 ISSN : 2230-7109 (Online) | ISSN : 2230-9543 (Print)

Antenna Array Side Lobe Reduction by Implementing Non – Uniform Amplitude Using Tsukamoto Fuzzy Logic Controller

[1]Sanmoy Bandyopadhyay, [2]Hiranmay Mistri, [3]Paragkanti Chattopadhyay, [4]B. Maji
[1,2,4]Dept. of ECE, National Institute of Technology, Durgapur, West Bengal, India
[3]Dept. of CSE, Dr. B.C. Roy Engineering College, Jemua Road, Fuljhore, Durgapur, India

Abstract
This paper deals with a scheme of Antenna array side lobe reduction by varying amplitude of each element of the antenna array using the Tsukamoto fuzzy logic controller. Here it has been tried to reduce the Side Lobe Level of the antenna array radiation pattern by changing the amplitude of the antenna array elements. Spacing between the antenna array elements and the corresponding phase - shift is given in the input of the Tsukamoto fuzzy logic controller and corresponding values of amplitude is obtained at the output of the controller. Implementing the newlyobtained values of amplitude to the each element of the antenna array, the new radiation pattern with reduced side lobe level will be obtained.

Keywords
Side Lobe Level, Radiation Pattern, Fuzzifier, Defuzzifier, Fuzzy Logic, Fuzzy Logic Controller, Antenna Array, Array Side Lobe Reduction, Rule – Base; Inference Engine

I. Introduction

Antenna array is a set of several antenna elements. It is mainly used to generate radiation pattern with a high directivity. In case of practical use, it is desirable to have the radiation in a certain direction. The task, in general, is to find out the antenna configuration as well as geometrical dimension and excitation distribution [1]. Any practical use of an antenna array, it should ensure the minimum acceptable radiation pattern under certain constraints. The aim is to determine the physical layout of the antenna array that produces a radiation pattern which is nearest to the desired pattern [2]. This process is, in general, called synthesis. We can synthesize the antenna array by reducing its side lobe level or by decreasing its null point etc. There are various methods that can be used for the antenna array side lobe reduction, namely GAs [3-5], Simulated Annealing (SA) [6], Tabu Search [7], Taguchi's method [8], Memetic Algorithm (MAs) [9], PSO [10], Fuzzy Genetic Algorithm [11], Fitness-Adaptive Differential Algorithm[12], Fuzzy PSO Algorithm [13], Bacteria Foraging Optimization Technique [14] etc. In this work we have tried to synthesize the antenna array radiation pattern by implementing non – uniform amplitude using fuzzy logic [15]. For this work we have used the Tsukamoto fuzzy logic controller.

The Tsukamoto fuzzy model was proposed by Y. Tsukamoto in year 1979. In Tsukamoto fuzzy models[16], it stated that the consequent of each fuzzy if-then rule is represented by a fuzzy set with a monotonical Membership Function. The overall output is taken as the weighted average of each rule's output. Since each ruleinfers a crisp output, the Tsukamoto fuzzy model aggregate each rule's output by the method of weightedaverage and thus avoids the time consuming process of defuzzification.

Our paper mainly contain three main sections, section II, gives the idea about the previously related work done using the fuzzy logic, section III, deal with the main work done in synthesizing the radiation pattern of the antenna array, in section IV, the result of the work has been analyzed and in the last section V, gives the conclusion related to over all work done.

II. Proposed Method

In this work of Antenna array side lobe reduction by implementing non – uniform amplitude using Tsukamoto fuzzy logic controller we have tried to apply different amplitude for different elements of the antenna array and we have generated this amplitude using the Tsukamoto fuzzy logic controller. In this work our main intention is generate better result for antenna array side lobe reduction by implementing a quicker and easy method of calculation, using fuzzy logic. We have carried out this work using 10 elements linear antenna array. So, to synthesize the radiation pattern we have tried to change the value of the amplitude which was initially feed into the elements of the antenna array. So to implement new amplitude to the elements of the array we have generated 10 output amplitudes from the fuzzy controller for 10 elements of the antenna array. We have tried to generate the 10 output amplitudes based upon the given input in the fuzzifier of the fuzzy logic controller. The experimental set up for this work is shown in fig. 1.

