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Estimation of efficient pulse compression code using Multi objective Genetic Algorithm

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Abstract— Detection at large range in radar system required large peak power (large width pulse) to enhance the SNR at the time of target's return echo and it also required high bandwidth pulse(short duration pulse) to enhance the range resolution of radar system .Pulse compression is a method which allows the radar system to simultaneously achieve the energy of long pulse and resolution corresponding to short pulse by modulating the long duration pulse either in phase or frequency to increase its band width .This paper demonstrates the generation of long length bi phase pulse compression code by using a multi objective optimization genetic algorithm which is based on non dominated sorting known as NSGA- 2.While using the bi phase pulse compression code at the receiver side the output of matched filter(autocorrelation function) is a periodic in nature and contain time side lobe uniformly distributed both side of the main lobe .Which act as a noise signal to radar system detection .The efficiency of pulse compression code based on the peak value of side lobe with respect to main lobe and energy contained by all side lobes. Peak side lobe level (PSL) and integrated side lobe label (ISL) are the two parameters which signify the effectiveness of these code and treated as the objective function in proposed work which are optimized by using NSGA 2.
Keywords— Multi objective optimization, Pulse compression, NSGA-2 ,Binary phase code, PSL, ISL, Matched filter.

I. INTRODUCTION

In radar system to enhance the range resolution for better precision (location ,characterization) short pulses are used but transmission of these short pulses reduce the average transmitted power due to which a multifunctional radar like surveillance radar having limited mode of operation so it is often to desirable to increase pulse width to enhance the SNR at the output of matched filter while simultaneously maintaining high range resolution .Pulse compression technique is used in radar to achieve above objective .In pulse compression[1] one can utilized the fact that SNR at the output of matched filter depends only on the total transmitted power not on the presence of modulation so in pulse compression either frequency or phase modulation is used to increase the bandwidth of long pulse to get the high range resolution. Phase coded pulse compression waveform provide better range resolution than linear frequency modulated[1] (LFM) pulse compression waveform because in LFM, to compensate the side lobes level windowing is used which will broad the main lobe so range resolution may disturb. Binary phase pulse compression techniques are better than polyphase phase pulse compression techniques because the complexity in designing of filter for polyphase pulse compression code is greater than the binary phase pulse compression code.

1.1. Binary phase pulse compression code

Binary phase pulse compression[1,2] is a digital method for pulse compression in which a transmitted pulse of duration T is subdivided in to N number of pulse each having duration τ .In this technique phase of each pulse is changing in accordance with a binary sequence while maintaining the same carrier frequency for each sub pulse. The change in phase is either 0' or 180 in accordance with binary 1 and 0 in the sequence respectively .binary phase coded waveform is shown as figure 1

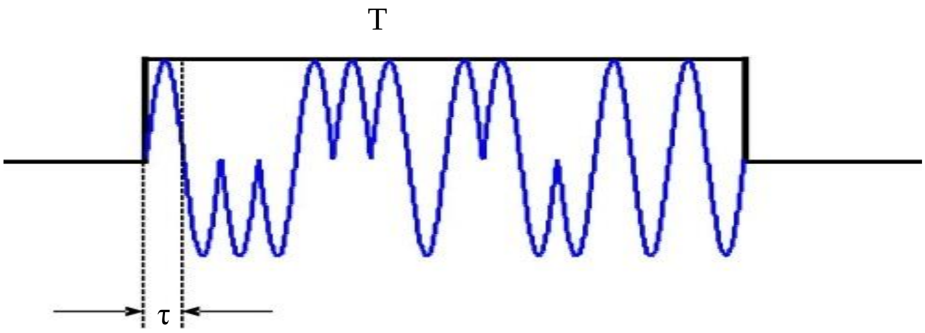

Figure.1.

