be optimal, if the coded waveform has impulsive ACF. Complementary codes waveforms support better resolutions compared to other pulses like LFM. A desirable property of the compressed pulse is that it should have low side lobes in order to prevent a weaker target from being masked in the side lobes of a nearby stronger target. The lower the side lobes relative to the main lobe peak, the better the main peak can be distinguished and hence the better is the corresponding code. In this we have proposed the LMS algorithm to design the complementary code for better performance measures like PSLR and ISLR and compared with matched filter values. The performance measures influence in discriminating the target from the noise environment.*

Keywords: *ACF, LMS, PSLR and ISLR.*

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I. Introduction

Complementary sequences, which have the property that the sum of their autocorrelation functions vanishes at all delays other than zero [1]. In existing system for radar communication by using the electromagnetic wave is used to find the targets in the radar receivers by extracting the received signal with the help of Barker, Walsh and Golay codes that are used to find the location and distance of the target. But problem occurred i.e., high side lobes are here one occurred in some cases where they dominate the main lobe it causing False Alarm[2]. In proposed system to avoid the side lobes or False alarm by using the new technique i.e., complementary codes are used instead of Barker, Walsh and Golay codes to get almost zero side lobes easy to find the target location and distance from radar[3-6].

II. Generation Of Complementary Code Pairs

Here generation of complementary codes is presented whose sum of autocorrelation functions is double the length of the sequence for zero shift and zero for other shifts[7-12]. The energy efficiency of the sequences is found as unity or 100%. The choice of the selection of the sequence in the case of complementary sequences is restricted to a few numbers of sequences[13].

The radar ambiguity function represents the output of the matched filter used by the radar designers which provides information about how different waveforms may be suitable for various radar applications. The behavior of complementary sequences is studied in ambiguity domain[14-16].

Let

$$S = (x_{0,}x_{1,}x_{2,} \dots \dots \dots .. x_{n-1,}) \quad (1)$$

be a real sequence of length N.

Consider the following two subsequences as an example of a complementary code pair

S1 = {1, 1, 1, –1, 1, 1, –1, 1} (2)

S2 = {1, 1, 1, –1, –1, –1, 1, –1} (3)

The ACF's of the subsequences in (2.2) and (2.3) are respectively

r1(k) = {1, 0, 1, 0, 3, 0, –1, 8, –1, 0, 3, 0, 1, 0, 1} (4)

r2(k) = {–1, 0, –1, 0, –3, 0, 1, 8, 1, 0, –3, 0, –1, 0, –1} (5)

Adding the two auto correlation functions together, element-by-element, generates the final decoded sequence, r(k)= r1(k) + r2(k) given by

r(k) = {0, 0, 0, 0, 0, 0, 0, 16, 0, 0, 0, 0, 0, 0, 0} (6)

A complementary code pair consists of two equal length subsequences with the property that the algebraic sum of the Auto Correlation Functions' (ACFs) of the subsequences is zero expect for only one sample point (r (0)) as given in equation.

ACF of the subsequences in (2.4) and (2.5) are respectively

R11= {1 0 1 0 3 0 –1 8 –1 0 3 0 1 0 1} (7)

R22= {-1 0 -1 0 -3 0 1 8 1 0 -3 0 -1 0 -1} (8)

R(k) represents Auto Correlation Function's (ACF's) of two equal length subsequences with the property that the algebraic sum of the Auto Correlation Function's (ACF's) of the subsequences is zero expect for only one sample point (r (0)),R(11) and R(12) represents Auto Correlation Function's (ACF's) of 8bit Sequence[17-19].

III. Adaptive Theory For LMS Analysis

a) ADAPTIVE FILTERING TECHNIQUES

The architecture of an adaptive filter which is a linear combiner is depicted in Figure below. The basic feature of any adaptive filter in common is that an input vector X and desired response d are used to compute an estimated error e which in turn controls the values of a set of adjustable filter coefficients[20].

