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Optimal Target Detection Using Coded Waveform Design

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ABSTRACT
A novel design approach has been proposed to evaluate the detection ability of high range resolution radar(HRR) systems using poly-semantic sequences (PSS) in the presence of high additive noise. The PSS are optimized by employing Hamming Backtrack algorithm with figure of merit as the measure of goodness. The simulation results show that the proposed sequences give improved robustness of noise for HRR target detection.

KEYWORDS
Hamming Backtrack Algorithm, High Range resolution Radar, Poly-Semantic Sequences, Optimal Binary Codes.

I. INTRODUCTION

The notion of poly-alphabetic radar [1], [2] introduced earlier based on simultaneous multiple interpretations of pre-designed returned waveform, results into improved detection performance of binary pulse compression radar at the affordable cost of an additional signal processing. In fact, the central idea of poly-alphabetic radar signal is poly-semanticism, which was achieved through poly-alphabetism. In the earlier work based on mono-alphabetic poly-semanticism [3], the problem of optimal target detection was discussed in the context of single target in noise free environment. In our approach, Optimal Binary Codes (OBC) and randomly generated mono-alphabetic codes are considered to generate poly-semantic sequences of larger lengths up to 5100. The receiver system is designed by considering multiple targets with noisy environment. The quantitative measures; Discrimination(D) and Figure of merit(F) suggested by Moharir [4] for binary sequences are used to evaluate the detection performance of the poly-semantic codes. The transmitted binary sequence is optimized by employing poly-semantic Hamming backtrack scan algorithm such that each of the poly-semantic interpretations lead to maximum discrimination or figure of merit. The generations of poly-semantic sequences and radar signal processor for application in high resolution radar target detection are discussed in Sec II. The rest of this paper is organized as follows. Calculations of figure of merit are presented in section III. In sections IV, V and VI, we present the noise, range resolution and detection performances of poly-semantic sequences to obtain noise rejection with respect to figure of merit in the application of high resolution radar. Conclusion are made in section VII.

II. POLY-SEMANTIC RADAR SIGNAL PROCESSOR

The generation of poly-semantic sequences is completed in two steps: first one using restricted (selective) Hamming backtrack scan for interspersed binary sequences and the second, using a complete Hamming backtrack scan for poly-semantic sequences with figure of merit as joint objective function. The block schematic diagram of poly-semantic radar signal processor at the transmitter is shown in Fig.1(a).

1 First Step in the Signal Design

Consider, optimal binary codes or randomly generated binary codes of length N, given by

$S_1 = A = [a_i]$ (1)

$B = [b_i]$ (2)

and $C = [c_i]$ (3)

where i = 0, 1 ,2, 3 , …, N-1.

The elements of these sequences are drawn from alphabet {-1, +1}.

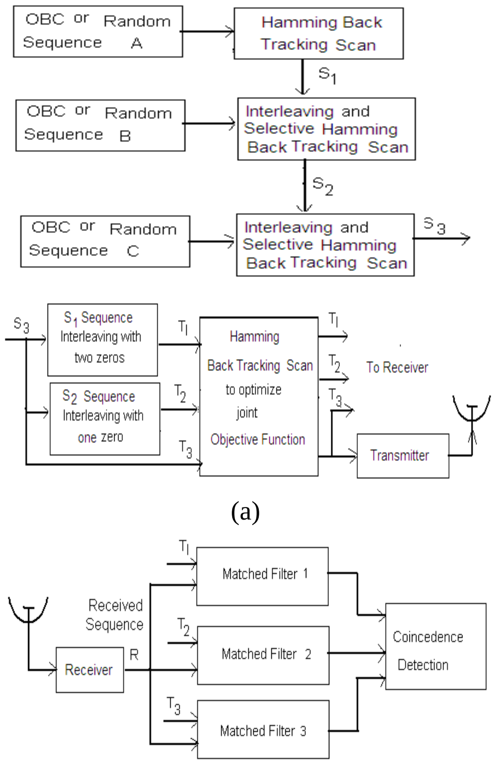
The sequence S_1 is mutated using Hamming backtrack algorithm to get optimum figure of merit. The sequences S_2 of length 2N and S_3 of length 3N are generated by interleaving the elements of S_1 & B, and S_2 & C respectively as shown in Fig.1(a). Therefore

$S_2 = [a_i \; b_i]$ (4)

and $S_3 = [a_i \; b_i \; c_i]$ (5)

where i = 0, 1 ,2, 3 , …, N-1.

