Design of an UWB Microstrip Antenna With DGS Based on Genetic Algorithm

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***Abstract*—In this paper, genetic algorithm (GA) and the defected ground structure (DGS) are combined to design the UWB antenna. Genetic algorithm is used to optimize the structure of the rectangular microstrip antenna so that the antenna can be built and optimized independently. At the same time, the defected ground structure is added to make the S_{11} lower in order to meet the demand of the UWB. The final S_{11} of the proposed antenna is under -10dB from 2.5-10.6GHz and the simulation results agree well with the measured results. Compared with the traditional antenna design methods, which is blind and time-consuming, the new approach shown as follows can obviously help us obtain better antenna performances in a short time, which improves the efficiency of antenna design.**

***Keywords*——Microstrip antenna, UWB, genetic algorithm, defected ground structure**

I. INTRODUCTION

With the rapid development of modern communication technology, people's demand for transmission bandwidth of antenna is higher and higher. The race for this contributes to the popularity of the UWB(The FCC regulates from 3.1 to 10.6GHz) communication, which has obvious merits such as large bandwidth, good confidentiality, high positioning accuracy, high transmission rate, strong anti-interference performance, small transmission power and low power consumption. The UWB antenna has been used in indoor communication, accurate geographic positioning, radar monitoring, high-speed WLAN and many other fields.

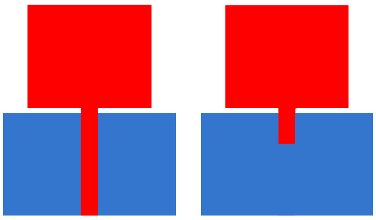
Generally, the shape of UWB antenna is relatively complex, such as fractal UWB antenna[1], dovetail UWB antenna[2] and elliptical monopole antenna[3], which is difficult to be processed and constructed. While the rectangular antenna is simple in appearance, the rectangular or rhombic antennas can only meet the performance requirements of single notch wave[4], double notch wave[5] and maximum triple notch wave[6]. It is hard for S_{11} to be all lower than -10dB in a large frequency range, and the bandwidth cannot reach the targets of the UWB. As shown in [7]-[8], the rectangular UWB antenna with a relatively complex structure can only be built through experience accumulation and constant attempts, which is blind and time-consuming. In this paper, the genetic algorithm is used to automatically optimize the structure of the rectangular patch, making the rectangular microstrip antenna's average S_{11} lower than -10dB, at the same time, through the [4],[9]-[10], the defected ground structure is added to make the antenna S_{11} further reduced, while guarantee the antenna structure is simple, with a shorter time to finish the UWB antenna design.

II. An UWB Microstrip Antenna Based on Genetic Algorithm

Genetic Algorithm (GA), also known as evolutionary Algorithm, is a heuristic global search Algorithm inspired by Mendelian genetics and Darwin's theory of evolution. It was proposed by professor J.Holland of the United States in 1975. Its main feature is that it directly operates on structural objects and has excellent global optimization ability. Its probabilistic optimization method can automatically obtain and guide the optimized search space, and adaptively adjust the search direction without determining the rules. It's one of the key technologies in modern intelligent computing.

A. Initial antenna structure

The antenna dielectric plate adopts FR4 material (dielectric constant is 4.4) with a size of 33.6mm×43mm and a thickness of 1.6mm. The floor is located at the bottom of the dielectric plate, the size of which is 33.6mm×20mm. Feeding is carried out with 50 ohms microstrip line, and its size is 3.2mm×21mm. In order to make the antenna have better impedance matching, a rectangular groove of size 3.2mm×6mm is etched in the antenna floor, which is located directly under the microstrip line. The patch adopts the rectangular metal patch with the size of 24mm×20mm and uniformly divides the rectangular patch into 15×10 grids. The size of each grid is 1.6mm×2mm. The initial structure of the antenna is shown in Figure 1.



(a) (b)

Figure 1. (a) The top view of the antenna.
(b) The bottom view of the antenna.

The UWB microstrip antenna with symmetrical structure can generate symmetrical orientation diagram, and the construction and processing are especially convenient. Therefore, the antenna optimized by genetic algorithm in this paper is also symmetrical. When binary encoding is carried out for the antenna, each small rectangular patch has two states of "0" or "1". "0" is to remove the rectangular patch, and "1" is to retain the rectangular patch. During encoding, only seven columns on the left and the eighth column in the middle need to be coded so that the entire matrix is then mapped to a binary code of 150 bits long.