.At the receiver end at output of matched filter the autocorrelation function due to transmission of binary phase pulse compression wave form contain number of time side lobe uniformly distributed both sides of main lobe as shown in figure 2.These side lobes act as self clutter for radar system operation and effect the operational perfection of radar system . Peak side lobe level (PSL) with respect to main lobe and sum of energy contain in all side lobe (ISL) are the two main parameter to decide the efficiency of a code . Barker codes[3] are the binary phase pulse compression code in these code selection of phase for code is done in such a way so that all side lobe having equal magnitude but the maximum length of barker code is 13 and the auto correlation function at the output of matched filter contain six equal side lobe both side of main lobe having PSL value equal to unity but having limited length. In some radar application larger length code is required to enhance the SNR for this purpose by using computer search programming longest code of length 28 with side lobe level 2 was developed by Turin[4] and Linder[5] and code of length 51,69 and 88 with side lobe level 3,4 and 5 respectively developed by Kerdock ,Mayer and D. Van.[6].

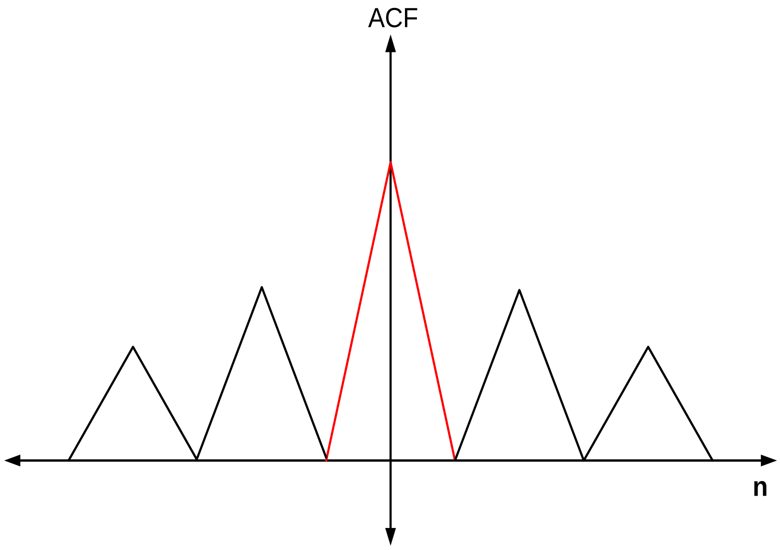

Figure.2.

lthese code are generated at a cost of minimum value of either PSL or ISl. In this paper we have introduce a matlab optimization tool box based method to find efficient bi phase code which simultaneously produced the best optimal values of PLS as well as ISL based on the multi objective optimization algorithm NSGA 2 devoloped by Kalyan Moy Dev [7] .it is based on Pareto optimization and Pareto front of this optimization multiple code of same length as user define with different values of PSL and ISL values on the basis of application of Radar system one can choose the best solution.

1.2 Multi objective optimization technique NSGA 2

Multi objective optimization is a vectored optimization method in which a vector of independent variable or decision variable is evaluated to optimize the dependent variable vector containing multiple objective function . Operations of algorithm are performed under some equality and inequality constrain. The solution of multi objective optimization method is based on Pareto optimal theory .it means it does not provide a unique solution rather it provide multiple solution for single objective so one can choose the best solution as per requirement .NSGA 2 developed by by Kalyan Moy Deb (2002),it is based on elitism evolutionary algorithm known as non dominated sorting genetic algorithm which provide fast solution with lesser complexity .An elite preservation operator is used to preserve the elite in to the population by allowing them directly to take part in to next generation until next best value is obtained. Figure(3) shows the flow chart of NSGA 2.