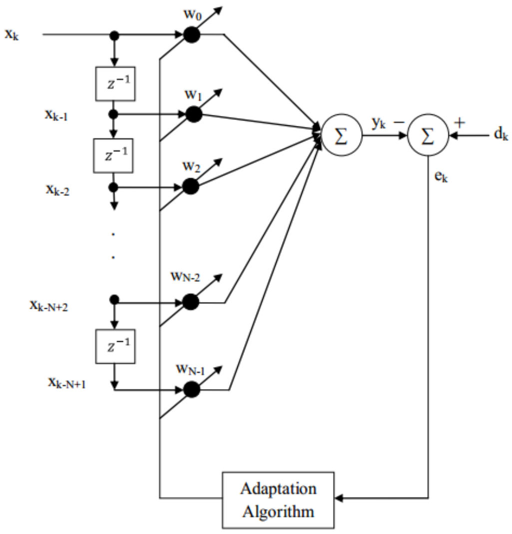


Figure 1: The architecture of adaptive linear combiner.

b) LEAST MEAN SQUARE (LMS) ALGORITHM

The Least-Mean-Square (LMS) is a search algorithm in which a simplification of the gradient vector computation is made possible by appropriately modifying the objective function. The convergence characteristics of the LMS algorithm are examined in order to establish a range for the convergence factor that will guarantee stability. The convergence speed of the LMS is shown to be dependent on the eigen value spread of the input signal correlation matrix. The LMS algorithm is by far the most widely used algorithm in adaptive filtering for several reasons

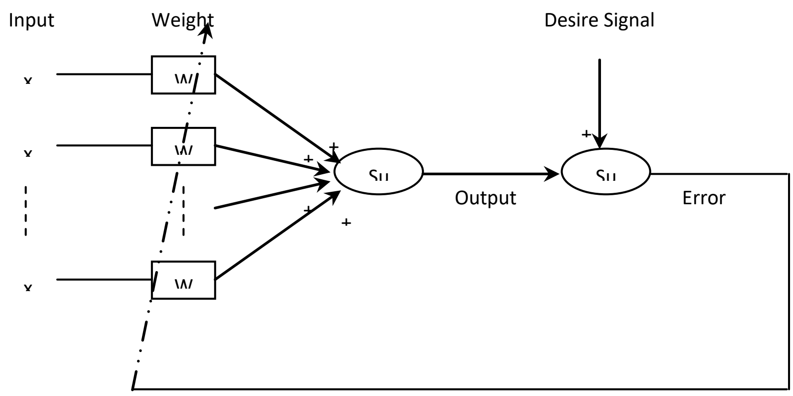


Figure 2: LMS algorithm diagram

IV. Least Mean Square Algorithm Based Pulse Compressor

The LMS algorithm is very significant algorithm for many adaptive signal processing applications because of its ease of computation and its simplicity and it doesn't require repetitions of data and off-line gradient estimations.

Let $X_k = [X_K, X_{K-1}, X_{k-2}, \ldots\ldots, X_{k-N+2}, X_{K-N+1}]$ (9)

be input vector given to combiner in serial form and

$W_k = [w_0, w_1, w_2, \ldots\ldots\ldots\ldots, w_{N-2}, w_{N-1}]$ (10)

be weight vector which are tap weights.

Now $y_k = X_k^T W_k$ (11)

Thelinear combiner output is given by the error signal with time index is given by

$$\begin{aligned} e_k &= d_k - y_k \\ &= d_k - X_k^T W_k \end{aligned} \quad (12)$$

Where d_k is the desired response at time index k.

To develop LMS algorithm, e_k^2 is taken as the estimate of gradient. Then in the adaptive process at each iteration, the gradient estimate will be of the form:

$$\hat{\nabla}_k = \begin{bmatrix} \frac{\partial e_\lambda^2}{\partial w_0} \\ \vdots \\ \frac{\partial e_\lambda^2}{\partial w_{N-1}} \end{bmatrix} = 2e_n \begin{bmatrix} \frac{\partial e_\lambda}{\partial w_0} \\ \vdots \\ \frac{\partial e_\lambda}{\partial w_{N-1}} \end{bmatrix} = -2e_\lambda X_\lambda \quad (13)$$