B. Generation of the initial population

Due to antenna's symmetry, each individual only needs to be binary coded for 10×8 rectangular patches, and the binary number of each individual is set to 80. To save optimization time, the number of individuals in the population is set to 20, so the initial population should be a binary matrix of 20×80. In order to solve the problem of vertex connection and prevent the failure of HFSS simulation, the median filtering method is adopted in this paper to limit the antenna structure. At the same time, the probability of 0 in each individual should be about 0.1, neither too large nor too small. Otherwise, the antenna structure and optimization speed will be seriously affected.

C. Selection of fitness function

Fitness function, also known as objective function, is the function to be optimized. The main index of UWB antenna design is the antenna bandwidth, which requires the reflection coefficient S_{11} to be less than -10dB between 3.1-10.6GHz. Considering various calculation and simulation errors, the optimization frequency range is from 3 to 11GHz.

D. Selection, crossover and mutation

In this paper, the roulette method are used to select the highly adaptable individuals from the population to return to the offspring, and assume that 80% of the population is copied. When crossing, a single crossover is adopted, and a pair of individuals in the old population is returned to their offspring according to the probability of 0.7. Each element of the chromosome in the old population was mutated with a probability of 0.5 to produce a new offspring.

E. Termination condition

When the fitness function of the day line is equal to or infinitely close to 10, the termination condition is considered to be reached, or when the program iterates for 30 times, it terminates automatically.

If it meets the termination conditions, we need to put out parameters of the decoding, if it is not satisfied, we have to use selection (leave the highly adaptable individual by means of roulette), crossover, mutation and other operations to generate the offspring individual to calculate the fitness value again and make judgment until the termination condition is satisfied.

The antenna structure after GA optimization is shown in Figure 2. Figure 3 shows the comparison of S_{11} before and after GA.

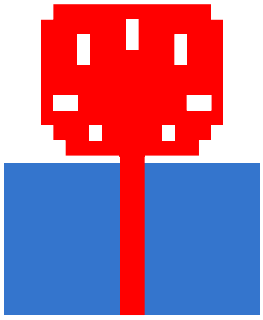


Figure 2. The antenna structure after GA.

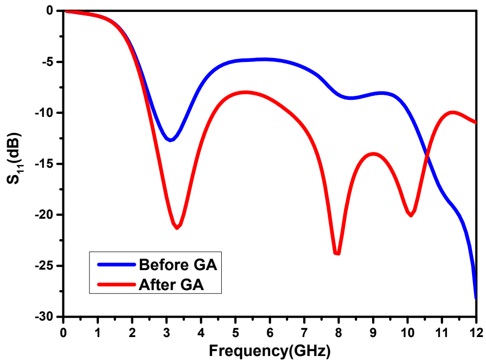


Figure 3. The comparison of S_{11} before and after GA.

It can be seen from Figure 3 that compared with the antennas before optimization with genetic algorithm, the structure of Figure 2 reduces the S_{11} a lot (the average value is down to -10dB), and the running time of the whole program is 30 hours, which is more convenient and time-saving than manually designing the antenna.

III. Design and optimization of the defected ground structure

The UWB antenna with entrapment can be realized through many different structures, for example, introduce the parasitic element, adopt fractal structure, or add tuned branches and slots. Among them, the most widely used method is the radiated patch or the slot on the floor. As shown in literature [9], rectangular groove on the floor can reduce the return loss. Also, it can be realized by opening the resonant ring on the antenna patch as shown in [4] and [10].

In this paper, it is found that the value of S_{11} can be effectively cut down by etching the rectangular groove and opening the resonant rings on the floor. Figure 4 shows the final structure of the antenna after adding defected ground structure. Table 1 shows the dimension of the defected ground structure.

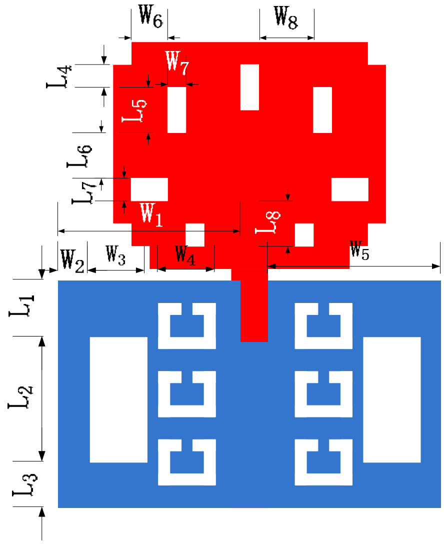


Figure 4. The final structure of the antenna after the DGS is added.

TABLE 1. THE DIMENSION OF THE DGS

Parameters	Value(mm)	Parameters	Value(mm)
W_1	16	L_1	5
W_2	2.8	L_2	11
W_3	5	L_3	4
W_4	5	L_4	2
W_5	15.2	L_5	4
W_6	3.2	L_6	4
W_7	1.6	L_7	2
W_8	4.8	L_8	4

Figure 5 shows the change of S_{11} before and after add the defected ground structure. It can be seen that through adopting the DGS, the S_{11} is further reduced, which is lower than -10dB from 2.5 to 10.6GHz.