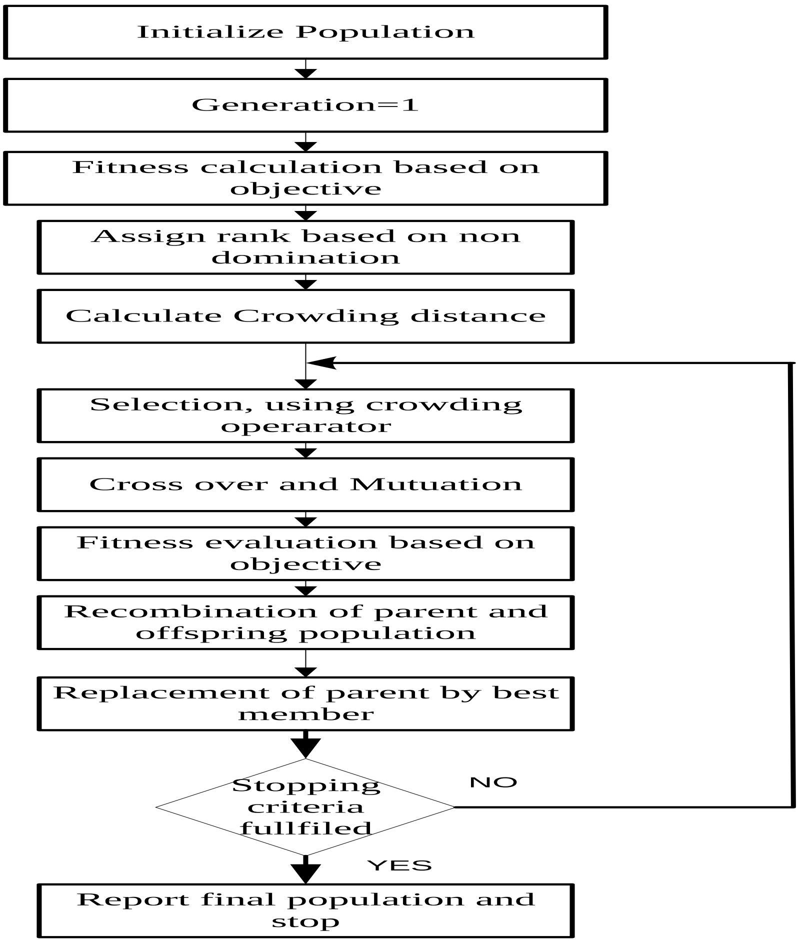

Figure.3.

Basic algorithm steps proposed by Dev[7]

1. Initialize the population of size N.
2. Sorting is done based on non domination.
3. Fitness value sis assign to each solution based on non domination level.
4. Calculate crowding distance ,selection of parent done by crowding distance operator.
5. Mutation and crossover done to generate offspring of size N.
6. The fitness value of new offspring is calculated.
7. A new population of size 2N is formed by the current population of size N and current offspring of population N. Sorting is done based on non domination.
8. A new population of size N is formed starting with best value from sorted front.
9. Stopping criteria are checked.
10. If stopping criteria is not fully filled repeat step 4 to 9.

III. METHODOLOGY

Suppose a phase code of binary sequence of length L is used for pulse compression.

B=(b_1, b_2, b_3,, b_4 ……………………………… b_L)

Where each element of **B** taken values either +1 or -1, according to binary 1 and 0 respectivelly.

From the theory of matched filter[8] ,at the output of matched filter the value of autocorrelation function as shown in figure(2) is given by

$ACF_n(B) = \sum_{i=1}^{L-n} b_i\, b_{i+1}$………

Where n=0,1,2,3…..L-1

But from figure(2) It is clear that while performing pulse compression using biphase code the autocorrelation function of matched filter is not impulsive in nature rather it contain some side lobe distributed uniformly both side of main lobe .These side lobe act as a self clutter for radar application so there are two parameter used to define efficiency of biphase code first one is peak side lobe level(PSL) which represent the magnitude value largest side lobe peak with respect to main lobe in autocorrelation function and given as

PSL= max|| $ACF_n(B)$||, when n≠0 ,…………………………..

And second one is integrated side lobe level which represent the sum of energy contained in all side lobe in autocorrelation function and given as…

ISL=$2\sum_{n=1}^{L-1} ACF_n^2$, when n≠0 ,………………………….