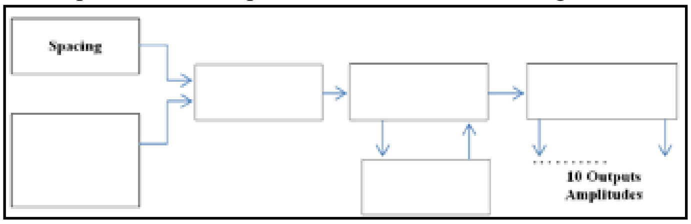
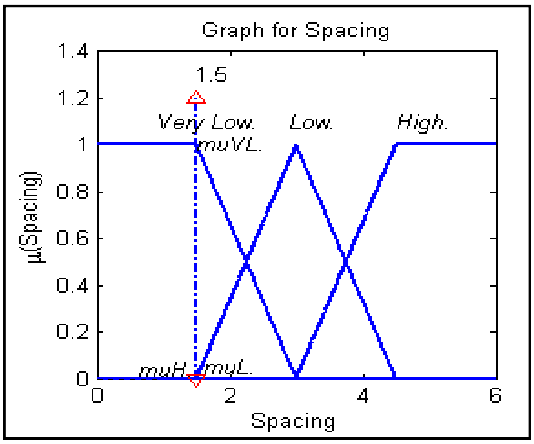


Fig. 1: Experimental Setup of Antenna Array Side Lobe Reduction Using Tsukamoto Fuzzy Logic Controller

In this work we have taken spacing between the elements of the antenna array and previous amplitude of the antenna array as the input to the fuzzifier. In fuzzifier output we have taken three linguistic variables for both spacing and previous amplitude. For spacing the three linguistic variables are namely Very Low, Low, and High, similarly for previous amplitude there are three linguistic variables namely No Change, Low and High. The fuzzifier outputs are shown in fig. 2.



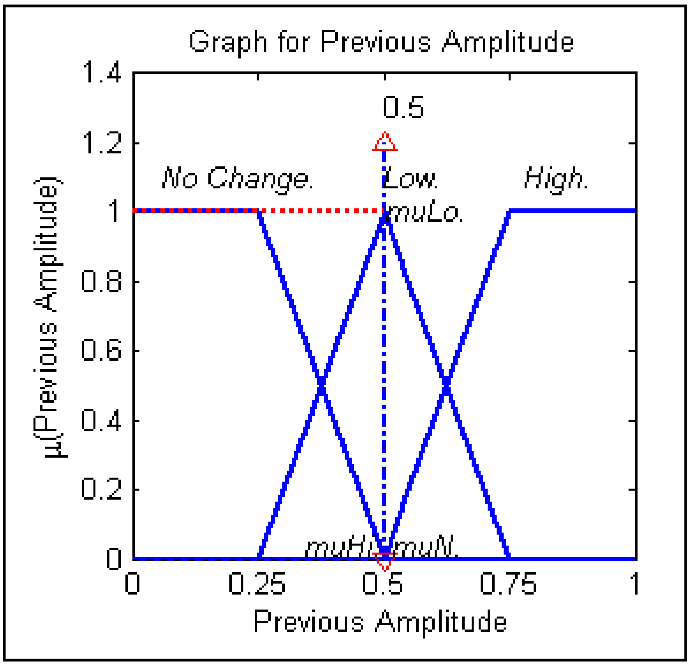


Fig. 2: Figure Showing the Fuzzifier Output for Input Spacing and Previous Amplitude

After getting the fuzzified result from the fuzzifier we applied the fuzzified result into the inference engine. As the inference engine gives its decision by consulting with the rule base, so in our problem we have implemented a rule base based upon some previous output from the antenna array side lobe reduction result to get the desired antenna array radiation pattern.