Where the derivatives of e with respect to weights is computed by equation (2.17).The method of steepest descent type of adaptive algorithm is expressed as

$$W_{i-1} = W_i - \mu \nabla^{\wedge}{}_k \quad (14)$$

Substituting (2.26) in (2.27) we get the updating equation of weights in LMS algorithm as follows

$$W_{\lambda+1} = W_\lambda + 2\mu e_\lambda X_\lambda \quad (15)$$

where μ is the gain constant that regulates the step size. It has the dimensions reciprocal to that of signal power. The weights are updated for each iteration until the estimate of the gradient gets minimized.

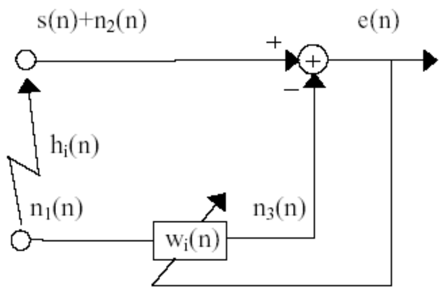


Fig 3: Adaptive Noise Canceller

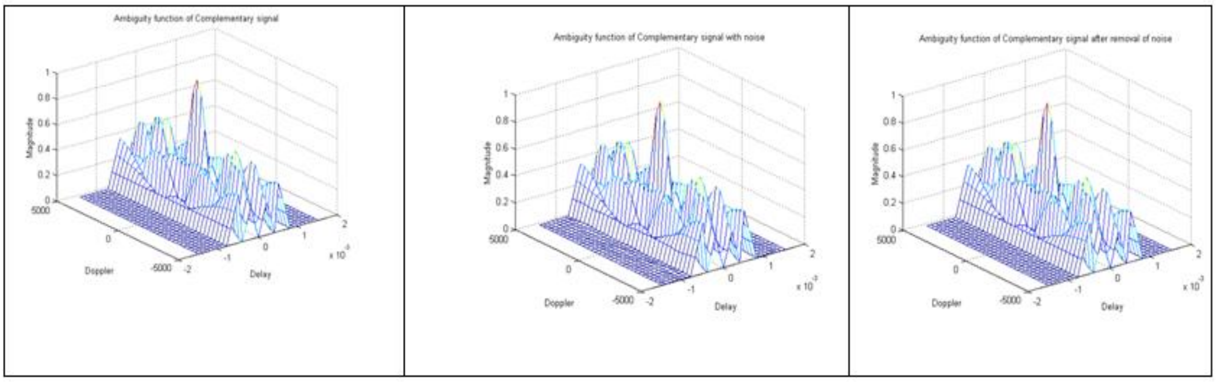
V. Results And Discussion

The main performance measures ISLR & PSLR in range &doppler domains of signal under study are evaluated. LMS algorithm is used to find the target location by applying complementary codes. The main purpose of this study is to analyze which of these signals have the better (lower) values of Peak Side lobe Level and Integrate Side lobe Level. Here the performance measures ISLR & PSLR in range &doppler domains with LMS algorithm are shown in the tables 1, 2&3 for comparison with matched filter (Direct) values.

TABLE 1: Performances Measures Of 16 Bit Complementary Code In Range And Doppler Domains

S.NO	SNR (dB)	Range resolution				Doppler resolution			
		ISLR		PSLR		ISLR3		PSLR3	
		Without LMS	With LMS	Without LMS	With LMS	Without LMS	With LMS	Without LMS	With LMS
1	0	-3.2713	**-5.1981**	-0.0321	**-0.9218**	-0.6104	**-1.1018**	-0.0817	**-1.9214**
2	5	-5.2918	**-6.1151**	-0.2624	**-0.9892**	-1.2129	**-2.1156**	-0.1274	**-3.0126**
3	10	-6.4817	**-7.1011**	-0.8412	**-1.6096**	-1.8029	**-3.2578**	-0.2719	**-3.1810**
4	15	-6.9821	**-7.1018**	-1.1867	**-1.7510**	-1.9217	**-5.1819**	-0.8243	**-4.7219**
5	20	-7.0127	**-8.6209**	-1.7624	**-1.9818**	-2.0992	**-7.8246**	-0.9778	**-6.9280**
6	25	-10.1572	**-17.6211**	-1.9108	**-2.0230**	-2.1924	**-8.4126**	-1.5467	**-9.2174**
7	**30**	**-12.1421**	**-18.4210**	**-1.9891**	**-2.1465**	**-2.3916**	**-9.2302**	**-1.9321**	**-11.4127**