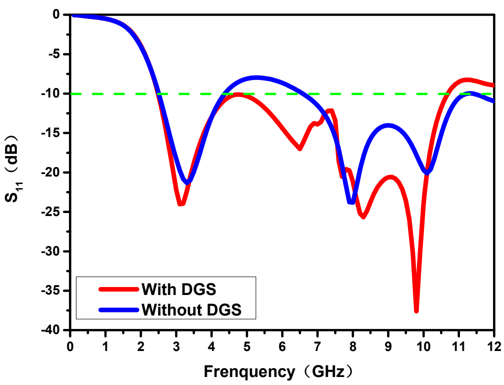


Figure 5. The S_{11} with and without the DGS.

Figure 6 shows the surface current distribution of the antenna at different frequency. It can be seen from the picture that at 3-5GHz, the radiation of the antenna is mainly concentrated at the offline end of the microstrip and the interface between the rectangular patch and the microstrip line. At 7GHz, the radiation of the antenna is mainly focused on the middle and lower part of the microstrip line, and the current around the first pair of resonant rings on the floor is also strengthened. At 9-10 GHz, the radiation in the upper middle, lower part of the microstrip line and the lower part of the rectangular patch is enhanced.

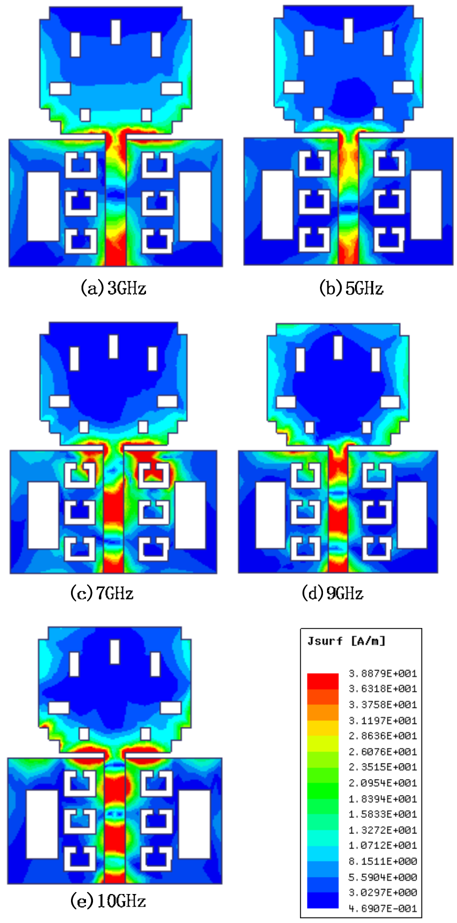


Figure 6. The surface current distribution of the antenna.

Figure 7 shows the simulated radiation pattern of the antenna at different frequency. At 3 GHz, E surface maximum radiation direction of the antenna is 180˚, and H plane direction diagram likes the figure '8', the maximum radiation direction is 0˚and 180˚. At 6 GHz, the maximum radiation direction of the E surface changes to 0˚, H plane direction graph maximum radiation direction doesn't vary a lot with its directionality increases. At 8 GHz, the E surface maximum radiation direction is 90˚ and 180˚ with two side lobes , the H surface maximum radiation direction is 15˚and 170˚, and has three side lobes; At 10GHz, the antenna's directional pattern starts to become irregular, with multiple side lobes. It can be seen from the direction diagram that after the microstrip antenna is made into UWB antenna, although the frequency band is widened, the direction diagram cannot reach the omnidirectional radiation.

