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Design of Ternary Sequence Using MSAA

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ABSTRACT
Pulse Compression Sequence (PCS) are widely used in radar to increase the range resolution. Binary sequence has the limitation that the compression ratio is small. Ternary code is suggested as an alternative. The design of ternary sequence with good Discriminating Factor (DF) and merit factor can be considered as a nonlinear multivariable optimization problem which is difficult to solve. In this paper, we proposed a new method for designing ternary sequence by using Modified Simulated Annealing Algorithm (MSAA). The general features such as global convergence and robustness of the statistical algorithm are revealed.

Keywords
Pulse Compression, Ternary Code, Multivariable Optimization and Discriminating Factor.

INTRODUCTION
Pulse compressionpermitsmeasuring instrumentto realizethe typicaltransmitted power ofa comparativelylong pulse,whereasgettingthevaryresolution of short pulse. Inmeasuring instrumentwherevertheresquare measurelimitations onthe heightpower, pulse compressionis that thesolelysuggests thatto getthe resolution and accuracyrelated toa pointypulsehowever ata similartimegettingthe detection capability ofa protractedpulse. There searchers developed severalpulse compressionmeasuring instrumentsignalsassistedbytrendysignalprocess systems. Consequently, signals in severalshapesaregivenlike partcoded signalslikeBarker codes, nested Barker codes and frequency coded signalslike easypulse, Linearmodulation (LFM), Hyperbolicmodulation(HFM) and Costas undulation.Everyof thosesignals have its ownblessing sand downsides. Inmeasuring instrumentstate of affairs, noundulationis optimum for target resolutiongenerally. The applications likeradars, communications and system identificationsquare measurein generating the sequences withsensibleautocorrelation properties.

Polyphase sequence has been suggested by Levanon N [3] which uses in applications like signal processing of sonar and also radar significantly. A very important criterion within the field of signal processing of sonar, system identification and radar has been given by Barker [5].

A problem of optimization for designing of signals for the application of radar sequences like binary, ternary, polyphase and quaternary has viewed and suggested as optimization problem by Griep Karl R John et al [7]. For obtaining good discriminating factor as well as merit factor values work has been carried out extensively.By using shift registers Ipatov [1-2] has designed a large scale of ternary sequences. Ternary sequences of length 2n-1 have been constructed by Shedd and D Sarwatte[4] and Moharir[10] has perfectly given some conditions for the existence of ternary sequences. For generation of ternary codes with good discriminating factor has been given in architecture of VLSI by N Balaji et al [6]. Hoholdt, Tom et al in [8] constructed ternary sequence with periodic autocorrelation.

J.J Blakley,1998 [9] implemented programmable hardware architecture ternary de Brujin which generates ternary sequences. By considering Hamming scan algorithm Pasha I.A, P. S. Moharir and N. SudarshanRao [11] has view that the generation of ternary sequencesas a problem of optimization. The technique for the generation of two different lengths of ternary preamble sequences has been proposed by Yuen-Sam[12].Naga Jyothi.A et al[18] has proposed an efficient VLSI architecture for generation and implementation of the ternary sequences using Finite State Machines (FSM). K SubbaRao and S P Singh [15,16] combined Hamming scan algorithm with Simulated Annealing algorithm and proposed Modified Simulated. Annealing Algorithm (MSAA) to design binary and thirty –two phase sequences .In this paper,MSAA is used for generating ternary codes with good discriminating factor values.

2. TERNARY SEQUENCE
The ternary sequences are also known as non-binary sequences and have the elements of unequal magnitude. Hence they do not have the ideal energy efficiency i.e. their energy efficiency is less than unity. The alphabet of a ternary sequence is [-1, 0, +1]. The ternary alphabet has zero as an element, which implies no transmission during some time slots. It is considered difficult to have on±off switching at high power in comparison to phase shifting. Binary sequence has a disadvantage that they do not have high merit factor.

Ternary sequence (TSs) eliminates the drawbacks of the binary and polyphase sequences. Generally TSs has good merit factors at all length. Ternary alphabet shares one common property of binary and poly phase sequence of peakiness.

$$p = \frac{r(0)}{2\sum_{k=1}^{N-1} |r(k)|} \quad (1)$$

For a sequence of length N=20, the number of search would be only 3^20 as against M^20 where M is generally greater than 4. Hence, the search of ternary sequence is relatively easier than polyphase sequence. The major demerit of TSs is due to inclusion of zero in the alphabet, which is corresponds to a pause in transmission.

The main criteria of goodness of pulse compression sequences or codes are the discriminating factor (DF) and merit factor (MF).The factors DF and MF must be as large as possible for a good sequence or code.

