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Sweet Spot Search of Array Antenna Beam using the Modified Genetic Algorithm and Fuzzy Logic System

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Abstract

This paper presents a method that quickly search for sweet spot of array antenna, and keep it for fast speed transmission in millimeter wave. The proposed method is the Modified Genetic Algorithm (MGA) and Fuzzy Logic system. The MGA is used to find the approximate range as a pre-processing function. And the fuzzy logic system is used to find the exact sweet spot. We can transfer and receive a large data in millimeter wave bandwidth. Because antenna signal accounts for a few bits, influence on communication performance is little. MGA operators are used one-point crossover, rank-based selection, bit string mutation, elitism and 16bit split gene. In the fuzzy logic system, Rule base inference is used the max-min inference procedure. Defuzzification is used the center of gravity computation. The efficiency of the proposed method is verified by means of simulations.

Keywords: *Array Antenna Beam, Sweet Spot, Modified Genetic Algorithm, 16bit split gene, Fuzzy Logic System, Millimeter Wave*

1. Introduction

Today communication has important position to society, and then requires the communication of many information. In traditional bandwidth, there is no sufficient space and it needs cost for using. Broad spectrum space and free frequency bandwidth is 2.5GHz or more [1]. Therefore we think that, in communication, if an antenna beam could preserve sweet spot alignment, it is possible that Giga-bps transfer could be realized. And if communication is disconnected, quickly search for the sweet spot of the other array antenna and maintain communication. Considering real situation to adjust array antenna, to fix beam is dangerous for SNR (Signal to noise ratio) reduction or unexpected disconnect. We think that mutually in communication if antenna beam should preserve sweet spot, it is possible that Giga-bps transfer be realized.

This paper proposes an adaptive method which searches a sweet spot between each station on array antenna link, and keeps it. We use TDD (Time Division Duplex) as transfer method, and it transfers the control data of antenna. The propose method is using the Modified Genetic Algorithm (MGA) and Fuzzy Logic system. The MGA is used to find the approximate range as a pre-processing function. The MGA is selects a superior initial group through preprocessing in order to solve the local solution in genetic algorithm. And Chromosome is used 16bit split gene. 16bit split gene is each antenna has 8bit gene and combine each gene as

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one. The fuzzy logic system is used to find the exact sweet spot. In order to verify the effectiveness of the proposed method, we simulated of array antenna.

2. The Proposed Method

2.1. Sweet Spot Search of Array Antenna

In beam networks, finding and preserving a beam's suitable direction is required to prevent SNR reduction and disconnect. But if communication is disconnected by power failure, breakdown antenna system, *etc.*, then quickly search for the sweet spot of the other array antenna and maintain the link. Figure 1 shows the ideal array antenna beam's sweet spot. Figure 1 shows the intensity of the Station and the maximum point is the sweet spot.

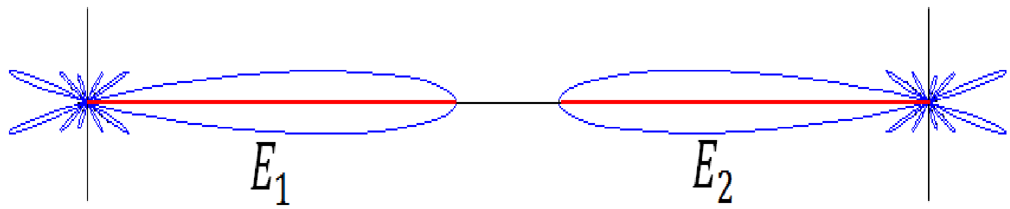


Figure 1. Ideal State of Beam

E_1 and E_2 are values that present intensity of each station as distance value about angle. If the angle from horizon between each station sets θ_1 and θ_2 then E_1 and E_2 are given like equation (1) and (2) [2-3].

$$E_1 = \sum_{n=1}^{N/2} w_n \cos((2n-1)\frac{\pi d}{\lambda}(\sin\theta - \sin\theta_1)) \quad (1)$$

$$E_2 = \sum_{n=1}^{N/2} w_n \cos((2n-1)\frac{\pi d}{\lambda}(\sin\theta - \sin\theta_2)) \quad (2)$$

Where, W_n is array weight, d and λ are distance and wavelength of each antenna and N is array number.

