Generation of New Complementary and Sub Complementary Pulse Compression Code Sequences

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Abstract— Phase coding and linear frequency modulations are commonly used in radar systems for pulse compression to achieve high range resolution. In this paper aims to make an in-depth study of Radar pulse compression technique. Pulse compression (PC) is an important module in many of the modern radar systems. It is used to overcome major problem of a radar system that requires a long pulse to achieve large radiated energy but simultaneously a short pulse for range resolution .Range resolution is an ability of the receiver to detect nearby targets. The performance measures of PC techniques are MSE, PSNR loss and Doppler shift. A new type of codes, named subcomplementary codes, is introduced. These codes are close to, but not strictly, complementary. Each of the two sequences of the pair has an equal number of opposite elements, which enables the codes to have very high interference suppression factor (ISF) performances in and around the radar center frequency. The disadvantage of these codes is the presence of sidelobes of amplitude of in their autocorrelation functions for lag 1 (being the code length). Some properties of these codes are presented along with a technique for generating the code pairs. Subcomplementary code pairs have been found for values of equal to 4, 8, 16 and 32. A simulation study confirms a major improvement in ISF over complementary code pairs around the zero Doppler frequency. The degradation in performance in signal-to-noise ratio observations is found to be noticeable but not severe. The subcomplementary code pairs may, therefore, be used in situations where their advantages for interference suppression are exploited and where the effects of their weaknesses are not so important as in the case of observations for applications in meteorology.

Keywords: Complementary sequences, sub complementary code pair, Auto correlation, interference stratosphere–troposphere radar.

I. INTRODUCTION

Pulse compression techniques involve transmission of a long coded pulse and compression of the received echo using matched filter to obtain a narrow pulse. These results in an increased detection performance associated with a long–pulse radar system while still maintaining the fine range resolution of a short–pulse system. The matched filter maximizes the output signal to noise ratio (SNR). A measure of degree to which the pulse is compressed is given by the compression ratio defined as

$$CR = \frac{T}{\tau} = TB \qquad (1)$$

Where, T= transmitted pulse length, $\tau = 1/B$ = Compressed pulse length, and B is the bandwidth of the transmitted waveform.

For range resolution radar, a coded waveform or a sequence can be taken as

$$X = x_0, x_1, x_2, ..., x_{N-1} \qquad (2)$$

With a periodic autocorrelation

$$r(k) = \sum_{i=0}^{N-1-k} x_i \, x_{i+k} \qquad (3)$$

Where $k = 0, 1, 2, ..., N-1$

For sequences to be good, the autocorrelation should have very large peak for zero shift with very small side lobes. In other words, r(0) to be very large and r(k≠0) to be ideally zero is required.

II. COMPLEMENTARY CODED WAVEFORMS

As defined by Golay in [3], the basic property of complementary series may be expressed in auto correlative terms. Let the various a_i and b_i elements $(i = 1,2,3.............n)$ of two n-long complementary series be either +1 and -1, -and let their respective autocorrelation series be defined by

$$R_A(j) = \sum_{i=1}^{N-j} a_i a_{i+j} \qquad (4)$$

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and $$R_B(j) = \sum_{i=1}^{N-j} b_i b_{i+j} \quad (5)$$

We have

$$R_A(j) + R_B(j) = \begin{cases} 2N & j = 0 \\ 0 & j \neq 0 \end{cases} \quad (8)$$

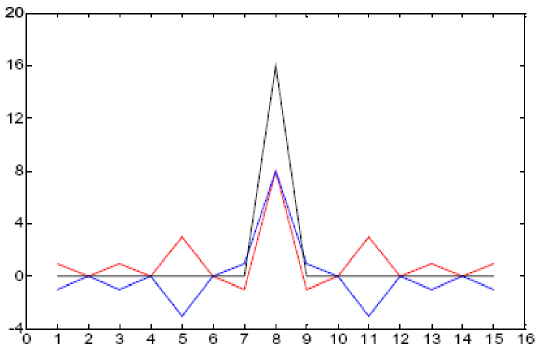

Figure 1: Autocorrelation Functions R_A (red), R_B (blue), and $R_A + R_B$ (black)

A complementary code pair, as defined by Golay [3], consists 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)) as given in equation (6) [1].