A selective Hamming backtracking algorithm [5], [6] is applied on the sequences S_2 and S_3 , so that the figure of merit of the output sequence is optimized. This algorithm performs mutations only on the embedded elements, *i.e.*, b_0, b_1, b_2, b_3 … of the sequence S_2, and c_0, c_1, c_2, c_3 … of the sequence S_3, without disturbing the other elements.



(a)

(b)

Fig.1. Block schematic diagram of poly-semantic radar signal processor (a) Transmitter (b) Receiver.

2 Second Step in the Signal Design

Since, S_3 is interspersed by binary sequences S_1 and S_2, it is equivalent to three sequences with good autocorrelation properties being transmitted in the form of S_3. To use the good correlation properties of the binary sequences S_1, S_2 and S_3 jointly, the elements of S_1, S_2 and S_3 are taken from S_3 and embedded with zeros which results, the new sequences of length 3N given by

$$T_1 = [\ a_0, 0, 0,\ a_1, 0,\ 0,\ a_2,\ 0,\ 0\ \ldots\ a_{N-1},\ 0, 0\ ] \quad (6)$$
$$T_2 = [\ a_0, b_0,\ 0,\ a_1,\ b_1,\ 0,\ a_2,\ b_2,\ 0 \ldots a_{N-1},\ b_{N-1},\ 0\ ] \quad (7)$$
$$T_3 = S_3 = [\ a_0,\ b_0,\ c_0,\ a_1,\ b_1,\ c_1,\ a_2,\ b_2,\ c_2 \ldots\ a_{N-1},\ b_{N-1},\ c_{N-1}\ ] \quad (8)$$

The Hamming backtrack algorithm is applied on T_1, T_2 and T_3 for optimizing the joint figure of merit of the cross correlated of sequences S_3 & T_1, S_3 & T_2 and S_3 & T_3. The good cross-correlation properties of these three interpretations are jointly used through coincidence detection for the detection of targets. The binary sequence S_3 (T3) is transmitted as a waveform.

The signal processing system at the receiver is shown in Fig.1(b). On reception, the received waveform which is perturbed by Gaussian noise is decoded into binary sequence (R). The received binary sequence R is cross correlated with three embedded sequences T_1, T_2 and T_3 (or S_3) in three channels separately using matched filters. In coincidence detection, the simultaneous alignments of three cross correlation peaks from three channels indicate the presence of the target. It can also be observed that the time sidelobes in three channels do not align. This in turn reduces the degree of false alarm due to time sidelobes in the return signal.

III. IMPROVED FIGURE OF MERIT

The discrimination or figure of merit of any sequence deteriorates as the noise strength increases and has individual performance deterioration pattern. That is the rate of deterioration can also vary from sequence to sequence. Thus, a sequence with superior performance at low noise levels could have a faster rate of deterioration as noise level increases than another sequence which has inferior performance at low noise levels coupled with slower rate of deterioration. Under such situations, the ranking of sequences may be different at different noise levels [7], [8]. But, for poly-semantic sequences the rate of deterioration in figure of merit remains uniform with respect to increase in noise. The Figure of merit of the poly-semantic sequence depends on the Hamming neighborhood of the transmitted signal so that the received signal is allowed to be anywhere in that neighborhood. Since the poly-semantic sequences are optimized with HBT algorithm, at higher sequence lengths as the size of the neighborhood increases, we can achieve better noise and high resolution in terms of figures of merit. Table.I gives the figure of merit of poly-semantic sequences of length, N=585 to 5100. These results provide evidence that the figure of merit is high at larger lengths and become stable as length increases further.