*without LMS means Matched filter (Direct) values



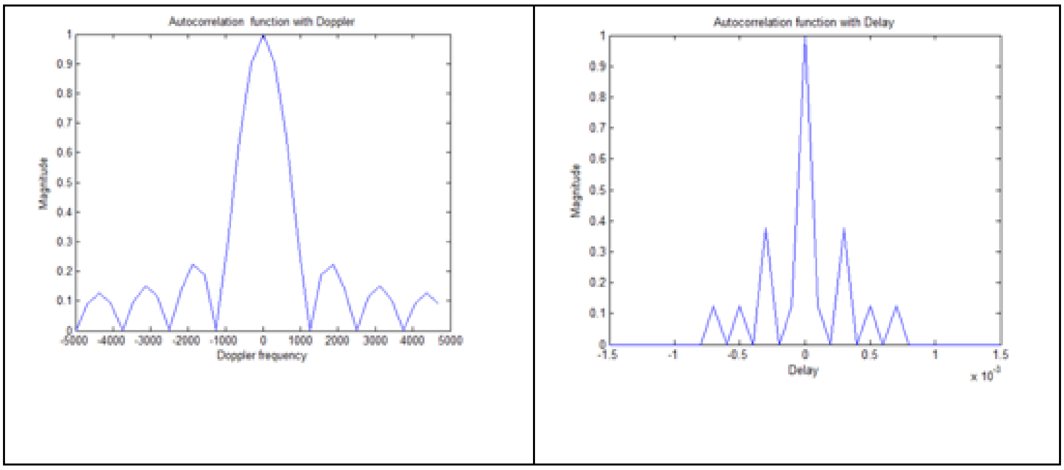
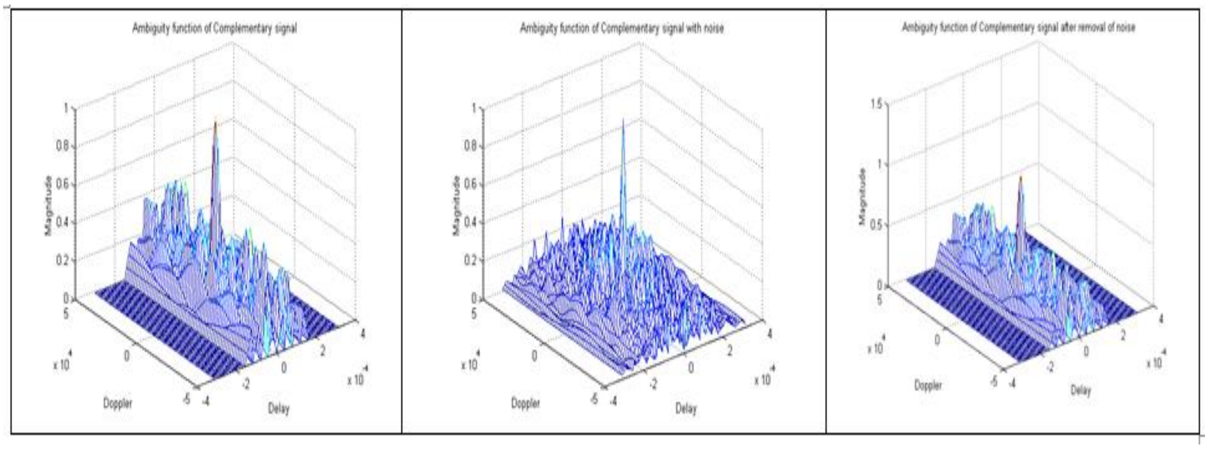


