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Wideband Circularly Polarized Fragmental E-Shaped Patch Antenna Optimized by Monte Carlo Method

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***Abstract*- A method to improve the bandwidth of classical E-shaped circularly polarized patch antenna is proposed in this paper. By adding metallic fragments to the long slot of the E-shaped patch antenna and representing the fragments numerically in a matrix, the computer can automatically generate the antenna geometry and finds the best solution for a wider axial ratio (AR) bandwidth through Monte Carlo method. The simulation results show that the fragmental E-shaped patch antenna has much wider AR bandwidth (15.89%) than the conventional E-shaped patch antenna (7.28%) with the same size.**

***Index Terms* — Circular polarization; E-shaped patch; fragment-type antenna; microstrip antennas; Monte Carlo method; wideband antenna.**

I. Introduction

Circularly polarized (CP) antennas are widely used to alleviate the polarization mismatch and multi-path fading [1]. Among all kinds of CP antennas, the single-fed CP antenna normally has narrow axial ratio (AR) bandwidth, but features simple feeding network, making it attractive for various applications [2]. To improve the bandwidth of single-fed CP antennas, considerable efforts have been devoted, including the stacked patch antenna [3], [4], annular-ring antenna with integrated feeding network [5], parasitic patches loaded corner truncated antenna [6], meandering probe-fed patch antenna [7] and so on.

Although all the aforementioned antennas achieve good performance, the design process of these antennas mainly relies on the established knowledge both from the antenna geometry and EM theory. Besides, the predetermined antenna geometry often determines the performance of the finished antenna. Due to the prior experience, some "irregular" shaped antennas are rarely considered, even though such antennas may have better performance. Therefore, from the unique perspective of the machine, the optimization algorithm which automatically generates the suitable antenna geometry is employed in this work to meet the design purpose and explore the potential of those "irregular" antenna structures, which may achieve unexpected results.

The well-known E-shaped patch antenna [8] is investigated in this paper for bandwidth improvement by using the Monte Carlo method. Filling the original E-shaped slot with metallic fragments which are automatically generated by Monte Carlo Method, much wider bandwidth can be obtained by the fragmental E-shaped antenna. Specifically, the AR bandwidth of the fragmental E-shaped patch reaches 15.89% (2.26GHz-2.65GHz) while the AR bandwidth of conventional E-shaped patch antenna with the same size is only 7.28%. Considering that nearly no extra space and cost is needed for the newly designed antenna compared to the traditional E-shaped patch antenna, the proposed method is quite effective in the optimization procedure of the E-shaped patch antenna, and is expected to be applicable for other kinds of antenna to improve the performance.

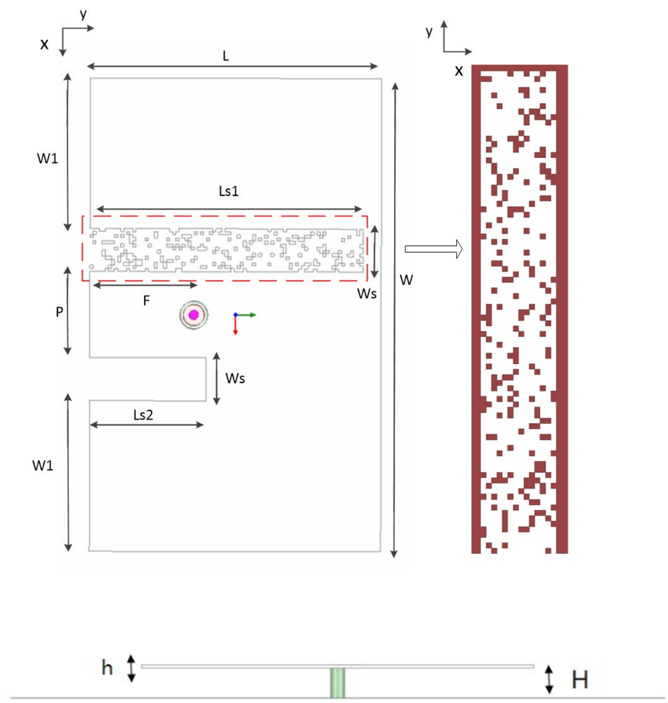


Figure 1. Geometry of the proposed antenna.

Table I. The detailed design parameters of the proposed antenna(mm).