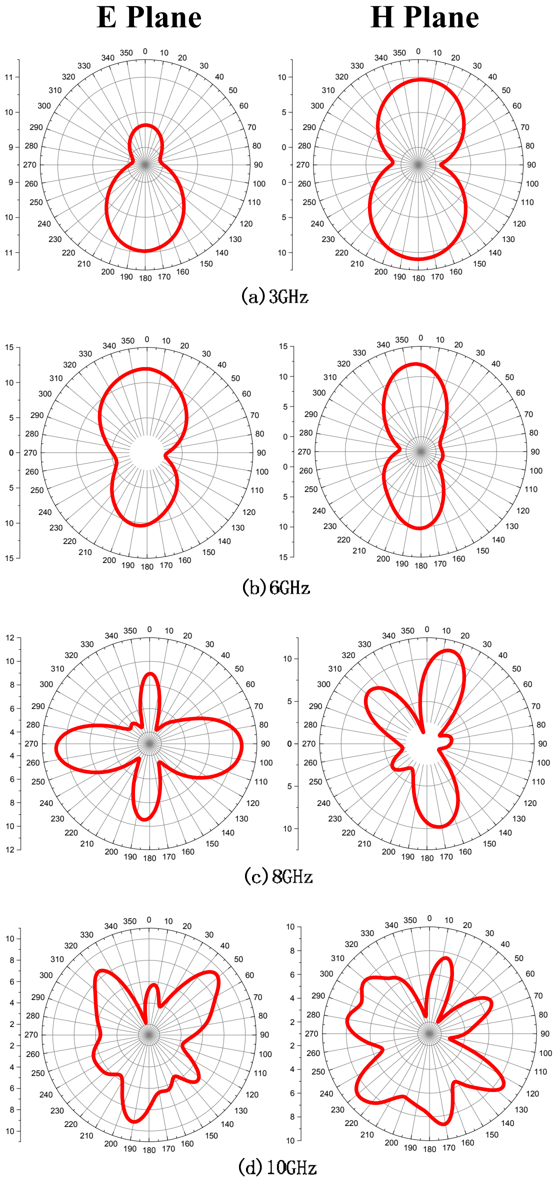


Figure 7. Simulated radiation patter

IV. CONCLUSIONS

As presented in this paper, the antenna design rule based on genetic algorithm can try different possible antenna structures and run the optimization automatically. It takes less time to run the program, and the average S_{11} is lower than -10dB. What's more, through introducing the periodic resonance rings and the rectangular DGS, the value of S_{11} can be further reduced, which is under -10dB from 2.5 to 10.6 GHz, larger than the UWB regulations. In conclusion, the method of antenna design based on genetic algorithm improves the efficiency of antenna design and it can help us to optimize and debug the antenna constructions automatically and the DGS is an effective way to reduce S_{11}.

REFERENCES

[1] Zhao Xiao-ying, Zang Hong-ming, Zhang Gong-lei, and Lu Jing-jing, "A Novel Ultra-wideband Fractal Tree-shape Antenna", Journal of Electronics & Information Technology, vol. 37, no. 4, pp. 1008-1012, Apr, 2015.

[2] Sun Rong-hui, Gao Wei-dong, Liu Han, Li Le, and Shen Xu, "Dual Band-notched Ultra-wideband Antenna with Single Complementary Split Ring Resonator ", Journal of Detection & Control, vol. 33, no. 5, pp. 15-19, Oct, 2011.

[3] Qi Ben-sheng,Wei Qing-juan, Li Xin-xin, and Xiao Jiang-yu, "An Improved Compact UWB Antenna", Journal of Microwaves, vol. 28, no. 6, pp. 32-34, Dec, 2012.

[4] Wen-jun Lui, Chong-hu Cheng, and Hong-bo Zhu, "Improved Frequency Notched Ultrawideband Slot Antenna Using Square Ring Resonator", IEEE Transactions on Antennas and Propagation, vol. 55, no. 9, pp. 2445-2449, Sept, 2007.

[5] Negin Manshouri, Mehdi Najafpour, Ayhan Yazgan, Masoud Maleki, Haydar Kaya, "A Novel Rectangular Microstrip Antenna for Ultra-Wideband Applications with Dual BandNotched Characteristic ", IEEE 22nd Signal Processing and Communications Applications Conference, pp. 1035-1038, 2014.

[6] Wu Ai-ting, and Guan Bo-ran, "Design and Research of a Compact CPW-fed UWB Antenna with Triple Band-notched Characteristic", Journal of Microwaves, vol. 31, no. 2, pp. 15-19, Apr, 2015.

[7] Yi-Cheng Lin, and Kuan-Jung Hung, "Compact Ultrawideband Rectangular Aperture Antenna and Band-Notched Designs", IEEE Transactions on Antennas and Propagation, vol. 54, no. 11, pp. 3075-3081, Nov, 2006.

[8] Mohammad Ojaroudi and Nasser Ojaroudi, "Ultra-Wideband Small Rectangular Slot Antenna With Variable Band-Stop Function ", IEEE Transactions on Antennas and Propagation, vol. 62, no. 1, pp. 490-494, Jan, 2014.

[9] Dong Jian, Hu Guo-qiang, Xu Xi, and Shi Rong-hua, "Design and Analysis of Controllable Tri-band-notched Ultrawide Band Antenna ", Journal of Electronics & Information Technology, vol. 37, no. 9, pp. 2277-2281, Sept, 2015.

[10] Swati Yadav, Anil Kumar Gautam, Binod Kumar Kanaujia, Karumudi Rambabu, "Design of band-rejected UWB planar antenna with integrated Bluetooth band", IET Microwaves, Antennas & Propagation, vol. 10, pp. 1528-1533, 2016.

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