Table 2: Performances Measures of 32 Bit Complementary Code in Range and Doppler Domains

S.NO	SNR (dB)	Range resolution				Doppler resolution			
		ISLR		PSLR		ISLR3		PSLR3	
		Without LMS	With LMS	Without LMS	With LMS	Without LMS	With LMS	Without LMS	With LMS
1	0	-8.9416	**-9.9289**	-0.4846	**-0.9686**	-0.6303	**-3.2032**	-0.0899	**-3.2945**
2	5	-9.0576	**-10.0250**	-0.6445	**-1.0434**	-1.6240	**-3.7984**	-0.1894	**-4.2394**
3	10	-10.2612	**-11.0578**	-1.2881	**-4.1152**	-1.9023	**-5.2970**	-0.3275	**-4.9915**
4	15	-11.0854	**-11.3248**	-2.24	**-4.3259**	-2.0762	**-7.5416**	-0.9738	**-6.4898**
5	20	-11.8255	**-12.1591**	-2.2704	**-4.3290**	-2.3943	**-11.7843**	-1.2030	**-9.4520**
6	25	-11.9948	**-17.4846**	-2.8061	**-4.5106**	-2.7889	**-13.2599**	-1.7855	**-14.8154**
7	**30**	**-18.1027**	**-39.8743**	**-3.0964**	**-4.6513**	**-2.9472**	**-15.3646**	**-2.9777**	**-24.3875**



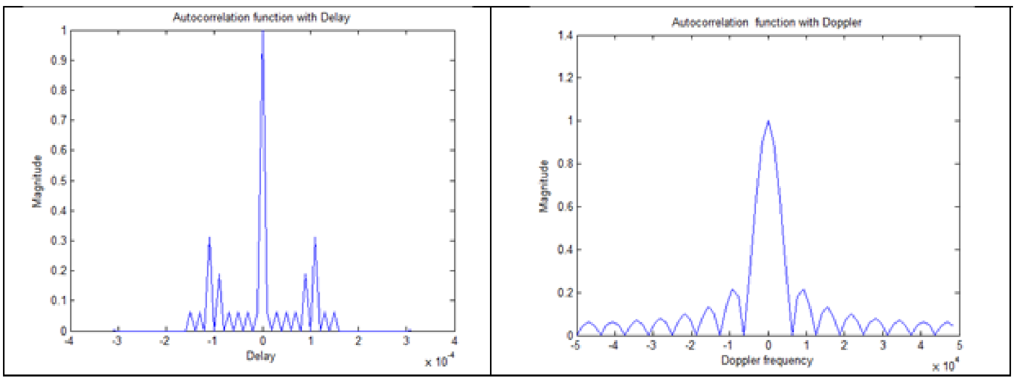
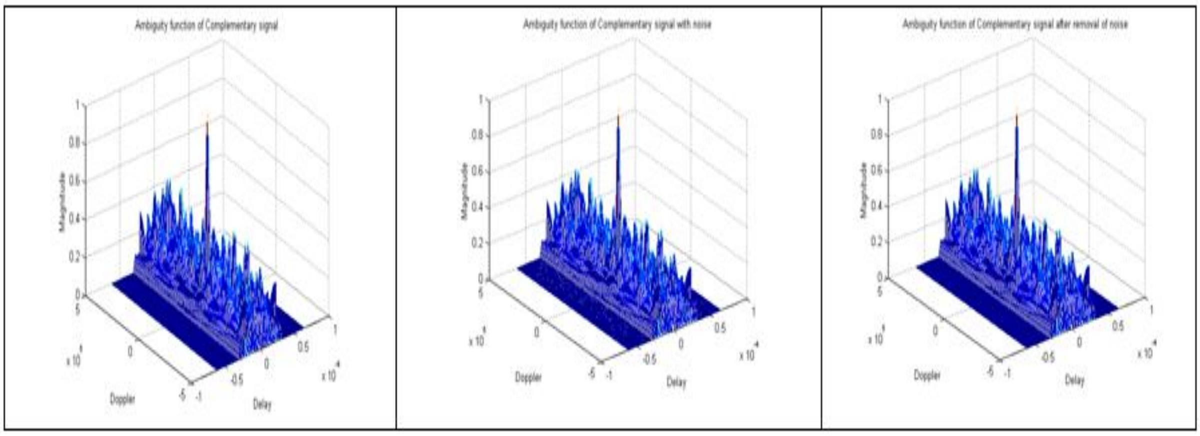
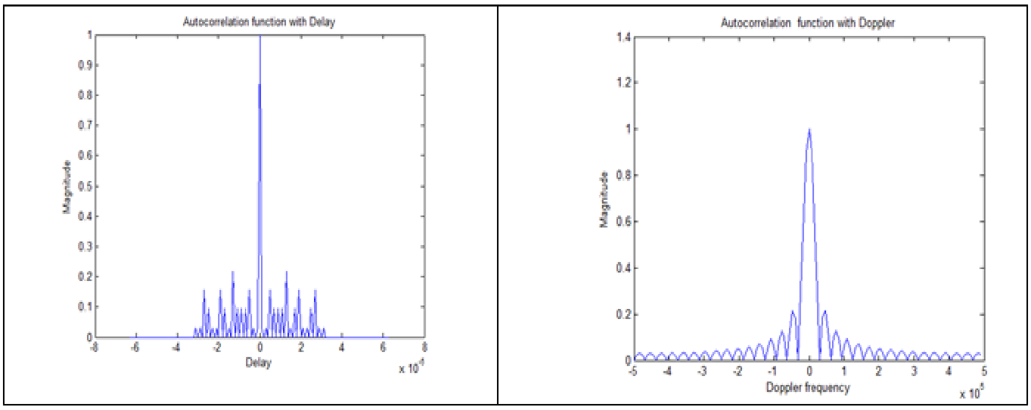