W	L	Ws	Ls1	Ls2	P	F	H	h	W1
77	47.5	7	44.5	19	14	17	10	0.787	24.5

II. Antenna Design Procedure and Method

The geometry of the proposed antenna is shown in Fig. 1, with its detailed design parameters shown in Table1. As shown, a fragmental E-shaped patch antenna is printed on a Rogers RO5880 substrate with a thickness of 0.787mm. The substrate is placed at a height of 9.213mm from the ground (top surface of the substrate is 10mm away from the ground), and the size of the ground plane is 200 mm × 95 mm. Similar to the E-shaped patch presented in [8] air layer is utilized between the substrate and the ground.

It is worthy pointing out that all values of the geometrical parameters of the proposed antenna are the same as that of the E-shaped patch antenna shown in [8]. The only difference between these two antennas is that the longer slot of the proposed antenna is filled with metallic fragments, as indicated by the magnified picture in Fig. 1. To generate these metallic fragments, the longer slot is discretized and represented by a matrix [9]. In this matrix, element 1 represents the metallic fragment while element 0 represents the air. As the size of the slot is 7mm × 44.5mm, the zero-one matrix with size of 14 × 89 can represent this slot given that the size of each square unit fragment is 0.5 mm × 0.5 mm. In this manner, the design procedure of the proposed antenna for better AR performance can be formulated as an optimization problem searching for best AR bandwidth, which can be solved by an intelligent optimization algorithm. Moreover, the fragmentation of the antenna numerically in matrix form enables a faster and more straightforward adjustment, making the solution space more homogeneous and diverse.

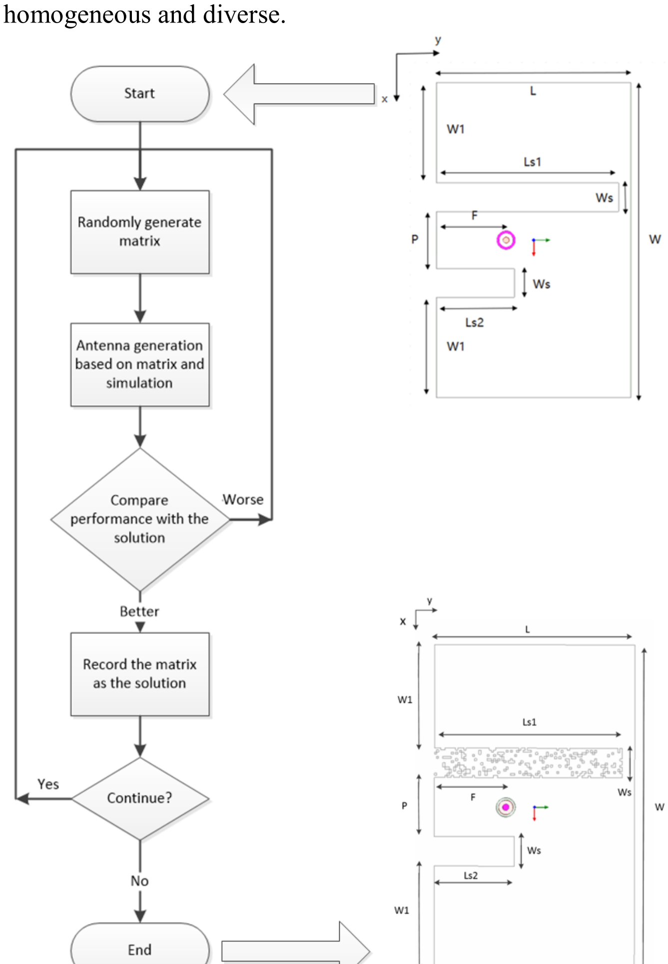


Figure 2. The flow chart of the Monte Carlo optimization process.

The flow chart of the optimization process is shown in Fig. 2. By using the Monte Carlo method, the computer is used to implement a random sampling process to obtain an approximate solution for the optimization problem, which will be close to the true solution of the problem if the number of sampling points are big enough. In this work, the fragmented slot is generated by the random matrices. By comparing the ARs of different fragmental antennas represented by different matrices, a more qualified approximate solution can be found, which can eventually lead to a satisfactory solution. Based on this solution, the antenna geometry can be finalized.

III. Results and Discussions

The finalized antenna structure is shown in Fig. 1. To investigate its performance, the reflection coefficient, gain, AR, and radiation patterns are studied.