Sweet spot search is to compute optimized value of direction of beams between two stations. Data of beam's direction of each station becomes gene of each generation, and we can find sweet spot by using multiplication of E_1 and E_2 as equation (1) and (2). Suitable function Z is illustrated as equation (3). Wanted target value is a point when suitable function becomes maximum value.

$$Z = E_1 \times E_2 \quad (3)$$

The proposed method was to use GA to find the approximate location of sweet spot and using the fuzzy logic system locating the exact sweet spot. Figure 2 is flow chart of the proposed method.

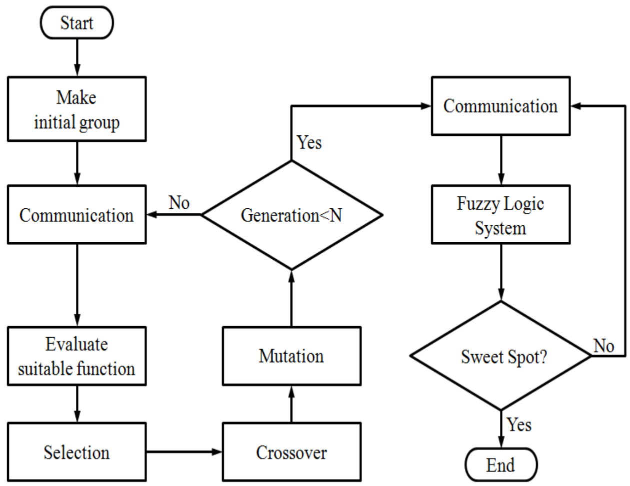


Figure 2. Flow Chart of Proposed Method

2.2. Modified Genetic Algorithm

MGA is search the approximate location of the sweet spot faster than the fuzzy logic system. But search the exact sweet spot slower than the fuzzy logic system [4]. Therefore MGA is used as a pre-process to search the approximate location of the sweet spot.

The local minima problem of GA is resulted from the selection of the initial generation. In the proposed method, in order to resolve this problem MGA preprocesses initial generations which are based on a master / slave model [4-6]. MGA makes k - slave generation and each slave generation evaluates suitability. The master processor sets the most superior group (generation) to initial generation and weeds out the other group. The master processor executes GA by selecting a superior initial group.

A master processor, which stores whole slave group in its own memory, is in charge of selecting the initial group. And k - slave processors are in charge of evaluating the functions of initial groups.

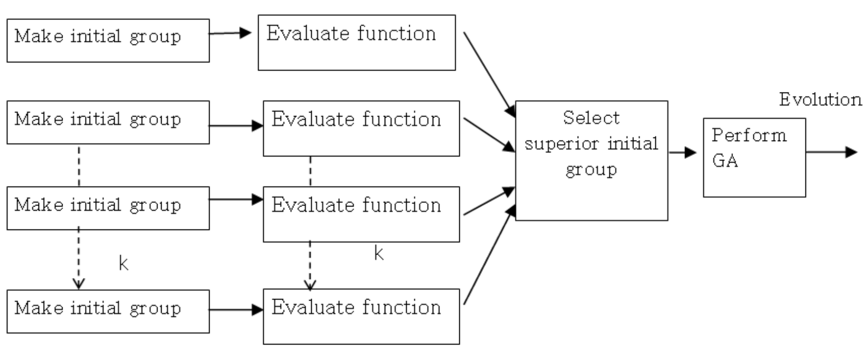


Figure 3. Proposed MGA

In MGA operators are used one-point crossover, rank-based selection, bit string mutation and elitism. Chromosome is used 16bit split gene [4-7].