We have considered here single the rule base for all the output amplitudes. Table 1. is an example of such a rule base which is applied in our work to calculate the fuzzified output for the amplitude.

Now by consulting with the rule base the inference engine give the multiple numbers of fuzzified outputs of amplitude for the antenna array elements. Here also we have taken the number of output same as number of amplitude for the antenna array elements.

Table 1: Rule Base Used to Find Out Amplitude of the First Element

Spacing / Previous amplitude	No Change A	Low A	High A
No Change	Output Amplitude Low1	Output Amplitude Low3	Output Amplitude Very Low3
Low	Output Amplitude Low2	Output Amplitude Very Low2	Output Amplitude No Change2
High	Output Amplitude Very Low1	Output Amplitude No Change1	Output Amplitude No Change3

In this fuzzified output of the amplitude for the array elements we have also taken three linguistic variables these are namely No Change, Very low and Low. The linguistic variable shown in Fig. 3 is the output linguistic variable of fuzzified output for the first amplitude.

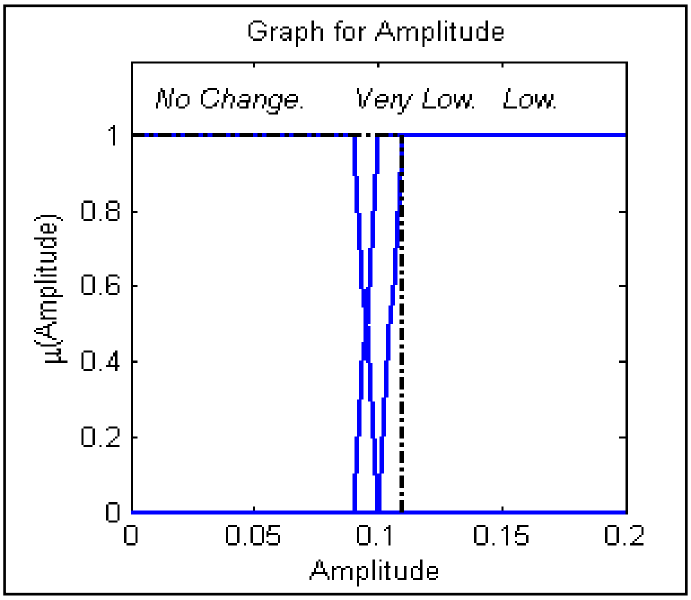


Fig. 3: Linguistic Variable of the Fuzzified Output for the First Amplitude

Similarly we have also implemented linguistic variable of different range for rest of the 9 elements for the work of Antenna Array Side lobe reduction by varying the amplitude of each elements of the antenna array. In the inference engine the work had been carried out by taking total of 10 fuzzified outputs. In the work the range of the fuzzified output has been varied according to the need of the problem. Now all this fuzzified value of the output amplitude is applied into the defuzzifier from the inference engine to obtain the output amplitude in terms of the crisp value. Since we have used 10 fuzzified outputs at the inference engine thus all this 10 fuzzified output has been converted into the defuzzified value and thus we obtained the outputs from the defuzzifier that generates 10 outputs (crisp value) in terms of the amplitude. Now the newly obtained value of amplitude is put into the formula of the array factor and as a result we obtain the synthesized radiation pattern of the antenna array.

III. Result Analysis

Due to easiness of the calculation in our work we have used trapezoidal and the triangular function in the linguistic variable of the fuzzy controller which are given by equation (1) and (2).

