Reconfigurable Microstrip Antenna Design Based on Genetic Algorithm*

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1.Introduction

Reconfigurable antenna is a novel concept of antenna [1]. At present, there are two main domains to be researched for reconfigurable antenna: the one is to reconfigure the radiation patterns with fixed operation frequencies [2-4], the other is to reconfigure the operation frequencies with uniform radiation patterns [5-7]. However the core of the desired characteristics of modern reconfigurable antenna is that the antenna can reconfigure the radiation patterns over an extremely wide band. There is a large gap between the present researches and the ultimate objective. A novel scheme of reconfigurable microstrip antenna is presented due to its advantages of low profile, light weight, conformability, and especially ease of fabrication and integration with RF devices.

The finite-difference time-domain (FDTD) method and GA optimizers are used to optimize the antenna states according to the selected goals. This work attempts to explore the possibilities of microstrip antenna for reconfiguring the radiation characteristics over an extremely wide band. The design results indicate that this antenna can obtain the required goals over an ultra-wide band through reconfiguring the states of the switch array installed in shared aperture when it operates with the higher order modes.

2. Scheme of Reconfigurable Microstrip Antenna

A novel scheme of reconfigurable microstrip antenna is presented in this paper. The center part of patch of a microstrip antenna shown in Fig. 1(a) is replaced by a 4×4 small patch array and a microstrip ring with the width of W_r is remained, just like showing of Fig. 1(b). The fractal units are connected with the MEMS switches, which can be controlled by special circuits (including optical controlling circuits). The relative dielectric constant and the thickness of the microstrip substrate is $\varepsilon_r = 2.22$ and $h = 0.794$ *mm*, respectively. The area of the whole patch and every small patch are $L_y \times L_z = 16.0 \times 16.0\ mm^2$ and $2.0 \times 2.0\ mm^2$, respectively. The parameter of W_r is $2.0\ mm$. The selected width of the microstrip feed line is $W_f = 2.4\ mm$ so that the characteristic impedance is 50 ohm. The switch area is $0.8 \times 0.4 mm^2$, which is approximately equal to the dimensions of a practical MEMS switch [8].

Based on the cavity mode, a preliminary analysis on the influence of a slot which is brought by opening the MEMS switches on the radiation patterns is done in literature [9] by us. The analysis indicates that a slot on the patch arouses the radiation of an equivalent magnetic dipole. So using the MEMS switch array can obtain the different magnetic dipole arrays, which corresponds to the different antenna characteristics.

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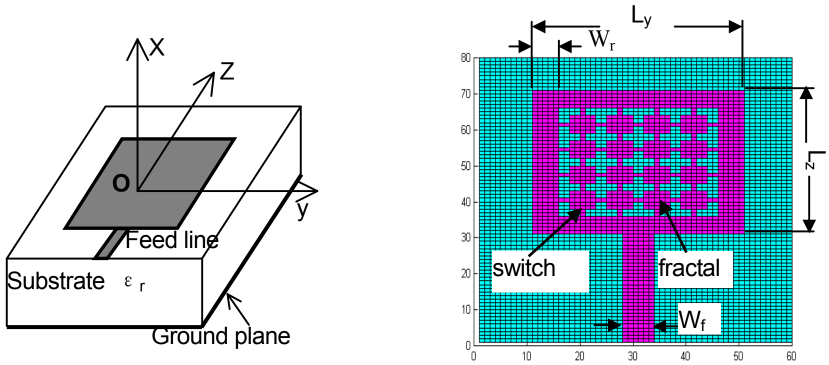


(a) (b)

Figura 1. Microstrip antenna and reconfigurable microstrip antenna scheme. (a)Three-dimensional view of microstrip antenna; (b) The scheme of a reconfigurable microstrip antenna

Compared with the traditional antennas, the relationship between the operation characteristics and the structures of the proposed antenna is very complicated. Thereby it is difficult yet to design a reconfigurable microstrip antenna with the synthesis methods.

3.The Antenna Design result by Genetic Algorithms

In Fig. 1(b), it is shown that there are 40 switches in the aperture. The solution that needs to be determined is the states of the switch array. GA [10] is selected for the optimization design of the reconfigurable microstrip antenna. We use a chromosome to denote the state of switch array, and a "0" or "1" in the chromosome denotes the off or on state of a switch, respectively. So a binary string composed of "0" and "1" with the length of 40 can describe the states of the switch array displayed in Fig. 1(b). Obviously, There is a one-to-one correspondence between a state of the switch array and a chromosome. In Fig. 2, an example of encoding for a state of the switch array is shown. In the arrangement of the bit of the chromosome, the order of the code is from rows to columns (from left to right in rows and from bottom to top in columns). The open or closed states of a switch are simulated by the absence or presence of a metal pad, respectively.

The selected population size is 32 individuals and the produced generations are 8. The probabilities of crossover and mutation are 0.875 and 0.01, respectively. Fitness proportional selection model is used. The final results memorized are the maximal value of the whole fitness function and the corresponding chromosome which stands for a better array state for the desired goal. The design and optimization program can be operated by embeding GA into FDTD method [11]. The block diagram of GA optimization is similar to literature [12].