Fig.3 shows the reflection coefficient of the proposed antenna. As shown, the impedance bandwidth of the proposed antenna is 16.50% (2.28GHz-2.69GHz). The comparison of the AR performance between the proposed antenna and the conventional E-shaped patch antenna is shown in Fig. 4. As shown, the AR bandwidth of the proposed antenna reaches 15.89% (2.26GHz-2.65GHz), which is much wider than that of the conventional E-shaped patch antenna (7.28%).

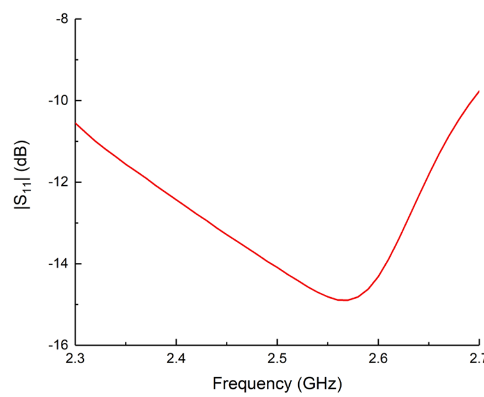


Figure 3. The |S11| of the fragmental E-Shaped antenna.

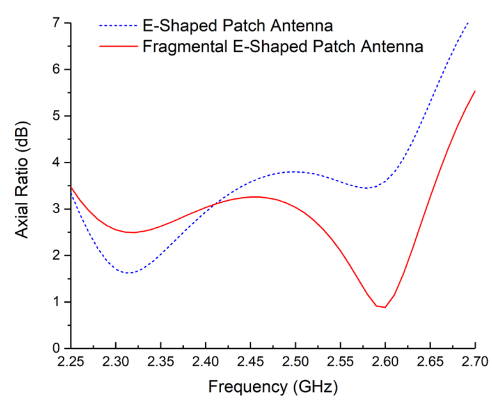


Figure 4. The AR of the fragmental E-Shaped antenna and E-Shaped antenna.

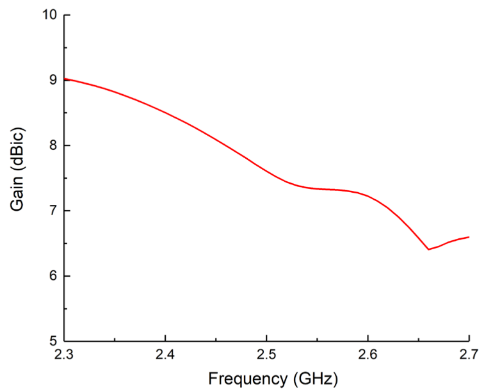
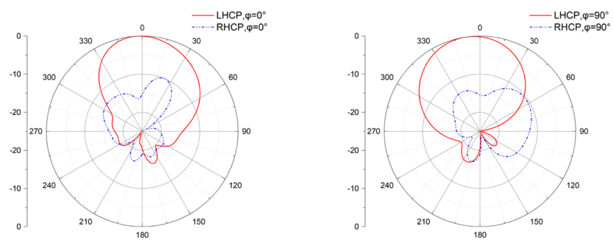


Figure 5. The Gain of the fragmental E-Shaped antenna.



(a) (b)

Figure 6. Radiation patterns of the fragmental E-Shaped Patch antenna at 2.4 GHz.

The gain and radiation patterns of the proposed antenna are shown in Fig. 5 and Fig. 6, respectively. As can be seen from Fig. 5, the antenna gain ranges from 6.5 dBic to 9 dBic within the operating bandwidth. The radiation patterns of the proposed antenna are a little tilted due to the presence of asymmetric slots, which can also be found in conventional E-shaped patch antennas.

IV. Conclusion

An optimization method of E-shaped patch antenna for better performance is proposed in this paper. By filling the longer slot of the conventional E-shaped patch antenna with metallic fragments and adopting the Monte Carlo method to optimize the antenna, an irregular E-shaped patch antenna with wider bandwidth is realized. As indicated by the simulation results, the AR bandwidth of the proposed antenna reaches 15.89%, which is much wider than that of the conventional E-shaped patch antenna. The proposed optimization method can also be used in the optimization procedure of other antennas, making it quite scalable and applicable for various antenna applications

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