Table.I Figure of merit and Discrimination for poly-semantic sequences

Length N	Figure of Merit	Discrmination
3159	0.9654	28.98
3645	0.9668	30.12
4092	0.9662	29.65
4293	0.9694	32.77
4743	0.9693	32.71
4890	0.9701	33.49
5100	0.9694	32.69

Length N	Figure of Merit	Discrimination
585	0.9368	15.81
633	0.94	16.65
825	0.9479	19.186
1071	0.9486	19.47
1173	0.9497	19.88
1377	0.9527	21.18
1575	0.9600	25.00
2250	0.9613	25.86

IV. NOISE ROBUSTNESS

To evaluate the noise performance, the poly-semantic sequences, which are perturbed by Gaussian noise at different Signal to Noise Ratio (η) are considered as input sequence. The noise effect on figure of merit at different sequence lengths is shown in Fig. 2. The noise performance is examined when the echo is received from a single target for different values of η ranging between 0 dB to -20 dB. The noise performance results clearly show that the PSS exhibits high noise robustness at the higher sequence lengths.

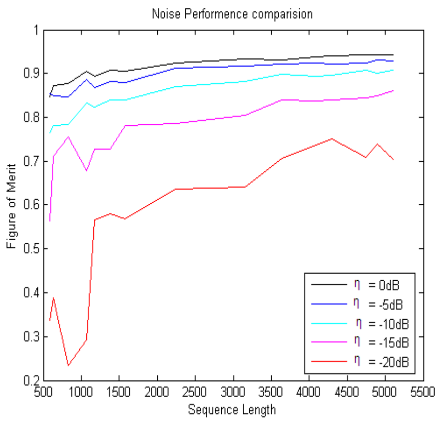


Fig. 2 Noise performance of poly semantic sequences

V. RANGE RESOLUTION

For range resolution ability, consider a target model when a dispersed echo is reflected from two targets located at sub-pulse duration apart (SPDA)[2] of zero to (N-1). Table. II gives the figure of merit for poly-semantic sequences of length, N=585 to 5100 when two targets are located at SPDA =2. It is observed that the figure of merit is same for both targets. The effect on figure of merit at different sequence lengths is shown in Fig. 3 when two targets are located at different SPDA. It is evident that the figure of merit is less for two targets when compare to single target. This is because of sharing of available energy between the peaks. Also when the targets are at different SPDA the variation in figure of merit is very less.

Length	Figure of Merit	
	Target-1	Target-2
585	0.88194	0.88194
633	0.88818	0.88818
825	0.90476	0.90476
1071	0.90556	0.90556
1173	0.90744	0.90744
1377	0.91336	0.91336
1575	0.92574	0.92574
2250	0.92813	0.92813
3159	0.93634	0.93634
3645	0.93715	0.93715
4092	0.94542	0.94542
4293	0.94204	0.94204
4743	0.94252	0.94252
4890	0.94235	0.94235
5100	0.94129	0.94129

Table.II Figure of merit for poly-semantic sequences of length, N=585 to 5100 when two targets are located at SPDA =2

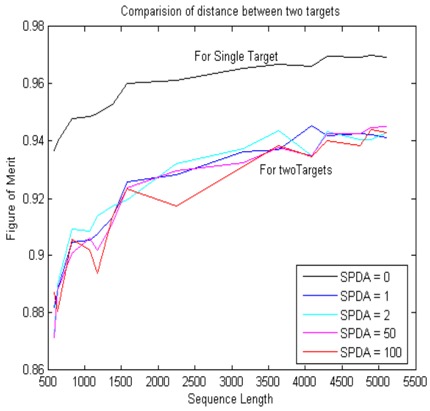


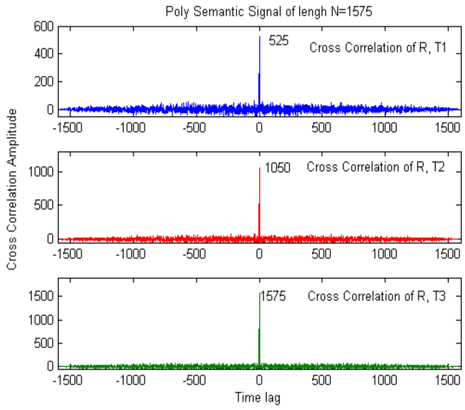
Fig. 3 Figure of merit of poly semantic signal when two targets are at different SPDA.