As an example

S1={1 1 1 –1 1 1 –1 1} (6)

S2={1 1 1 –1 –1 –1 1 -1} (7)

ACF of the subsequences in (6) and (7) are respectively

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

R22= {-1 0 -1 0 -3 0 1 8 1 0 -3 0 -1 0 -1} (9)

Adding the two autocorrelation functions (8) and (9) together element by element, final decoded sequence

R=R11+R22, given by

R= {0 0 0 8 0 0 0} (10)

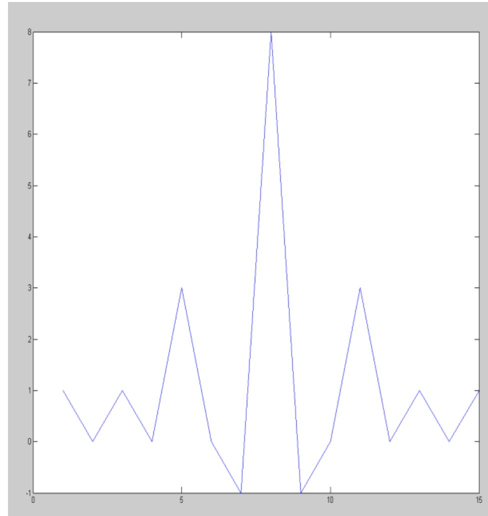

Figure 2: ACF of 8 bit R11

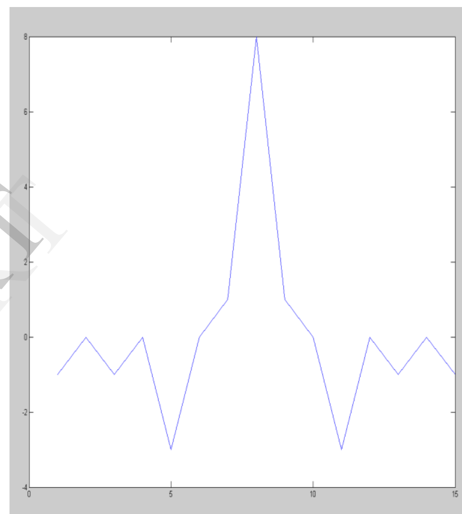

Figure 3: ACF of 8 bit R22

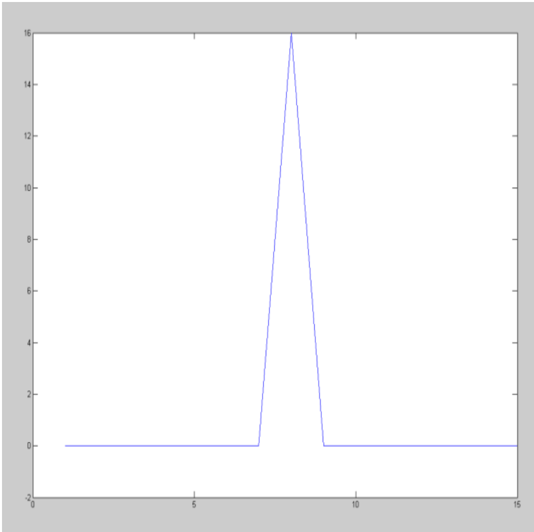

Figure 4: Sum of ACF 8 bit R(K)

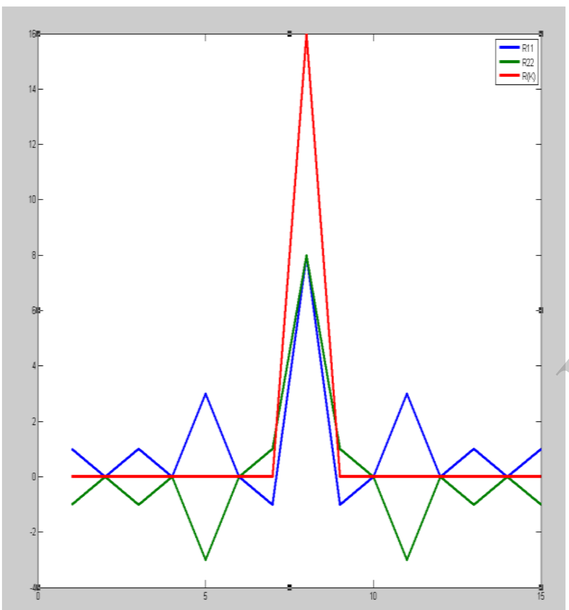

Figure 5: Comparison of ACF 8 bit R11, R22, R (K)