IV. ALGORITHM

- Initialize population randomly.
- Sorting is done based on non domination .following steps are performed for this purpose
- for each individual p in the main population *P*.
  1. Initialize *Sp* =ϕ. *The set of individuals dominated by p.*
  2. Initialize *np* = 0. *Individuals that dominate p.*
  3. for each individual *q* in *P*:

     If *p* dominates q then
     Add *q* to the set *Sp* i.e. *Sp = Sp U {q}*
     Else if *q* dominates *p* then
     Increment the domination counter i.e. *np* = *np* + 1
  4. If *no* = 0 then p belongs to the first front; Set the rank (fitness) of individuals up to one (prank = 1). Update the first front set by adding *p* to front one i.e. *F1 = F1 U {p}*

- This is carried out for all the individuals in main population P.
- Initialize the front counter to one. i = 1
- Following is carried out while the ith front is nonempty i.e. *Fi ≠ϕ*
  1. Q = ϕ. The set for storing the individuals for (i + 1)th front
  2. for each individual p in front *Fi*

     for each individual q in *Sp* (*Sp* is the set of individuals dominate by p)

     a. *nq* = *nq*-1, decrement the domination count for individual q.

     b. if *nq* = 0 then none of the individuals in the subsequent fronts would dominate q. Hence set qrank = i + 1. Updat the set Q with individual q i.e. Q = Q U q

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3. Increment the front counter by one.
4. Now the set Q is the next front and hence *Fi* = Q.

- Crowding distance…

After non dominated sort is complete, the crowding distance is assigned. Since the selection of individuals based on rank and crowding distance, all the individuals in the population are assigned a crowding distance value. It is assigned front wise. For each front Fi, where n is the number of individuals perform steps 1 to 4. Initialize the distance to be zero for all the individuals i.e. $F_i(d_j) = 0$, where j corresponds to the j^{th} individual in front Fi. For each objective function m, Sort the individuals in front F_i based on objective m i.e. I = sort (F_i, m)Assign infinite distance to boundry values for each individual in F_i, $I(d_1) = \infty$ and $I(d_n) = \infty$.
For k=2 to (n-1)

$I(d_k) = I(d_k) + \frac{I(k+1).m - I(k-1).m}{f_m^{max} - f_m^{min}}$. Where I(k) .m is the value of m^{th} objective function of k^{th} individual in I.

Selection procedure……..
Binary tournament selection is used to select an individual .following procedure follows while selecting an individual.
a) An individual having lower non domination rank than other is selected.
b) <u>If two individual having same rank i.e. belongs to same front than individual with higher</u> crowding distance is selected.

- Genetic operator

Single point mutation and crossover[9] is used.

- Selection…

The offspring population of size N combine with current population of size N then sorting of this population done based on non domination to form a new population of size N. If by adding all sorted individual the size of front exceed N then sorting is done by the help of their crowding distance in descending order.

V. RESULT

A multiobjective genetic algorithm is used to generate biphase pulse compression code of length 60 for lowest possible value of PSL and ISl . For this five iterative solutions Are specified in table no.1 and also the autocorrelation function (ACF) is shown in figure 3 corresponding to above sequences. The population size is taken as 200 while setting default values of mutation and crossover probabilities.

Table.1

PSL	ISL	Sequence of length 60
6.47	977.09	110001011000000000111111011011101111111011111001011011111101
7.04	708.73	111101111111101110101110100101111100011001101111110111111111
6.23	1135.61	110111110111101111010111111111100001101011010000110010011111
4.50	1493.31	100100110011101111000101101011100010101010010000011000001101
4.56	1329.65	100101110011101111000101101011100010101010010000011000001101

VI. CONCLUSION

By using NSGA 2 multiple iterative solutions are obtained for the code length 60 along with the values of PSL and ISL ,one can choose the code on the basis of application and environment condition.

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