The operation of 16bit split is as follows. In figure 4, each antenna has an 8bit gene. We combine each gene as one. That is, 8bit (A) + 8bit (B) = 16bit. So, the crossover and mutation are processed for the 16-bit gene. After all operation is finished, the gene splits into each antenna.

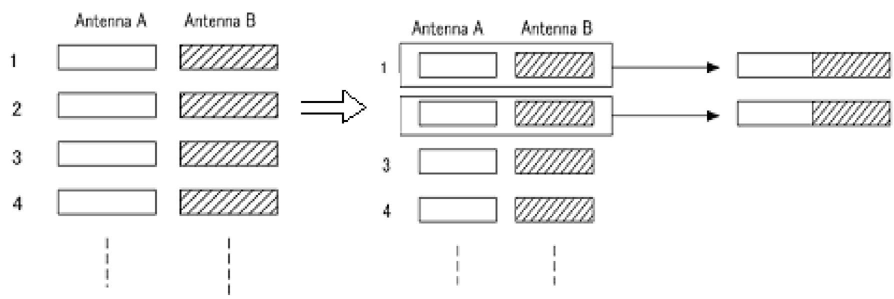


Figure 4. The Operation of 16bit Split

For example, if there are 40 individuals, 20 superior individuals are reproduced, and the other half is reproduced by flowing operation. About crossover, Figure 5 shows that genes are selected randomly, *e.g.*, No.2 and 7. If gene No2 and 7 are selected and cross point is antenna A side, the result means that antenna A only achieved crossover. There is the gene of No7 left in antenna B just as it is.

The crossover continues by the number of ¼ individual namely 10 individual. And the cross point is changed from antenna A side to B. So figure 6 shows new individual.

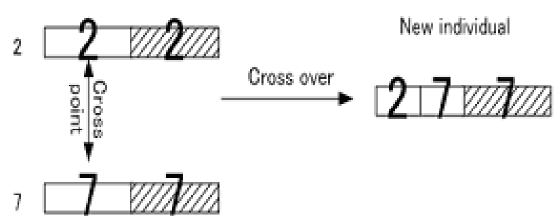


Figure 5. The Example of Crossover

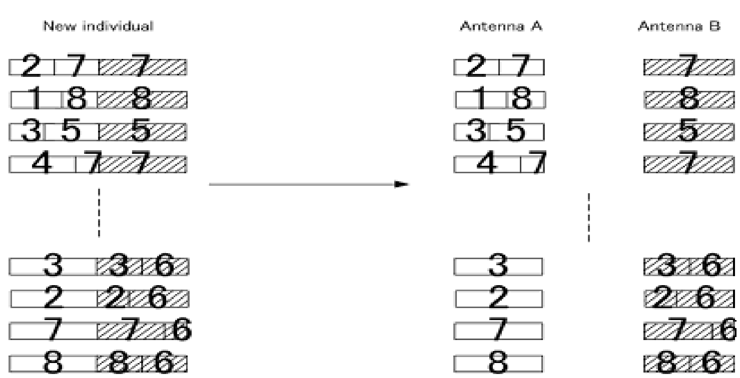


Figure 6. New Individual After Crossover

This result shows that the genes in the half of new individuals are left without crossover. In this method, we may operate crossover of the 16 bit gene by A and B shift. This result shows that the genes in the half of new individuals are left without crossover. In this method, we may operate crossover of the 16 bit gene by A and B shift.

A sweet spot search is used to compute an optimized value for the direction of beams between two stations. RSSI(Received Signal Strength Indication) value is as follows

$$RSSI_1 = 20 \log_{10}(E_1) \quad (4)$$

$$RSSI_2 = 20 \log_{10}(E_2) \quad (5)$$

Beam direction data for each station become gene for each generation, and we can find the sweet spot by using multiplication of $RSSI_1$ and $RSSI_2$ as equation (4) and (5). Suitable function 'z' is illustrated as equation (6). A desired target value is a point when suitable functions reach a maximum value.

$$Z = -1/(RSSI_1 + RSSI_2) \quad (6)$$

We use the TDD (Time Division Duplex) as a transfer method to control the data of antenna as Figure 7.

