Optimum Design of Ultra Wideband Disc Monopole Antennas by Employing Genetic Algorithm

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Abstract This paper proposes an optimum design method for an ultra wideband disc monopole antenna by employing a Genetic Algorithm. The paper also presents the structure of the optimally designed antenna, and the calculated and measured characteristics of the fabricated antenna. Based on the results, we verify that the fabricated disc monopole antenna exhibits the best performance of 177% relative bandwidth, and this design method is effective in constructing an ultra wideband disc monopole antenna.

Keywords Disc Monopole Antennas, Genetic Algorithm, Ultra Wide Band, Relative Bandwidth

1. INTRODUCTION

To achieve 100-Mbit/s high-speed communications, the ultra wideband (UWB) radio system has been considered. The UWB communication system, which uses a pulse signal or is based on OFDM technology, utilizes a very-wide frequency bandwidth compared to conventional radio communication systems. Therefore, wideband characteristics are required for the antennas to behave as a matching device to space. To realize such required characteristics, many kinds of wideband antennas have already been developed. One such wideband antenna is the disc monopole antenna.

Many types of disc monopole antennas have been proposed [1]-[4]. These antennas feature low cost and compactness. However, it is very difficult for us to optimize the design of a wideband antenna due to the many design parameters. To optimize wideband or multi-band antennas, employing a Genetic Algorithm (GA) is useful in the design method [5],[6].

This paper proposes a design method for an ultra wideband disc monopole antenna by employing a GA, and presents the calculated and measured results of the fabricated antenna in order to verify the usefulness of this design method. In Section 2, the design method for the disc monopole antenna using a GA is described, and the relationship between the number of frequency divisions and the relative bandwidth is shown with the target Voltage Standing Wave Ratio (VSWR) as a parameter. In Section 3, the structure of the fabricated antenna is obtained and the calculated and measured characteristics of the antenna are shown.

2. DESIGN OF DISC MONOPOLE ANTENNAS BY EMPLOYING GA

2.1 Design Techniques by Employing GA

The structure of the disc monopole antenna is shown in Fig. 1. The antenna is a symmetrical planar antenna. In the GA, points (Xn) on the x-coordinate and points (Zn) on the z-coordinate are treated as genes. Each parameter is expressed as six bits, and these parameters are expressed in one-bit rows as in Eq. (1). An object function is derived as follows.

$$x = Z_0 X_1 Z_1 X_2 Z_2 X_3 Z_3 X_4 Z_4 X_5 Z_5 X_6 Z_6 X_7 Z_7 Z_8 \quad (1)$$

$$o(x) = Relative\,Bandwidth(x) \quad (2)$$

Here, $Relative\,Bandwidth(x)$ is the relative bandwidth [%] of this antenna, and the moment method is applied to calculate the characteristics of this antenna.

The flow of the GA used in this paper is shown in Fig. 2. An initial group (population) is established. Next, an object function is evaluated, and it is terminated if the convergence conditions are satisfied; otherwise, the groups are passed to the next generation. In the flow of the GA, the object function is evaluated, and supernal individuals (bit row) remain (selection). The proposed design employs Roulette selection. Next, a new bit row is generated (crossover). In the proposed design, the rate of crossover is set to 0.8 using a one-point crossover. Finally, in order to avoid falling into a local solution, a bit is reversed in low probability (mutation). In the proposed design, the rate of mutation is set to 0.01. The GA performs this repetition and calculates the optimal solution.

2.2 Relationship between Number of Frequency Divisions and Relative Bandwidth

The performance of the disc monopole antenna after the algorithm converges is shown in Fig. 3. Here, the population and the number of generations are 200 and 200, respectively. The horizontal axis represents the number of frequency divisions in the frequency bands from 0.5 to 10.5 GHz, and the vertical axis represents the relative bandwidth. The marks, black rhombuses, white triangles, and white rectangular in Fig. 3 indicate the disc monopole antennas that target below 2.0, 1.8, and 1.5 for VSWR, respectively. Figure 3 shows that the relative bandwidth is almost constant when the number of frequency divisions is greater than 20.