Table 3: Performances Measures of 64 Bit Complementary Code in Range and Doppler Domains

S.NO	SNR (dB)	Range resolution				Doppler resolution			
		ISLR		PSLR		ISLR3		PSLR3	
		Without LMS	With LMS	Without LMS	With LMS	Without LMS	With LMS	Without LMS	With LMS
1	0	-8.9471	-9.9314	-0.4892	-1.0216	-0.6319	-4.1017	-0.0899	-3.4117
2	5	-10.1127	-11.4310	-0.6448	-2.0618	-1.6319	-4.2210	-0.1928	-4.5411
3	10	-10.2894	-12.2356	-1.3228	-5.0016	-1.9292	-5.4116	-0.3394	-4.9976
4	15	-11.3271	-12.9280	-2.6127	-5.4632	-2.2784	-8.1108	-0.9949	-6.8917
5	20	-11.9862	-13.1457	-2.6723	-5.7618	-2.9362	-12.9817	-1.2742	-9.8912
6	25	-12.9917	-19.7120	-2.9417	-5.9819	-3.0198	-14.7211	-2.3364	-14.9954
7	**30**	-18.9321	-39.9476	-3.2079	-6.0018	-3.2714	-15.7618	-3.1229	-24.9816





After applying LMS algorithm, the ISLR & PSLR values for 16, 32&64bits length at different SNRs i.e., 0, 5, 10, 15, 20, 25&30dB are falling to lower values than the values of without Adaptive (LMS) algorithm. This indicates falling of side lobes (or reduction of side lobes) with LMS algorithm.

VI. Conclusion

Based on the results obtained the noise performance measures, ISLRs & PSLRs are calculated for 16, 32 &64 bit lengths of complementary code. In all these cases the calculated values of ISLRs and PSLRs using ACF with LMS are low in magnitude. As SNR increases ACFs of ISLR & PSLR and ISLR3& PSLR3 decreases in 16, 32& 64 bit complementary codes in Range and Doppler domains. After applying LMS algorithm, the ISLRs & PSLRs values for 16, 32&64bits length at different SNRs ie 0, 5, 10,15,20,25 &30dB are falling to lower values than the values of without Adaptive (LMS) algorithm.

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