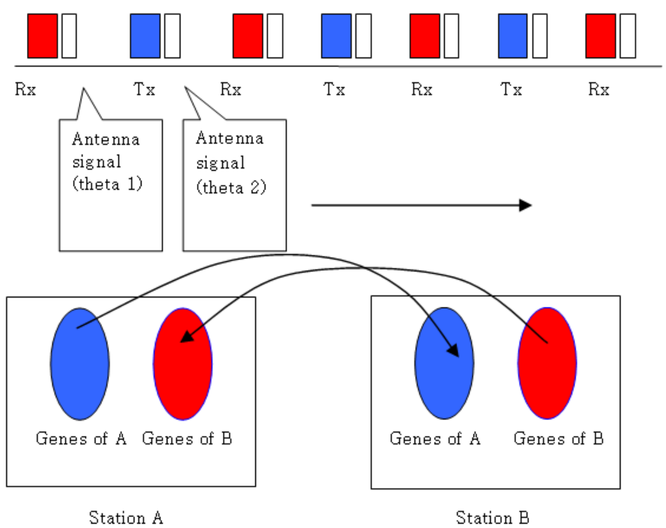


Figure 7. Communication of Antenna's Data

We can transfer and receive a large amount of data in the millimeter wave bandwidth. Because the antenna signal accounts for a few bits, influence on communication performance is small. Once the initial communication is completed for the specific number of individuals, no longer antenna's data will be transmitted until each station processes MGA in order to produce the next generation. After reproduction, individuals of the next generation become the data for the antenna, and communications between each other station is made again.

They transfer and receive the antenna's data for each other in each station, and each generation evaluates the function. So they process a MGA from selected initial group, and the produced individuals of the next generation send the data to the opposite station again. A flow chart of this algorithm is illustrated as follows.

2.3. Fuzzy Logic System

Fuzzy logic system is search the exact sweet spot faster than the GA if the approximate location of the sweet spot is found [4]. Proposed method is to find the difference intensity of the present beam and the previous beam and finding the antenna's degree of its movement by using fuzzy logic system. Figure 8 is Block Diagram of fuzzy logic system [4, 8-11].

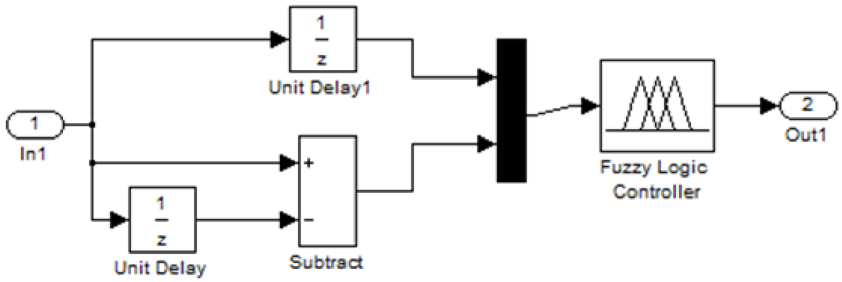
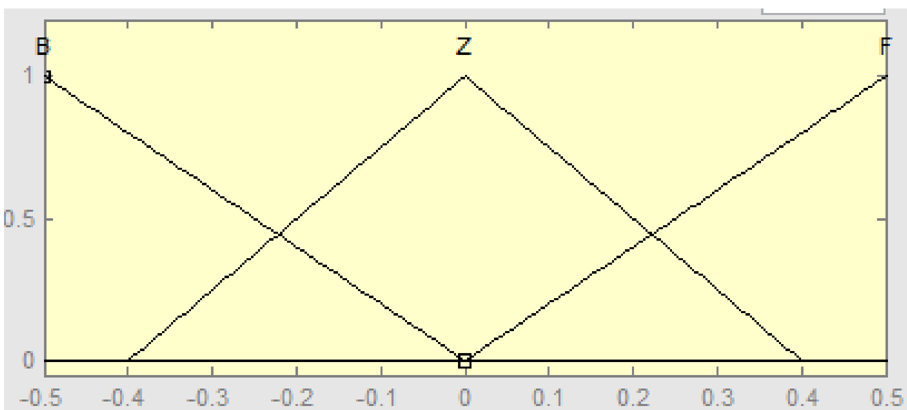
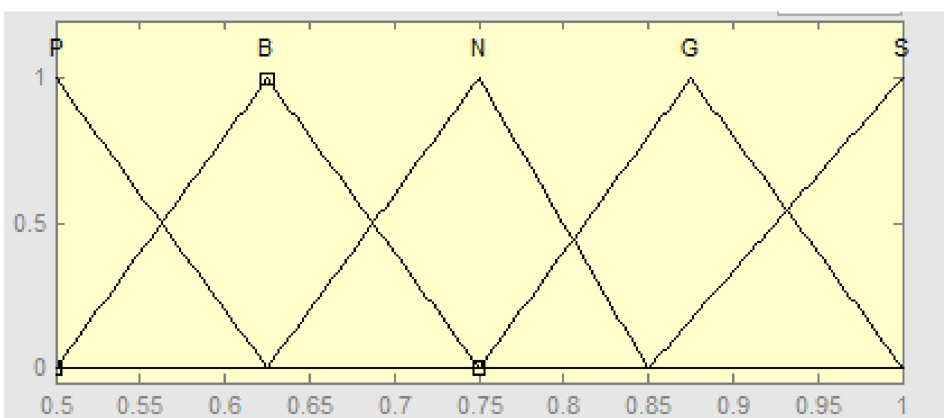