Triangular membership function is defined as:

$$\mu A(x) = \max\left[\min\{\min(x-a/b-a, c-x/c-b), 1\}, 0\right] \quad (1)$$

Trapezoidal membership function is defined as:

$$\mu A(x) = \max\left[\min\{\min(x-a/b-a, d-x/d-c), 1\}, 0\right] \quad (2)$$

Now in the process of defuzzification since we have used Tsukamoto fuzzy model and the Weighted Average methods for calculating the defuzzified value as written in equation (3), thus the formula we have used in this case is the formula for calculating the Weighted Average which as follows:

$$Defuzzified\ Output(Z) = \frac{(W_1 Z_1 + W_2 Z_2)}{(W_1 + W_2)} \quad (3)$$

Where:

W_1 and W_2 = represent the value of the membership function

obtained at the output graph for spacing.
And
Z_1 and Z_2 = represent the corresponding spacing value obtained from the graph of output spacing for W_1 and W_2 respectively.
Now in the work of antenna array radiation pattern we at first have implemented the array factor formula for the linear antenna array. The elements are consider as isotropic point source with initial spaced d = λ/2 and mutual coupling is not taken into account [17]. The array factor of a linear array of N elements placed along the z – axis is given by:

$$S(\theta) = \sum_{i=0}^{N-1} I_i \, e^{j(i\beta d\cos\theta + \Delta\varphi_i)} \quad (4)$$

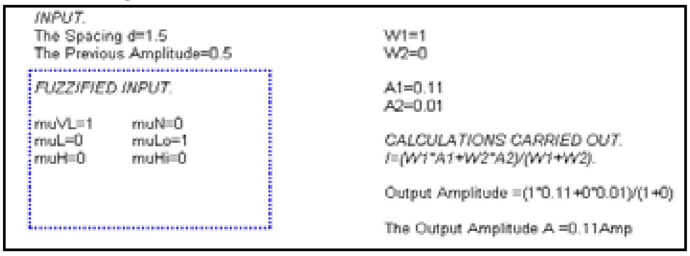
Where: I_i = Amplitude of i^{th} element
$\Delta\phi_i$ = Phase of each element
Here β indicates the wave number of the signal given by $\beta = 2\pi/\lambda$
Thus the multiplication of βand is given by equation (5).

$$\beta \times d = {}^{2\pi}/_{\lambda} * {}^{\lambda}/_{2} = \pi \quad (5)$$

Now to get the new side lobe of the antenna array radiation pattern we have modified the array factor of N element placed along the z – axis as given in equation (6)

$$S(\theta) = \sum_{i=0}^{N-1} I_i e^{j(i\pi\cos\theta + \Delta\varphi_i)} \quad (6)$$

In the graph shown in, for this we have applied the input spacing (d) equal to 1.5 and previous amplitude (α) equal to 0.5Amp and as a result we are getting the output from the fuzzifier as μ (Very Low) at 1 and μ (Low) at 1 from the graph of linguistic variable of spacing and previous amplitude respectively. Now based on this result the inference engine by consulting with the rule base for amplitude of first element generates the result for the fuzzified output amplitude for the first element of the antenna array at μ (Low) equal to 1 which is shown in fig. 3 and 4. Now according to the method of calculation of the defuzzified value that is the weighted sum method for the Tsukamoto fuzzy logic controller the program made by us generates the result output amplitude for the first element of the antenna array equal to 0.11 Amp as shown in fig. 4.


INPUT.
The Spacing d=1.5
The Previous Amplitude=0.5

FUZZIFIED INPUT.

muVL=1 muN=0
muL=0 muLo=1
muH=0 muHi=0

W1=1
W2=0

A1=0.11
A2=0.01

CALCULATIONS CARRIED OUT.
I=(W1*A1+W2*A2)/(W1+W2).