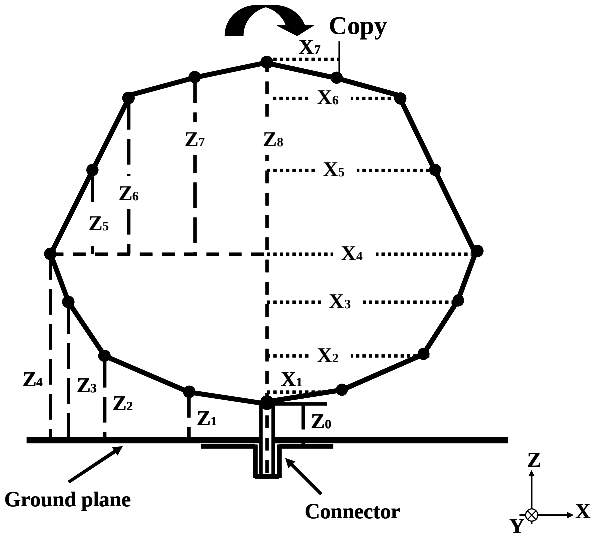

Fig.1 Structure of Planar monopole antenna

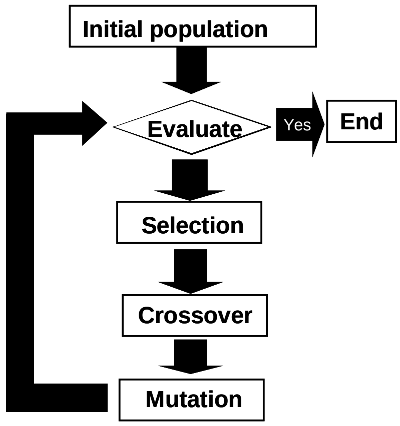

Fig.2 Flow of GA

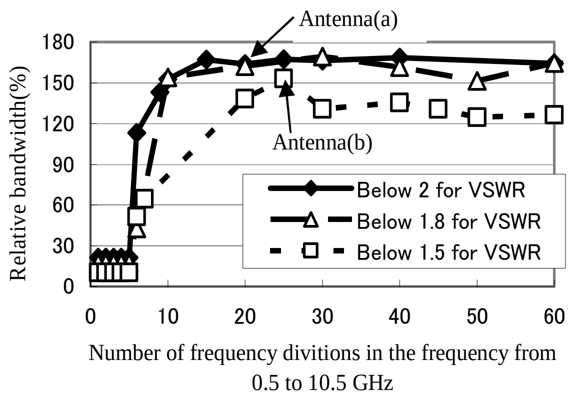

Fig.3 Relationship between number of frequency divisions in the frequency band and relative bandwidth

3. STRUCTURE AND PERFORMANCE OF NEW WIDEBAND DISC MONOPOLE ANTENNA

3.1 Structure of Optimally Designed Antenna

In order to verify the validity of the design method, we fabricated two types of optimally designed disc monopole antennas as indicated in Fig. 3: Antenna (a) and Antenna (b). Antenna (a) corresponds to an antenna that targets below 2.0 for VSWR and the number of frequency divisions is 20, and Antenna (b) corresponds to an antenna that targets below 1.5 for VSWR and the number of frequency divisions is 25. A photo of fabricated Antenna (a) is shown in Fig. 4 and the size of the antennas is given in Table 1.

3.2 Performance of Antenna (a)

Figure 5 shows the calculated and measured reflection characteristics of Antenna (a). Here, the target VSWR is below 2.0, and the solid line and the broken line denote the measured and the calculated results, respectively. The maximum relative bandwidths are 163% (calculated) and 167% (experimental). Figure 5 shows that the measured results agree well with the calculated results. Based on a comparison of the results, the optimum design method is effective for ultra wideband disc monopole antennas.

3.3 Performance of Antenna (b)

Figure 6 shows the calculated and measured reflection characteristics of Antenna (b). Here, the target VSWR is below 1.5. The maximum relative bandwidths are 153% (calculated) and 177% (experimental). The error between the measured and calculated results may be caused by manufacturing error of the feeding point. Figure 7 shows the calculated radiation patterns in the Y-Z plane, X-Z plane, and X-Y plane at the frequencies of 1.5 GHz, 5.0 GHz, and 8.5 GHz. These results verify the ultra wideband characteristics of the antenna are achieved.