III. SUB COMPLEMENTARY CODE PAIRS

New types of codes, named subcomplementary codes, are introduced. These codes are close to, but not strictly, complementary. Each of the two sequences of the pair has an equal number of opposite elements, which enables the codes to have very high interference-suppression-factor (ISF) performances in and around the radar center frequency. The disadvantage of these codes is the presence of sidelobes of amplitude of –N in their autocorrelation functions for lag 1 (N being the code length). Some properties of these codes are presented along with a technique for generating the code pairs. Subcomplementary code pairs have been found for values of N equal to 4, 8, 16, 20, and 32. A sub complementary code pair[4], consisting of the sequences C_0 and C_1, whose elements are given by (11) and (12) respectively, has the property that the sum of the ACFs of the two sequences of their p[air is equal to zero, except for 0 and 1 lags, where it has 2N and –N, respectively, i.e., (14)

$$C_0 = \{c_{1,} c_2, \ldots\ldots, c_N\} \qquad (11)$$

$$C_1 = \{c^1{}_{1,} c^1{}_2, \ldots\ldots, c^1{}_N\} \qquad (12)$$

Such that

$$c_{i,} c_i^1 \in \{1, -1\}, \qquad i = 1, 2, \ldots\ldots\ldots, N \qquad (13)$$

Where N is the number of elements of each sequence.

$$R_0(\gamma) + R(\gamma) = \begin{cases} 2N, if\ \gamma = 0 \\ -N, if\ \gamma = \pm 1 \\ 0, Otherwise \end{cases} \qquad (14)$$

As an example of a Subcomplementary code pair, consider the following two subsequences.

S1={1,-1,1,-1,1,-1,-1,1} (15)

S2={1,-1,1,-1,-1,1,1-1} (16)

The ACF's of the subsequences in (15) and (16) are respectively

r1(k)={1,-2,1,0,-1,2,-5,8,-5,2,-1,0,1,-2,1} (17)

r2(k) = {-1,2,-1,0,1,-2,-3,8,-3,-2,1,0,-1,2,-1} (18)

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

r(k) = {0, 0, 0, 0, 0, 0, -8, 16, -8, 0, 0, 0, 0, 0, 0} (19)

A Sub Complementary code pair, as defined by Golay [3], consists 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)) as given in equation .
ACF of the subsequences in (15) and (16) are respectively.

R11= {1,-2,1,0,-1,2,-5,8,-5,2,-1,0,1,-2,1} (20)

R22={-1,2,-1,0,1,-2,-3,8,-3,-2,1,0,-1,2,-1} (21)