Output Amplitude =(1*0.11+0*0.01)/(1+0)

The Output Amplitude A =0.11Amp

Fig. 4: Output Generated from the Tsukamoto Fuzzy Logic Controller Using the MATLAB Software

Similarly we have calculated the output amplitude for rest of the elements of the antenna array that is for amplitude of element (2) to amplitude of element (10). Here we kept the rule base same to obtain all the amplitude for element(2) to element(10), and the corresponding defuzzifier output for amplitude of each of the element are taken out from the fuzzy logic controller for element(2) to element(10). In this work we have changed the range of the output amplitude from element (1) to element (10) to get the desired radiation pattern. This rule base and the defuzzifier output had been designed using the MATLAB software. We have previously taken the amplitude value for all the elements to be same that is equal to 1 Amp in the array factor formula equation (4) As a result we obtained previously the value of antenna's first side lobe level of the antenna radiation pattern at -12.97 dB shown in fig. 5.

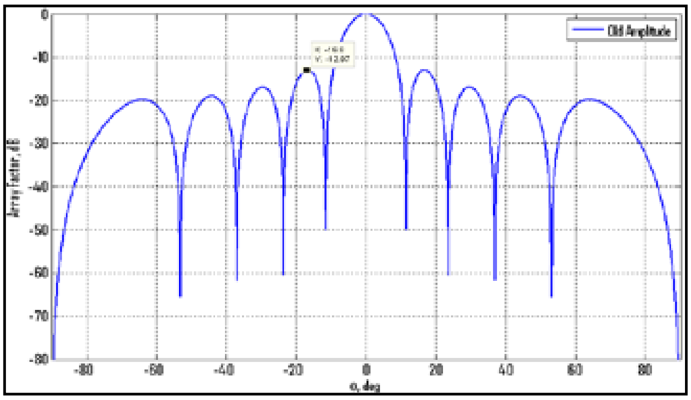


Fig. 5: Output Graph for the Antenna Radiation Pattern for 10 Elements Antenna Array and for Value of Amplitude Equal to 1 Amp Simulated from the MATLAB Software

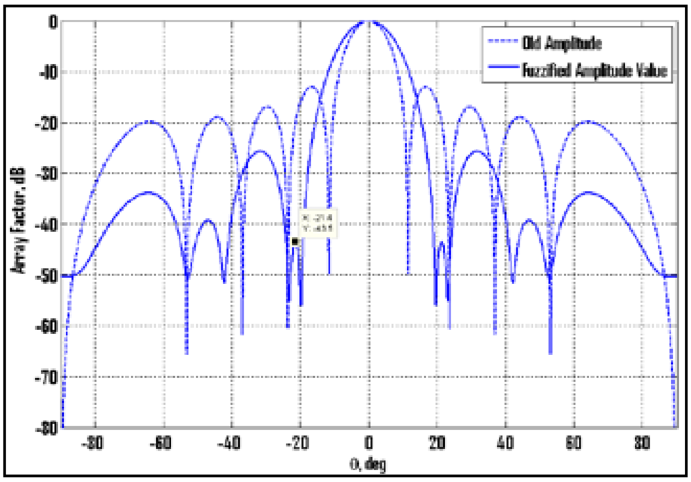


Fig. 6: Output Graph Showing the Original Antenna Array Radiation Pattern Denoted by the Solid Line and the Synthesized Antenna Array Radiation Pattern Having the Reduced Side Lobe Level of -43.5 dB Denoted by Dotted Line Obtained Using Tsukamoto Fuzzy Logic Controller

Now after putting the values of amplitude which is generated by using the Tsukamoto fuzzy logic controller we obtain the value of the first side lobe level of antenna radiation pattern at -43.5 dB shown in fig. 6.

IV. Conclusion

From the work done in this paper and the result obtained it can be easily stated that the antenna array side lobe reduction by implementing the non – uniform amplitude using Tsukamoto fuzzy logic controller can easily be implemented for reduction of side lobe level of the antenna array radiation pattern. It had also been seen that though there is a reduction in the side lobe level but the beamwidth of the radiation pattern had also increased. This is because in this work we had implemented the rule base used totally made of our own concept without using any other algorithm. This drawback can be overcome if we implement the rule base using the values from the previous made paper or values obtained using other algorithm such as Genetic Algorithm, PSO etc. The main advantage of this implementing fuzzy logic in Antenna Array Side lobe reduction is that, if we store the best result obtained from other algorithm such as GA, PSO etc. in the rule base then we can get the output of the array side lobe reduction quickly and more easily. Also we can implement this work where we have uncertainty present in the input data. This synthesization technique is also capable of to generate the radiation pattern of the antenna array where we have to deal with lack of proper data need for array side lobe reduction.