Figure 8. Block Diagram of Fuzzy Logic System

Figure 9 and 10 are input membership function and input membership function of fuzzy logic system. And Table 1 is fuzzy rule.



(a) Intensity of present beam



(b) Difference between the present beam and the previous beam

Figure 9. Input Membership Function of Fuzzy Logic System

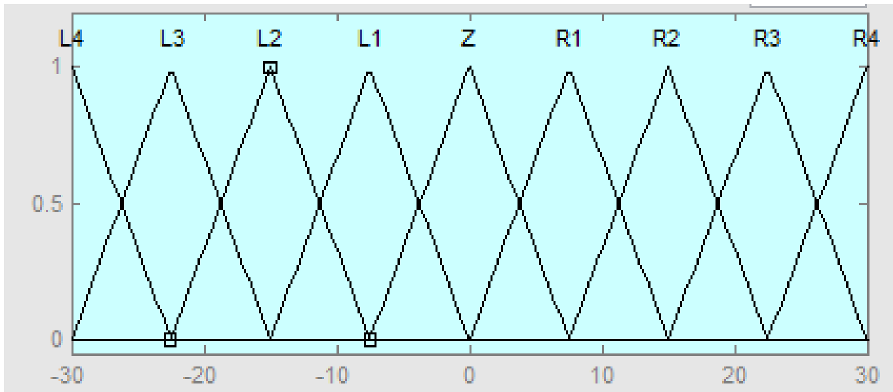


Figure 10. Output Membership Function of Fuzzy Logic System

Table 1. Fuzzy Rule

	P	B	N	G	S
B	L4	L3	L2	L1	Z
Z	R2	Z	Z	Z	Z
F	R4	R3	R2	R1	Z

Fuzzification is max-min ratiocination, and Defuzzi fication measuring by using center of gravity.

3. Simulation

The parameters of the simulations are shown in Table 2. The result of optimal on-line performances, when the parameters are selected by N = 30, d = 0.001, λ = 0.005, Crossover Rate =0.9 and Mutation Rate =0.05, was published.

Table 2. MGA Parameter

Parameter	Value
Population Size	2, 4, 6, 8
Generation	10, 15, 20
Crossover Rate	0.9
Mutation Rate	0.04

Figure 11 and 12 are simulation result of MGA and fuzzy logic system. Convergence probability is less than 60% and 80% when population size is 2 and 4. But population size is 8, convergence probability is over 90%. Optimal population size is 8, and optimal generation is 15. In Figure 12 the simulation result is near 1 when the k is 3, and ever since close to 1.