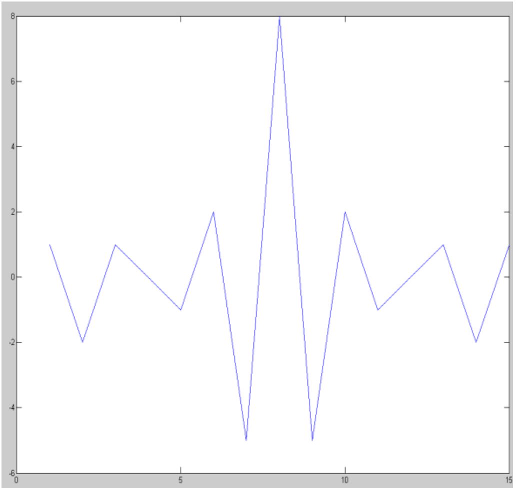

Figure 6: ACF of 8 bit R11

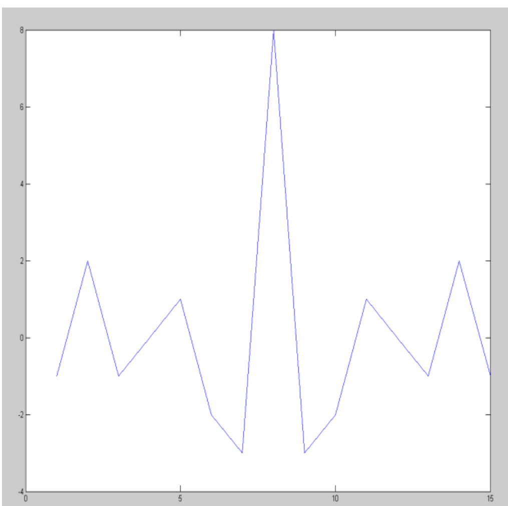

Figure 7: ACF of 8 bit R22

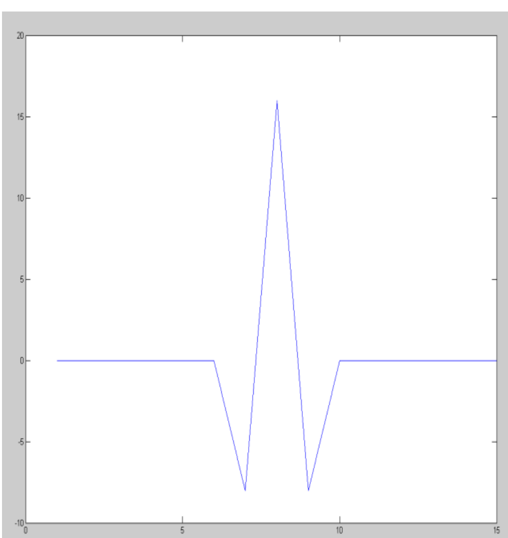

Figure 8: Sum of ACF 8 bit R(K)=R11+R22

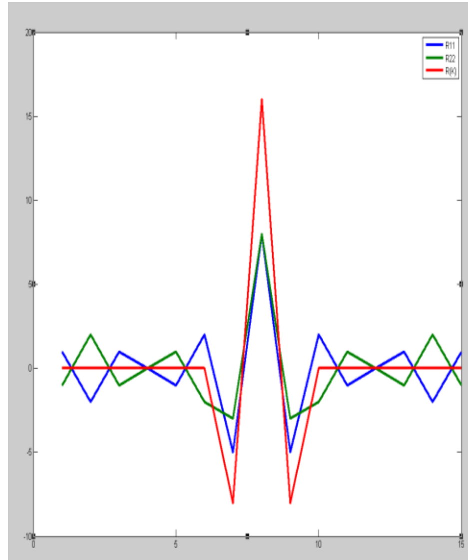

Figure 9: Comparison of ACF 8 bit R11, R22, R (K)