V. Acknowledgement

We would like to acknowledge the Department of Electronics and Communication Engineering of National Institute of Technology, Durgapur for helping us adequately by providing good Laboratory to implement our work on Antenna Array Side lobe reduction by Implementing Non-Uniform Amplitude using Fuzzy Logic. We would also like to acknowledge the faculty members of this department for their constant support behind our project. We also want to acknowledge the members and the faculty of the Department of Computer Science and Engineering, Dr. B.C. Roy Engineering College, for their support during this work.

Reference

[1] C. Balanis,"Antenna Theory: Analysis and Design", Wiley Publication, New York: 2011

[2] Aritra Chowdhury, Ritwik Giri, Arnob Ghosh, Swagatam Das, Ajith Abraham, Vaclav Snasel,"Linear antenna array synthesis using fitness-adaptive differential evolution algorithm", IEEE Congress on Evolutionary Computation (CEC), 2010, pp. 1-8, July 2010.

[3] J. H. Holland,"Adaptation in Natural and Artificial Systems", University of Michigan Press, Ann Harbor, 1975.

[4] T. Bäck, D. Fogel, Z. Michalewicz,"Handbook of Evolutionary Computation", Oxford Univ. Press.

[5] A.E. Eiben and J.E. Smith, "Introduction to Evolutionary Computing", Springer, 2003.

[6] S. Kirkpatrik, C. Gelatt, and M. Vecchi, "Optinization by Simulated Annealing", Science, 220, pp. 671-680, 1983.

[7] F. Glover, M. Laguna,"Tabu Search", Kluwer, Norwell, MA, 1997.

[8] G. Taguchi, S. Chowdhury, Y. Wu,"Taguchi's Quality Engineering Handbook", New York: Wiley, 2005.

[9] Y.-S. Ong, A.J. Keane,"Meta-lamarckian learning in memetic algorithms", IEEE Transactions on Evolutionary Computation, Vol. 8, No. 2, pp. 99-110, 2004.

[10] J. Kennedy, R. Eberhart,"Particle swarm optimization", Proc. IEEE Int. conf. Neural Networks, pp. 1942-1948, 1995.

[11] J. Kennedy, R.C. Eberhart, Y. Shi,"Swarm Intelligence", Morgan Kaufmann, San Francisco, CA, 2001.

[12] Kadri, B., Bendimered,"Linear Array Synthesis with a Fuzzy Genetic Algorithm", The International Conference on EUROCON, 2007, pp. 942-947, Sept, 2007.

[13] Ahmidi, N. Neyestanak, A.A.L. Dawes,"Elliptical Array Antenna Design Based on Particle Swarm Method Using Fuzzy Decision Rules", 24th Biennial Symposium on Communication, 2008, pp. 352-355, June 2008.

[14] Om Prakash Acharya, Amalendu Patnaik, Balamati Choudhury,"Fault Finding in Antenna Arrays Using Bacteria Foraging Optimization Technique", National Conference on Communication (NCC) 2011, pp. 16-31, Jan. 2011.

[15] Zadeh L. A.,"A theory of approximate reasoning", Machine Intelligence Magazine, Vol. 9, Halstead press, New York, pp. 149-194, 1979.

[16] Y. Tsukamoto,"An approach to fuzzy reasoning method", pp. 137-149, North-Holland, Amsterdam, 1979.

[17] D. Marcano, F. Duran,"Synthesis of antenna arrays using genetic algorithms", IEEE Antennas and Propagation Magazine, Vol. 42, Issue 3, pp. 12-20, June, 2000.