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Genetic Algorithm in Broadband Microstrip Antenna design

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Abstract- Genetic algorithm is utilized in the optimization of microstrip antenna with complicated structure. We've proposed a broadband single-patch microstrip patch antenna. The Capacitance compensated technique and an E-shaped patch are combined together to expand the bandwidth of this antenna. Genetic algorithm combined with Finite Element software is applied to optimize the structure of this antenna. The procedure for optimization is also discussed on this platform. The reliability and efficiency of this method is proved by comparing the antenna proposed in this paper to an un-optimized one. It can be clearly observed that the bandwidth expands from 6% of the un-optimized one to 16% of its capacity.

Key words: genetic algorithm; broadband; finite element; microstrip patch antenna; capacitance compensated technique; E-shaped patch.

I INTRODUCTION

The scalability in the area of Wireless communications has improved great folds in recent years. Microstrip patch antennas are expected to find many promising applications in wireless communications because of their attractive features like low profile, light weight, and economical efficiency. However, the main disadvantage being: narrow operating bandwidth.

Many efforts have been made to address the mentioned concern to some extent[l]. In [2], parasitic patches are employed to increase the bandwidth. Two V-shaped parasitic patches are located on the same layer with the main patch. By stacking a parasitic patch on the top of the main patch, bandwidth enhancement of the microstrip antenna has been obtained in reference [3-5]. However, these techniques do enlarge the antenna size at same time. In [6], by incorporating U-shaped slot into the patch, bandwidth enhancement is achieved. In [7], an E-shaped patch antenna with wide bandwidth is depicted.

With the fortunate, fast and rapid development of wireless communications, the microstrip patch antennas must meet more requirements, which make the configuration and design process much more complicated. Thus the antenna design problems (so to say) involve a large number of parameters which have great effect on performance of the antenna. These parameters must be taken as a whole into account. The traditional optimization techniques are not efficient in solving such problems. So genetic algorithm is utilized in the design process [8, 9]. In this paper, genetic algorithm is adopted to optimize the configuration of the antenna and a broadband microstrip patch antenna is being studied and investigated. The electrical properties of the antenna are computed using Finite Element software, HFSS, of ANSOFT.

II ANTENNA DESIGN

A. Configuration of Antenna

Fig.l depicts the configuration of the proposed antenna. It consists of a capacitance compensated fed half-wavelength patch with two slots incorporated into its radiating edge, forming E-shaped patch. The patch size is characterized by (L, W, h) and it is fed at position (X *f* ' *Yf*).

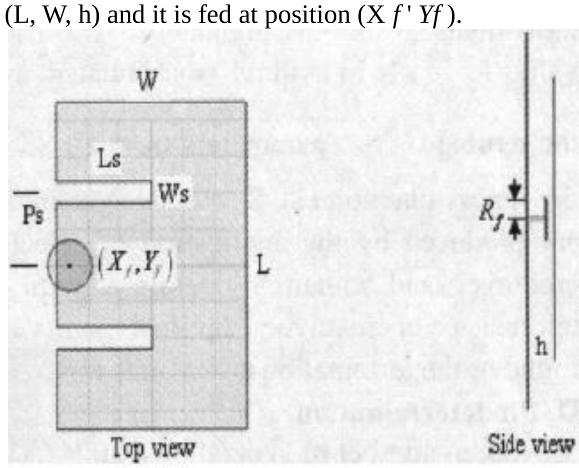

Fig.1 Geometry of the proposed patch antenna

The ordinary microstrip patch antenna can be modeled as a simple LC resonant circuit. The patch surface current path starts from the feed point to the radiating edges, whose length is approximately determined from one-quarter wavelength of the resonant frequency. L and C values are gauged by this length. When two slots are incorporated into

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the patch, the resonant behavior changes. In the middle part of the patch, the equivalent LC circuit doesn't change and resonates at initial resonant frequency. However, the slot in the patch can be modeled as an additional series inductance M [10]. So the equivalent LC circuit of the edge part resonates at a lower frequency. Thus the antenna changes from a single LC resonant circuit to a dual resonant circuit. These two resonant circuits couple together forming a broad bandwidth [7].

For the microstrip patch antenna fed by a coaxial probe, the inductance introduced by the probe will be quite significant when thick substrate is used for achieving a broad bandwidth. Therefore, it is necessary to compensate the inductance to overcome the aforementioned problems. The capacitance compensated excitation is achieved by means of a small planar plate mounted on the top of the coaxial probe. Through the radius and electrical properties of the dielectric substrate the capacitance can be determined. In order to obtain broad bandwidth, the two aforementioned methods are combined together. Two parallel slots are incorporated into the patch and positioned symmetrically with respect to the feed point. The slot length (Ls), slot width (Ws), slot position (Ps), the feed position (Y_f) , and the radius of the small planar plate (R_f) are important parameters which affect bandwidth of the proposed antenna. They shall be optimized as a whole in this design to achieve better performance.

B. Optimization Strategy

To optimize the five parameters mentioned above, genetic algorithm has been adopted in this paper/study. There are two phases in a typical genetic-algorithm optimization. They are initiation, reproduction and generation replacement. Initiation consists of filling an initial population with a predetermined number of randomly created chromosomes.
Each of these chromosomes represents an individual prototype solution or, an individual. The set of individuals is called the current generation. Each individual in population is assigned a fitness value by evaluating the fitness function for each individual. The reproduction phase produces a new generation from the current generation. Selection with a preference for the individuals with higher fitness value is used to fill the new generation, and then crossover and mutation are applied to the individuals in the new generation. The selection, crossover, and mutation operations are repeated until the optimal or relative optimal solution is found.

C. Optimization Procedure

The selection strategy is straight and simple, its proportionate selection. Elitist strategy is adopted to accelerate the convergence rate.