VI. DETECTION PERFORMANCE

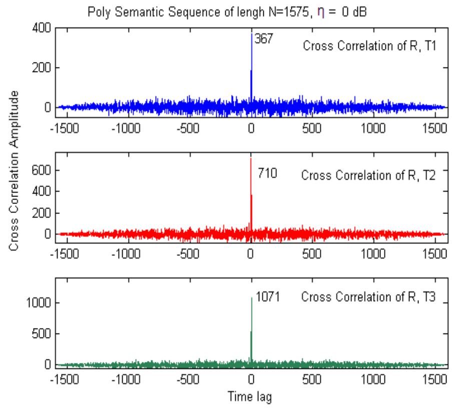
Let us consider a K_a-band 30 GHz radar, transmitting a poly-semantic sequence of length N=1575 with pulse interval of 36.25 μs. The sub-pulse time interval τ is 50 ns (signal bandwidth is 20 MHz and range resolution is 7.5 m). At the receiver, the resultant waveform is multiply interpreted for coincidence detection is shown in Fig. 4(a). When η decreases below 0 dB, the rate at which figure of merit deteriorates increases. It is observed from Fig. 4 (c), when η = -15dB, the main lobe peak at zero lag in the first display is completely masked due to high dense noise.

It is still possible to detect the target from the coincidence peaks of second and third display channels. The joint coincidence of autocorrelation peaks simultaneously in different channels indicates the presence of target. It is also interesting to observe that the surrounding side lobes will not align or synchronize in three channels. This eliminates the possibility of false target detection due to time side lobes. The figures of merits values corresponding to three detection stages in Fig. 4(b) are 0.0685, 0.2973 and 0.5314 respectively. When η exceeds -15dB, the target detection becomes very critical.

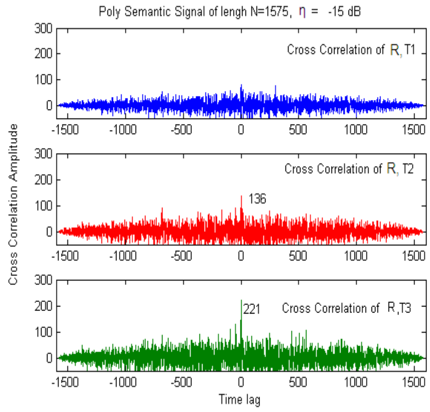
Fig.5 (a) shows the output waveforms of poly-semantic sequences when two targets are located at 50 SPDA in noise free environment, 5(b) when noise is at η = -10 dB. The targets can be detected even if the η falls to -15dB as shown in Fig.5(c). This is not possible with conventional sequences. Simulation results show that for HRR systems, poly semantic sequences show better noise robustness compare to conventional binary and poly-phase sequences [2].



(a)

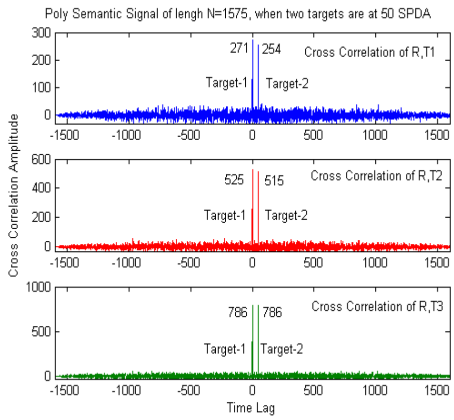


(b)