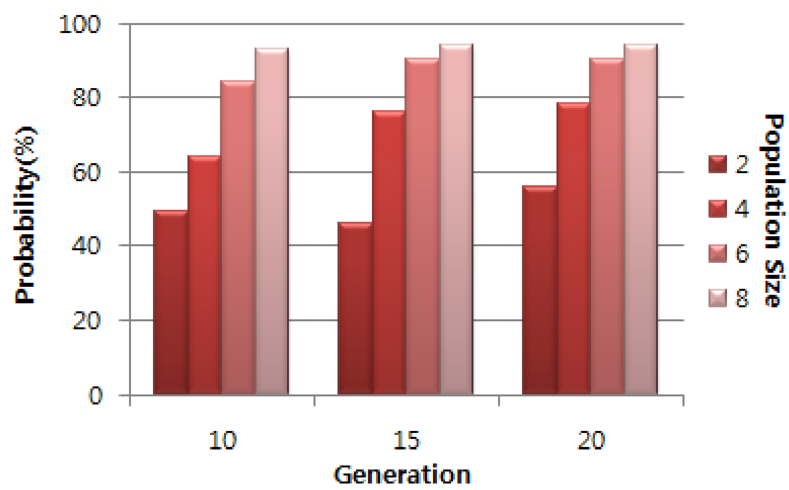


Figure 11. Simulation Result of GA

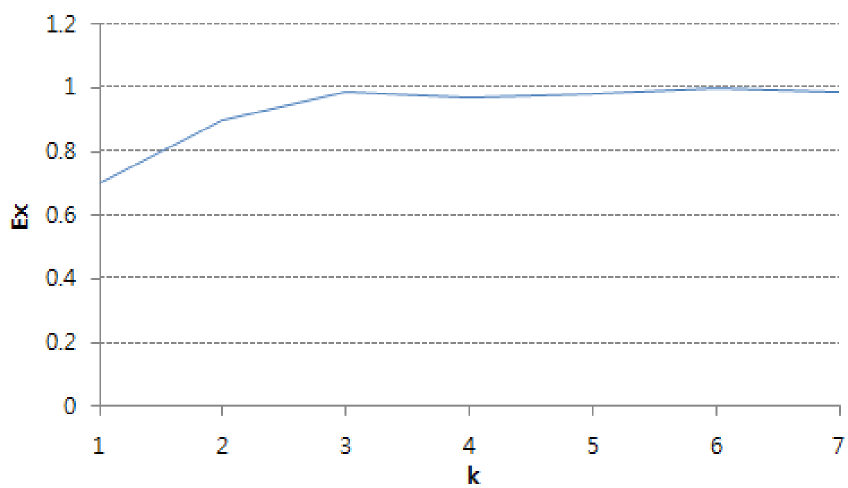


Figure 12. Simulation Result of Fuzzy Logic System

4. Conclusion

This paper proposed a method that search the sweet spot of array antenna beam, and keep it for fast speed transmission in millimeter wave on array antenna link. When each station transmits the data by TDD, they send antenna's information, and search the sweet spot using the information.

Proposed method was to use GA to find the approximate location of sweet spot and using the fuzzy logic system locating the exact sweet spot. The proposed scheme is validated by simulation results. Proposed method can quickly searches for the sweet spot of array antennas, and locks on to it. So it is possible that Giga-bps transfer could be realized.

Finally, the simulation and experiment results are summarized as follows:
- Convergence probability is less than 80% when the population size is 4.
- Convergence probability is over 90% when the population size is 8.
- Optimal population size and generation are 8 and 15
- Finding the sweet spot is more efficient than the using the fuzzy and GA.

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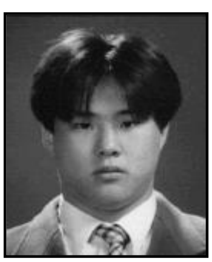

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