We do researches on the capability of this antenna for reconfiguring the radiation patterns over an extremely wide band. Two desired radiation directions are selected arbitrarily, for example: (1) $\theta_0 = 60^\circ, \varphi_0 = 0^\circ$ (where, θ_0 is the angle between the Z -axis and the direction vector, φ_0 is the angle between the X -axis and the projection vector of the direction vector in XOY -plane), (2) $\theta_0 = 120^\circ, \varphi_0 = 30^\circ$. Then several frequencies are selected randomly within the spectrum of the input signal, for instance, f_1 =10.0GHz, f_2 =15.0GHz, and f_3 =20.0GHz. The states of the switch array are optimized at the three different operation frequencies and two goals, respectively. For goal 1, the intensity patterns in $\varphi_0 = 0^\circ$ half plane, which is normalized by the maximal value of the radiation intensity over all directions, are shown in Fig. 3. The optimized return loss (S_{11}) at three different frequencies are –15dB, -15.3dB, and –13.5dB, respectively. The maximal radiation directions obtained by optimizing at three different frequencies are $(60^\circ, 0^\circ)$, $(59^\circ, 1^\circ)$, and $(51^\circ, 0^\circ)$, respectively. Table I lists the chromosome descriptions of the optimized switch array states. For goal 2, the normalized intensity patterns in $\varphi_0 = 30^\circ$ half plane are shown in Fig. 4. The optimized return loss at three different frequencies are –25dB, -14.3dB, and –15.9dB, respectively. The maximal radiation directions obtained by optimizing at three different frequencies are $(119^\circ, 30^\circ)$, $(119^\circ, 30^\circ)$, and $(118^\circ, 29^\circ)$, respectively. Table II lists the chromosome descriptions of the optimized switch array states. The results have indicated that the desired goals were achieved.

4. Discussions

From the above optimization results, it can be found that the proposed reconfigurable microstrip antenna can obtain the good reconfigurability. On the one hand, the antenna can reconfigure the operation frequencies

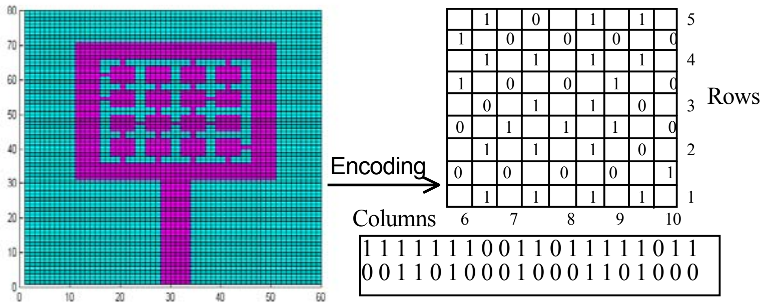
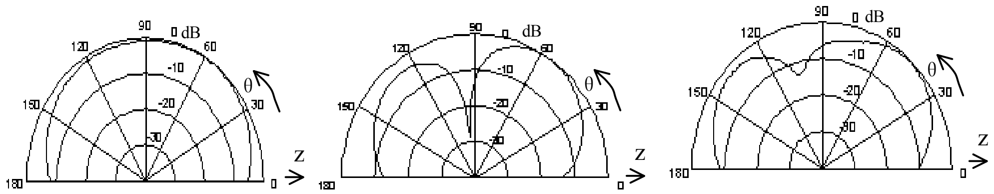
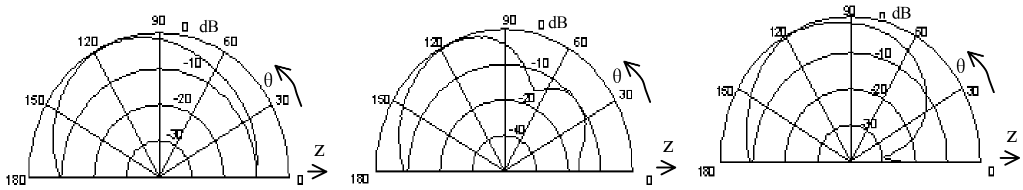


Figure 2. The encoding of the switch array state in GA.



(a) (b) (c)

Figure 3. The patterns in ϕ=0^0 half plane with the objective direction (θ=60^0, ϕ=0^0).
(a) f_1=10.0GHz; (b) f_2=15.0GHz; (c) f_3=20.0GHz



(a) (b) (c)

Figure 4. The patterns in ϕ=30^0 half plane with the objective direction (θ=120^0, ϕ=30^0).
(a) f_1=10.0GHz; (b) f_2=15.0GHz; (c) f_3=20.0GHz

f=10GHz	1011011111101100001001111111111110010010
f=15GHz	0000001110111011111000110011001001100001
f=20GHz	0011100001010100001011101111111100101100

Table I. The chromosome description of the switch array states corresponding to Fig. 3.

f=10GHz	0000110000000011111100110000000000111111
f=15GHz	0111011100011011000101110010100010001010
f=20GHz	1100101011101000110110100010000101001110

Table II. The chromosome description of the switch array states corresponding to Fig. 4.

with the fixed radiation directions. On the other hand, the antenna can reconfigure the radiation patterns with fixed operation frequencies. It can be predicted that the antenna can reconfigure the radiation patterns by optimizing the switch array states at every frequency within the frequency range from 10GHz to 20GHz and upwards.

According to the optimization results, we can found that it is difficult to obtain the narrower beam width and the deeper pattern null when the operation frequency is lower, but easy when the operation frequency is higher. According to the simulation and [9], it can be found that in order to obtain the good pattern reconfigurable characteristics, the antenna must operate with the higher modes. The detailed paper will be submitted to other journal in the future.

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