Let S= [x_0, x_1, $x_2 \ldots x_{N-1}$] be a real sequence of length N. Its aperiodic auto correlation is then defined as

$$\gamma(k) = \sum_{i=0}^{N-1-k} x_i x_{i+k} \quad (2)$$

where k=0, 1, 2…N-1.Ideally, the range resolution radar signal should have large auto-correlation for zero shift and zero auto-correlation for non-zero shift.

3. DISCRIMINATING FACTOR:

The discrimination (DF) is defined as ratio of main peak in autocorrelation to the absolute maximum amplitude among the side lobes.

$$DF = \frac{\gamma(0)}{\max_{k \neq 0} |\gamma(k)|} \quad (3)$$

4. PROPOSED METHODOLOGY

4.1 Simulated annealing algorithm

In this section, the Simulated annealing (SA) algorithm has been used for designing Ternary sequences with good autocorrelation properties. In this method, each point “s” of the search space is analogous to a state of some physical system, and the function E(s) to be minimized is analogous to the internal energy of the system in that state. The goal is to bring the system, from an arbitrary initial state, to a state with the minimum possible energy.

The implementation procedure is as follows:

1. An arbitrary code matrix X (0) is chosen as initial sequence set for optimization.

$$X(0)=\begin{bmatrix} x_{0,0} & x_{0,1} & . & . & x_{0,N-1} \\ x_{1,0} & x_{1,1} & . & . & x_{1,N-1} \\ . & . & . & . & . \\ . & . & . & . & . \\ x_{K-1,0} & x_{K-1,1} & . & . & x_{K-1,N-1} \end{bmatrix} \quad (4)$$

where $X_{(i\,,\,j)}$ Є (-1,0,1)$0 \leq i \leq K-1$ and $0 \leq j \leq N-1$

2. T(0) is chosen as initial temperature for annealing. Set the value of i, iterations tobe performed at each temperature and the value of ε, lowest possible temperature..

3. In addition the initial energy function value is calculated and designated as E(0).

4. Make a perturbation to the code matrix X(0) by randomly selecting an element $X_{(i\,,\,j)}$ from X(0) and changing it to - $X_{(i\,,\,j)}$ hence a new code matrix X(1) is generated and the new energy function value is designated as E(1).

5. If the energy is decreased i.e., E(1)<E(0) the new code matrix is accepted.

6. If the energy is increased i.e., E(1)>E(0) the new code matrix is accepted with Probability exp (-ΔE/T).

7. In the same way code matrix perturbation is repeated until the required iterations are performed at each temperature.

8. Then the temperature is reduced and new equilibrium is setup.

9. Repeat this cooling process until energy function reaches global minimum or the System is frozen (temperature is reduced to the lowest possible temperature.)

4.2 Hamming Scan Algorithm

The Hamming scan is employed for obtaining the pulse compression sequences of larger length with good autocorrelation and cross correlation properties. The basic difference between Genetic algorithm and Hamming scan algorithm is that Genetic algorithm uses random but possibly multiple mutations.

Mutation is a term metaphorically used for a change in an element in the sequence. For example, in the case of binary sequence, a mutation of ternary element implies -1→ +1, -1 → 0, +1→ 0, +1→ -1, 0 → -1, and0→ 1. Thus, a single mutation in a sequence results in hamming distance of one from the original sequence.

The Hamming scan algorithm mutates all the elements in a given sequence one by one and looks at all the first order hamming neighbors of the given sequence. Thus, Hamming scan performs recursively local search among all the Hamming-1 neighbors of the sequence and selects the one whose objective function value is minimum.

4.3 Modified Simulated Annealing Algorithm

Modified Simulated Annealing Algorithm is a combination of both Simulated Annealing and Hamming scan algorithm. It excerpts the good methodologies of these algorithms like fast convergence rate of Hamming scan algorithm and Global minima trapping capability of Simulated annealing algorithm to increase the probability of converging to the global minimum point.

The new modified simulated annealing algorithm overcomes these drawbacks as it makes use of simulated annealing to randomly generate a sequence and then it invokes the Hamming scan to converge to the local minima corresponding to that point. Thus the selection of Simulated Annealing and mutations of Hamming scan work well for this algorithm.

4.4 Working of Modified Simulated Annealing Algorithm

The figure 1 gives us a complete picture about working of the New Modified Simulated Annealing algorithm. The X-axis contains all the possible sequences and the Y-axis represents the Cost function.