IV. RESULTS

Complementary

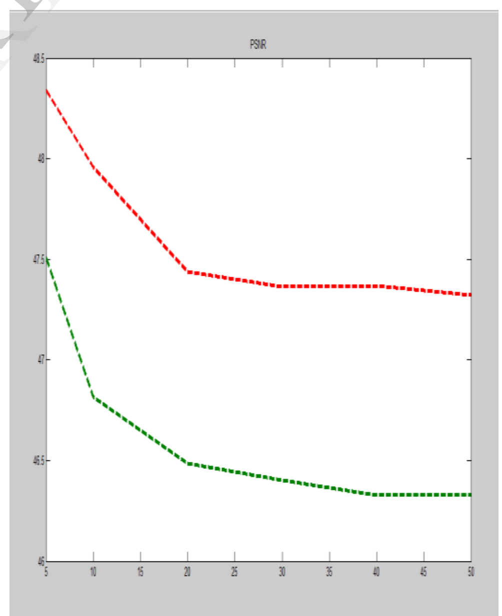

Figure 10: PSNR Complementary Sequences

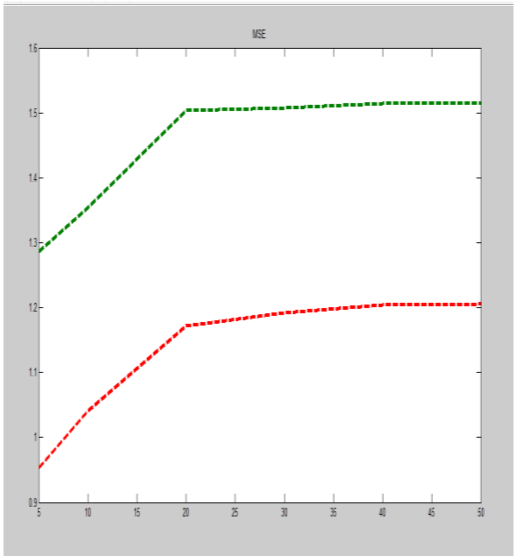

Figure 11: MSE Complementary Sequences

Subcomplementary

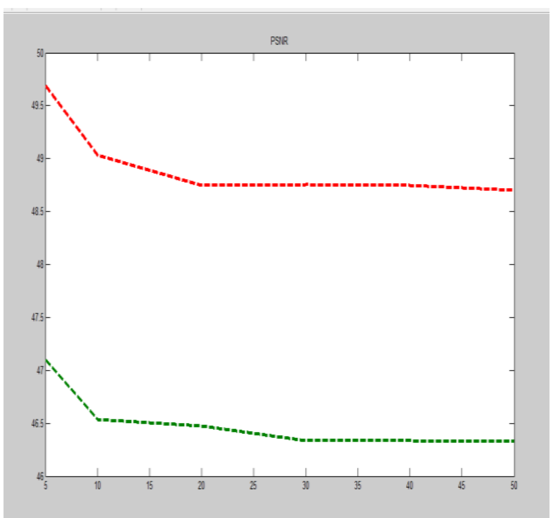

Figure 12: PSNR Sub Complementary Sequences

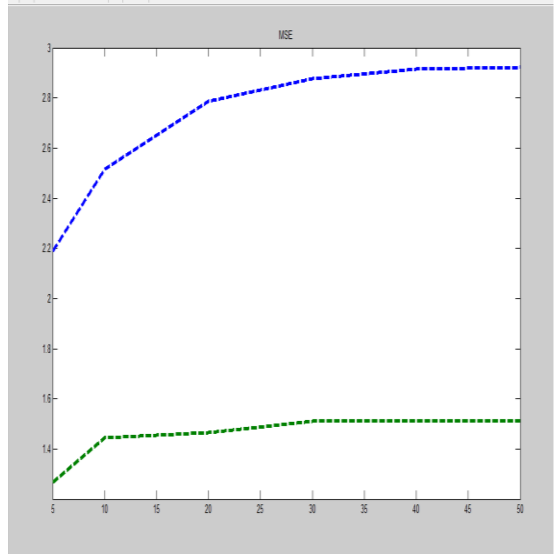

Figure 13: MSE Sub Complementary Sequences

V. CONCLUSION

Complementary code pairs and sub complementary code pairs of length-32 and complementary set of length 16 are used to radiate the power and returns for the atmosphere were processed. The experimental observations are preliminary and only done for few codes and it can also be extended for number of complementary codes with different lengths of different classes. The work can be extended to poly phase complementary codes. In this thesis we compare the merit factors of different side lobe reduction techniques with a novel technique, using Binary code of length. The tradeoff in reducing the Peak side lobe level is spreading of the compressed pulse. Pulse compression technique is that which uses two correlation filters to produce a single discrete filter, it reduces Peak side lobe level and Integrated side lobe level at sacrifice of main lobe splitting and 3 [dB] SNR losses. The modified forms of Pulse compression reduce the PSL further and also the main lobe splitting present in matched filter removed.

REFERENCES

[1] Nadav Levanon, Radar Signals,IEEE Press, Wiley 2004
[2] V. K.Anandan, signal detection and processing techniques for Atmospheric radars IETE-NARL seminar on Recent Trends in Modern Communications, Gadanki, 25th and 26th November 2005.
[3] M.J.E.Golay, Complementary series, Trans IEEE, vol IT-7,pp 82-87, 1961.
[4] O. Ghebrebrhan "Subcomplemntary code pairs: New codes for ST/MST Radar Observations" IEEE transactions on Geo science and remote sensing, Vol.41, No.1, Jan 2003

[5] M.J.E.Golay, Sieves for low autocorrelation binary sequences, Trans IEEE,
vol IT-23,pp 43-51, 1977.
[6] Merrill I. Skolnik Introduction to Radar Systems,third edition
[7] M. Zaki Ahmed, MSc. CE&SP Lecture notes 20012002, University of Plymouth, England,UK.
[8] Anand K. Ojha Characteristics of complementary coded Radar waveforms in noise and target fluctuations, IEEE Radar Conference, 1993.
[9] O. Ghebrebrhan and M. Crochet, "On full decoding of truncated ranges
For ST/MST radar applications," IEEE Trans. Geosci. Remote Sensing, vol. 30, pp. 38–45, Jan. 1992.
[10] E. Spano and O. Ghebrebrhan, "Sequences of complementary codes for the optimum decoding of truncated ranges and high sidelobe suppression factors for ST/MST radar systems," IEEE Trans. Geosci. Remote Sensing, vol. 34, pp. 330–345, Mar. 1996.
[11] O. Ghebrebrhan, H. Luce, M. Yamamoto, and S. Fukao, "Interference suppression factor characteristics of complementary codes for ST/MST radar applications," Radio Sci., submitted for publication.
[12] M. J. E. Golay, "Complementary series," IRE Trans. Inform. Theory, vol. IT-7, pp. 82–87, 1961

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