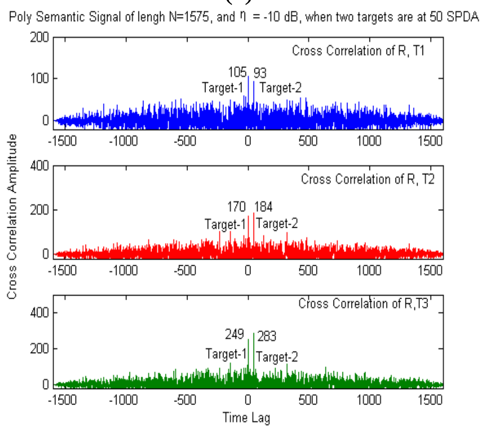


(c)

Fig. 4 Coincidence detection of the poly-semantic sequence at length N=1575 (a) when no noise (b) η = 0 dB and (c) η = -15 dB



(a)



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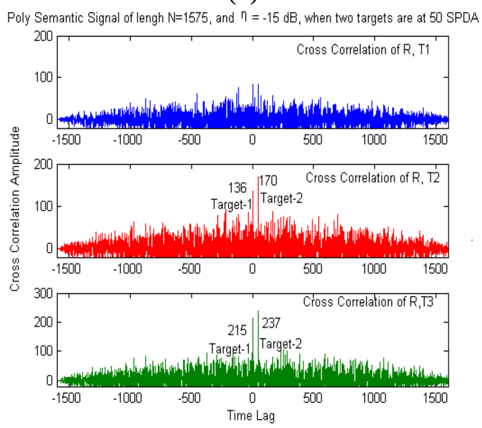

(c)

Fig.5 (a) Poly-semantic sequences of length 1575 for two targets at 100 SPDA with no noise, (b) at η = -10 dB (c) at η =-15 dB.

VII. CONCLUSIONS

The signal design problem for high resolution radar systems is solved by the notion of poly-semantic sequences

which are generated and transmitted with the existing transmission technology. The poly-semantic sequences are optimized by using Hamming backtrack scan algorithm. The received signal is subjected cross-correlation with reference poly-semantic sequences. These sequences are processed separately to setup a coincidence detection scheme. The simulation results indicate that the single or multiple target detection could be achieved up to η of -15 dB, which is significant improvement in the performance of pulse compression radar sequences in HRR target detection compared to conventional poly–phase sequences.

REFERENCES

[1]. I.A. Pasha, N. Sudershan Rao, P. S. Moharir, "Poly-alphabetic Pulse Compression Radar Signal Design," Modeling, Measurement & Control, Journal of AMSE, vol.74, no.4, pp.57-64, 2001.
[2]. Y. Mallikarjuna Reddy , I. A. Pasha, S. Vathsal, **"**Poly-alphabetic radar signal processor for efficient target detection" International radar Symposium I -2007, Bangalore, pp. 30-34.
[3]. I. A. Pasha, P. S. Moharir & V. M. Pandharipande, " Poly-semantic binary pulse compression radar sequences", IEEE TENCON 2003, IEEE Technical conference on convergent technologies for the Asia-Pacific.
[4]. Moharir. P.S., RajaRajeswari. K. and VenkataRao. K., "New figures of merit for pulse compression sequences", Journal of IETE, vol. 38, no. 4, pp. 209-216, 1992.
[5]. RajaRajeswari.K.et.al. "New figures of merit for range resolution radar using hamming and euclidean distance concepts" Proceedings of the 7th WSEAS International Conference on Multimedia Systems & Signal Processing, Hangzhou, China, April 15-17, 2007 pp.-139-145, 2007.
[6]. P.Z.Peebles,JR., Radar Principles," John Wiley & Sons, Inc.,2004.
[7]. Golay M J E, "The merit factor of long low autocorrelation binary sequences", IEEE Trans. Inf. Theory IT-28: 543-549, 1982.
[8]. R. J. Keeler and C. A. Hwang, "Pulse compression for weather radar," in Proc. IEEE Int. Radar Conf., pp. 529–535, 1995.