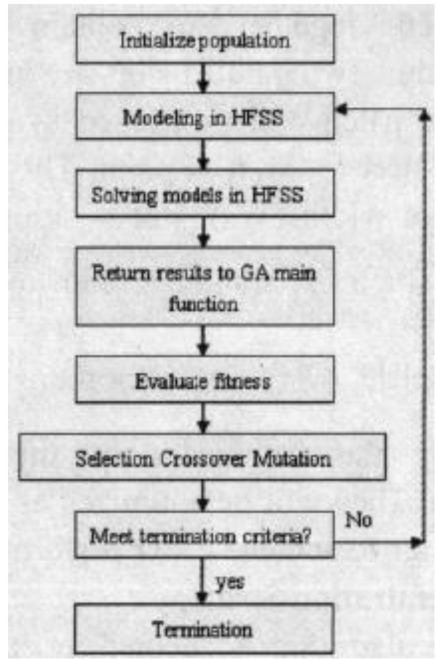

Fig. 2 A block diagram of genetic algorithm function used in this design

The block diagram of genetic algorithm function in this design is shown in Fig. 2.

The optimization procedure in this design is summarized as follow:

Step 1: To choose a coding of the parameters into genes. In this case, a binary-string coding will be used. There are five parameters, namely Ls, Ws, Ps, *Yj* and *Rj to* be optimized, so the chromosome structure is a five-part string. Each part of the string corresponds to one parameter.

Step 2: Create the initial population randomly, providing a reasonable starting point for the optimization. Then decode the chromosomes into parameter values.

Step 3: Create and solve models in HFSS. Create models according to the decoded parameters, set solving conditions and solve models in HFSS. Then return calculated S" parameters to main function automatically. The returned SII parameters will be called by fitness function.

Step 4: The genetic algorithm can begin optimizing. The fitness function, which is the measure of goodness of an individual, is used here to assign a fitness value to each of

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the individuals in the GA population. The fitness value for each individual is calculated using the returned S" parameters from HFSS and the fitness function (1). Successive generations are produced by the application of selection, crossover and mutation operators, until the optimal or a relatively optimal solution is found or the termination criterion is met.

D. Predetermination

Maximum number of generations: 200

Optimization object: S_{11} parameter

Size of population: 50

Probability of crossover: 0.7

Probability of mutation: 0.05

Fitness function:

$$P(x) = \frac{1}{N}\sum_{i=1}^{N} Q\,(f_i)$$

$$Q(f_i) = \begin{cases} 15 & S < -15 \\ |S_{11}\,(f_i)| & S \geq -15 \end{cases}$$

Where N is the number of sampling points, f_i is sampling frequency:

f_1=2.2GHz, *f2*=2.3GHz , f_3=2.4GHz, f_4=2.5GHz

The configuration parameters of the un-optimized patch antenna are as follow:

Patch size:

L=45mm,

W=30mm

Height of the antenna: h=5mm

Material: $\varepsilon_r = 3.55$

Ill CALCULATION AND ANALYSIS

Calculation is carried out to demonstrate the performance of the proposed antenna. The HFSS software based on Finite Element is used for analysis. The S" parameter of un-optimized ordinary rectangular patch antenna is shown in Fig. 3 for comparison.

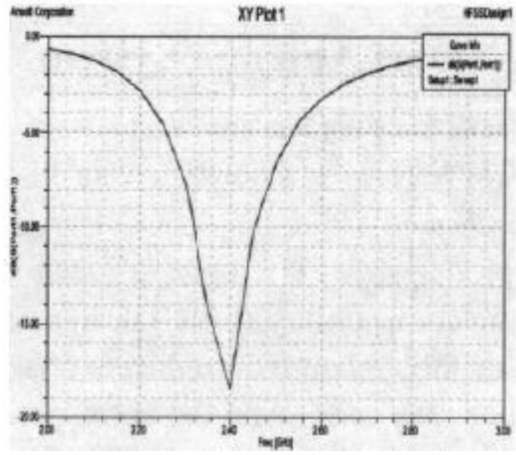

Fig 3. Calculated S_{11} parameters of un-optimized antenna

The S_{11} parameter of the proposed antenna is shown in Fig.4.

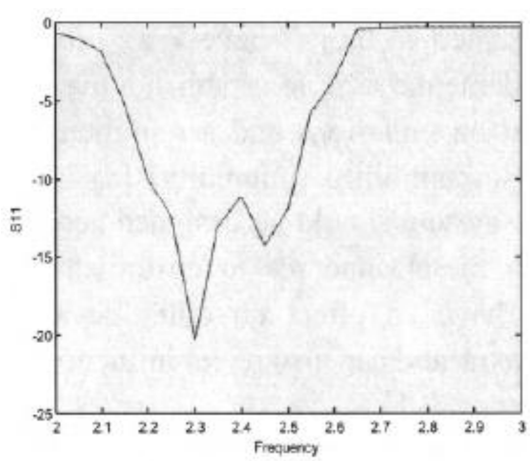

Fig.4 Calculated S_{11} parameter of proposed antenna

It can be observed from the figure that the return loss on the four frequency points mentioned above is lower than -10dB. Two neighboring resonant frequencies can be observed; they couple together and expand the bandwidth from 6% to 16%. Reasonable agreement between the theoretical analysis and the simulated results is obtained.

IV CONCLUSION

A capacitance compensated fed E-shaped patch antenna with broad bandwidth is realized and proposed in this paper/study. Genetic algorithm combined with Finite Element software is applied to optimize the configuration of the antenna. The optimization procedure is also included in the study. The bandwidth of antenna expands from 6% to 16%. The method suggested here has the attractive features of modularization and intellectualization.

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