Fig. 4 Fabricated Antenna (a)

Table 1. Size of Antennas

	Height(mm)	Width(mm)
Antenna(a)	67.4	54.9
Antenna(b)	57.3	52.7

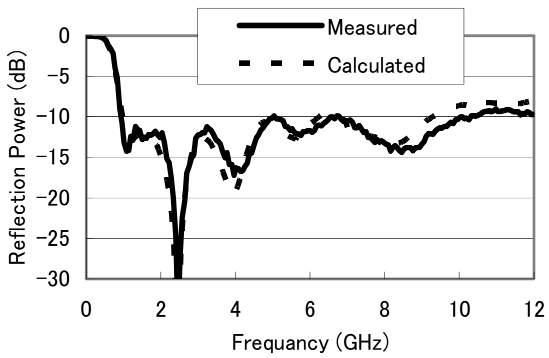

Fig. 5 Comparison of measured results to calculated results of antenna (a)

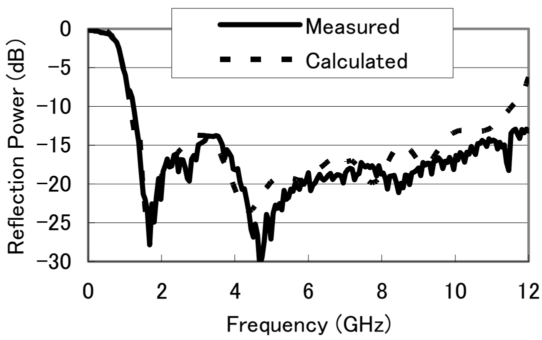

Fig. 6 Comparison of measured results to calculated results of antenna (b)

4. CONCLUSION

We proposed an optimum design method by employing the GA to achieve an ultra wideband disc monopole antenna. We presented the structure of the optimally designed antenna, and the calculated and measured results of the fabricated antenna in order to verify the usefulness of this design method.

In the design method, it is evident that the relative bandwidth is almost constant when the number of frequency divisions in the frequency bands from 0.5 to 10.5 GHz is greater than 20. Furthermore, we showed based on the measured results of the optimally designed fabricated antenna that 177% of the maximum relative bandwidth is achieved.

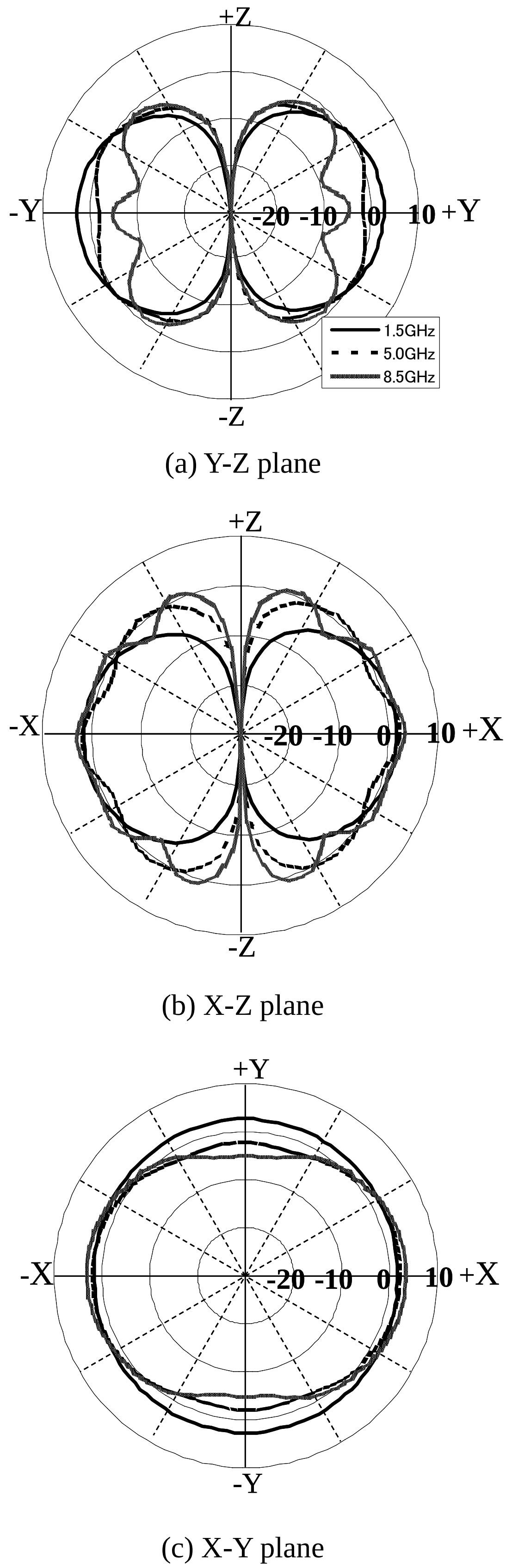

Fig. 7 Calculated radiation patterns

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