Let us consider that we initially start from a point say ‘A’. Now at this point we invoke the Simulated Annealing for selection procedure that is we randomly select a point. Let the new point chosen by this Algorithm be ‘B’. As the selection process is complete it is now time to invoke Hamming scan. Hamming scan ensures that the local minimum is reached which is at point C.This local minimum point is stored. Then again Simulated Annealing is invoked to get the point ‘D’ even though it is of higher cost because simulated annealing algorithm is a stochastic algorithm which accepts the higher cost function if it lies within certain range of the present cost in the hope that the selected point is in the valley of global minima then the Hamming scan algorithm is invoked for optimization to reach another Local minimum point say ‘E’ which might be global minima because one can find the global minima only after viewing the results of simulation.

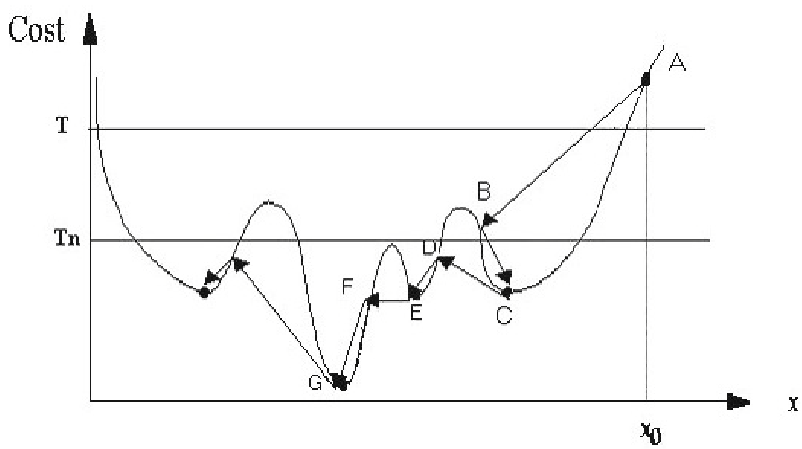

Figure 1. Working of Modified simulated annealing algorithm

At each temperature ‘T ’of simulated annealing algorithm, we continue the above process to find out all the local minimum points since the global minimum point is also one of the local minimum points. Thus this algorithm proves to be much more efficient in converging to a global minimum point.

5.RESULTS AND DISCUSSION

Various pairs of ternary sequences of different lengths having good autocorrelation properties which have been obtained using optimization techniques are given in this section.

Ternary sequences are designed using the MSAA. The length of the sequence N, is varied from 5 to 250. The cost function for the optimization is based on

$$DF= \frac{\gamma(0)}{\underset{k\neq 0}{\mathrm{Max}}\,|\,\gamma(k)\,|} \quad (5)$$

Below Table shows the synthesized results in Matlab. In column 2 and 5 show sequence length N, column 3 and 6show Discriminating factor (DF). From sequences of length from 5 to 250, the correlation properties are good. It may be observed that as the length N, increases, the DF also increases, which is the conformity with other finding.

S.No	**Sequence**	**DF**	**S.No**	**Sequence**	**DF**
(1)	**Length N (2)**	**(3)**	**(4)**	**Length N (5)**	**(6)**
1	5	5	37	107	14.3333
2	10	9	38	110	13.8333
3	12	12	39	120	13. 1667
4	13	13.0000	40	130	13.2500
5	15	14.0000	41	140	13.5000
6	17	16.0000	42	150	13.8571
7	18	15.0000	43	160	14.0000
8	20	16.0000	44	175	14.7500
9	25	18.0000	45	180	15.5714
10	35	14.0000	46	190	15.8000
11	40	14.5000	47	195	15.8571
12	45	15.0000	48	200	16.0000
13	47	12.6667	49	210	16.1667
14	48	13.3333	50	215	17.0000
15	50	12.6667	51	220	17.3000
16	52	14.0000	52	225	18.0000
17	53	14.3333	53	230	18.6667
18	55	13.0000	54	235	19.0000
19	57	14.6667	55	240	19.5000
20	59	12.5000	56	245	19.5000
36	105	13.8333	57	250	20.5000

Table 1:

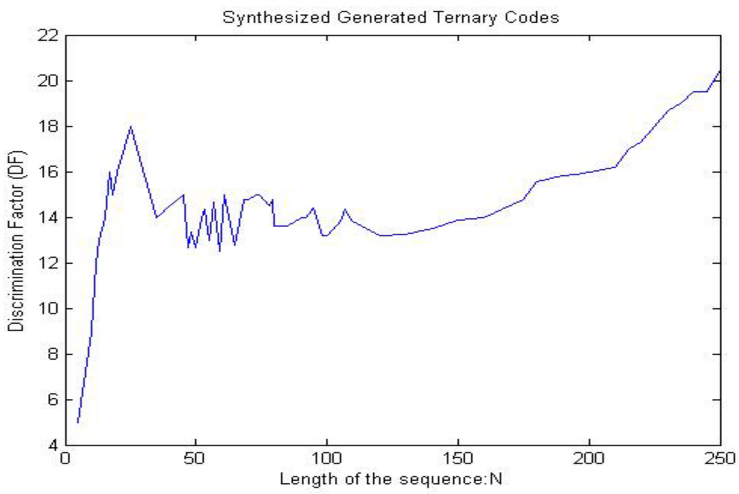

Figure 2: Synthesized generated ternary sequence

From figure 2, it is observe that as the length of the sequence increases the DF is also increased.

6.CONCLUSION

A novel methodology based on Modified simulated annealing algorithm was proposed in this paperto generate ternary codes for various lengths with good discriminating factor value.Length of the sequence and the number of iterations to be performed at a constant temperature is defined. Then the cost function value was also calculated for the generated sequence. Out proposed algorithm overcomes these disadvantages and proved to be more effective in synthesizing ternarycodes having good auto correlation and cross correlation properties. Results obtained by using this algorithm are better than the results existing in the literature**.**

7. REFERENCE

[1] Ipatov, V. P. "Ternary sequences with ideal periodic autocorrelation properties."*Radio Engineering and Electronic Physics* 24 (1979): 75-79.

[2] Ipatov, V. P., V. D. Platonov, and I. M. Samilov. "A new class of ternary sequences with ideal periodic autocorrelation properties." *Soviet Math.(IzvestiyaVuz) English Translation* 27 (1983): 57-61.

[3] Levanon. N, Eli Mozeson, "*Radar Signals*", Wiley, New York, 2004

[4]Shedd, D., and D. Sarwate."Construction of sequences with good correlation properties (Corresp.)."*Information Theory, IEEE Transactions on* 25.1 (1979): 94-97.

[5] R. H. Barker, "Group synchronizing of binary digital systems, in Communication theory", Butterworth, London, 1953, pp. 273-287.

[6] Balaji, N., K. SubbaRao, and M. SrinivasaRao. "FPGA implementation of ternary pulse compression sequences with superior merit factors." *NAUN international Journal of Circuits, systems and signal processing* 2.3 (2009): 47-54.

[7] Griep, Karl R., James A. Ritcey, and John J. Burlingame. "Poly-phase codes and optimal filters for multiple user ranging."*Aerospace and Electronic Systems, IEEE Transactions on* 31.2 (1995): 752-767

[8] Hoholdt, Tom, and JørnJustesen. "Ternary sequences with perfect periodic autocorrelation (Corresp.)." *Information Theory, IEEE Transactions on* 29.4 (1983): 597-600.

[9] Blakley, J. J. "Architecture for hardware implementation of programmable ternary de Bruijn sequence generators." *Electronics Letters* 34.25 (1998): 2389-2390

[10] Moharir, P. "Generalized PN sequences (Corresp.)." *Information Theory, IEEE Transactions on* 23.6 (1977): 782-784

[11] Pasha, I. A., P. S. Moharir, and N. SudarshanRao. "Bi-alphabetic pulse compression radar signal design." *Sadhana*25.5 (2000): 481-488.

[12] Lei, Zhongding, Francois Chin, and Yuen-Sam Kwok. "UWB ranging with energy detectors using ternary preamble sequences." *Wireless Communications and Networking Conference, 2006. WCNC 2006.IEEE.*Vol. 2.IEEE, 2006.

[13] Moharir, P.S., "Signal Design" Journal of IETE, Vol.41, Oct. 1976, pp. 381-398

[14] Moharir, P. S., R. Singh, and V. M. Maru. "SKH algorithm for signal design."*Electronics letters* 32.18 (1996): 1648.

[15] S P Singh and K SubbaRao, " Binary Sequence Design" Journel of Technology and Engineering Sciences. Vol 1,2009.

[16] S P Singh and K SubbaRao"Thirty-Two phase sequences with good Autocorrelation properties" Sadhana Vol. 35, Part 1, February 2010, pp.63-73. Indian Academy of Sciences India.

[17] Naga Jyothi.A., and K.RajaRajeswari., "Implementation and Generation of Barker and nested Barker codes" ARCNET-2013, NSTL Visakhapatnam

[18] Naga JyothiAggala and Raja Rajeswari K, " Design and Implementation of the Ternary Sequences with Good Merit Factor Values" IJCA 92(9):5-7, April 2014.