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Anisotropic ferrite microstrip antenna simulation and analysis

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ABSTRACT

This article takes research on the impedance and radiation properties of anisotropic magnetized ferrite microstrip antenna using SO-FDTD method. The author derives the iterative formula of three-dimensional magnetized anisotropic material and confirms it correct in a numerical method. The author also calculates and simulates the ferrite microstrip antenna and plots its return loss, input impedance and radiation pattern. The results show that many different properties are shown in the ferrite microstrip antenna compared with general antenna when the magnetic field is constant. By varying the placement of the antenna, different resonant frequency, under whose effect the radiation characteristics is affected by the magnetic field, can be attained.

1. Introduction

Recent years, it is more and more concentrated on the research of magnetized ferrite. The so called magnetized ferrite is a kind of dispersive dielectric material which shows anisotropy when there is outside magnetic field. The electric-magnetic properties of magnetized ferrite varies with the strength and direction of the outside filed. These properties make it widely applied in microwave integrated circuit and antenna designing. Research shows that by adjusting outside bias magnetic field, the variety of the resonant frequency of microstrip made by anisotropic ferrite base can get to 40% [1]. The radar target covered by anisotropic ferrite can reduce its radar cross section (RCS) in a further way and make it easier to stealth [2]. The research of anisotropic ferrite is widely concentrated. Because of the anisotropy, many research methods are difficult. Lee and his partner take spectral domain moment method to research the RCS of anisotropic ferrite [3]. Yang and her partner use recursive convolution finite-difference time-domain (RC-FDTD) and Z-transform finite-difference time-domain (Z-FDTD) to research the scattering properties [4,5]. In recent years, Pereda and other teams calculate the electromagnetic wave propagation in dispersive media using shift operator (SO) and other method [6–9], in 2003, Ge uses shift operator finite-difference time-domain (SO-FDTD) to calculate scattering of anisotropic magnetized plasma[10]. This article analyses ferrite microstrip antenna's impedance and radiation characteristics using SO-FDTD method [11–13,18,19].

2. Microstrip antenna simulation

The microstrip antenna is of low profile, small size and light weight; it is widely applied in integrated circuit and high-speed vehicle information receiving system [14]. FDTD is a strong tool in simulation method of microstrip antenna. Many wide band properties we can attain by simulating once and it is widely used to analyze the microwave circuit. Takes FDTD method and simulates the ordinary microstrip antenna in [14], the model is shown in Fig. 1. We can get the important parameters like return loss, impedance and radiation pattern. The parameter of simple microstrip antenna is: patch $l_x \times l_y = 36.6 \times 26\,\mathrm{mm}^2$ the depth of the medium $h = 1.58\,\mathrm{mm}$, relative dielectric constant $\varepsilon_r = 2.17$ the radius of the coaxial probe $r = 0.24\,\mathrm{mm}$, feed point location is on l_x, $d_s = 6.5\,\mathrm{mm}$. FDTD mesh's size $\Delta x = 1.83\,\mathrm{mm}$, $\Delta y = 1.625\,\mathrm{mm}$, $\Delta z = 0.79\,\mathrm{mm}$, time step $\Delta t = \Delta z/2c$, where c is the speed of light. Take 10 layers convolution perfectly matched layer (CPML) as absorb boundary [15–17]. Fig. 2 is the return loss curve of the antenna whose resonant frequency is 3.54 GHz. Figs. 3–5 are the input impedance and radiation pattern of the antenna. According to the properties of the resonant, the microstrip antenna is well matched in the resonant frequency places. According to the properties of the resonant, the microstrip antenna is well-directed while

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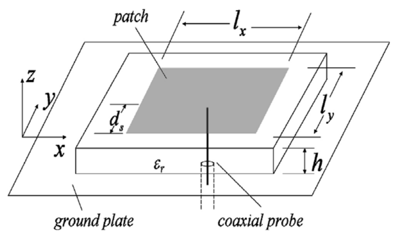

Fig. 1. The model of microstrip antenna.

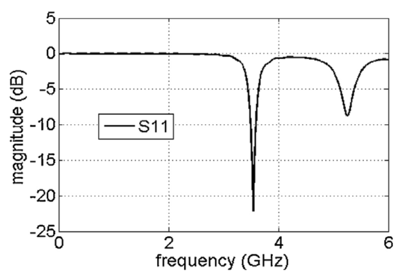

Fig. 2. Return loss of the microstrip antenna.

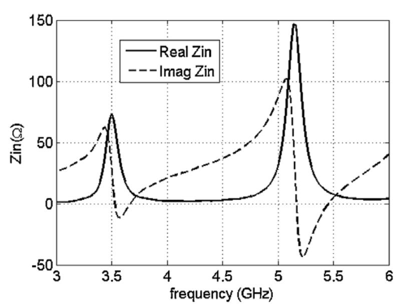

Fig. 3. Input impedance of the microstrip antenna.

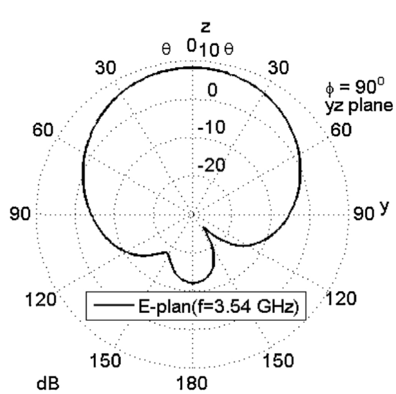

Fig. 4. E-plan direction patterns of the microstrip antenna.

the limited size of ground plate makes the antenna some kinds of backward radiation.

3. SO-FDTD method of magnetized anisotropic materials

Substitute the media board of the metal microstrip antenna into magnetized anisotropic ferrite material and it becomes anisotropic ferrite microstrip antenna. Because of the anisotropy of the anisotropic ferrite, we need to derive the formula of

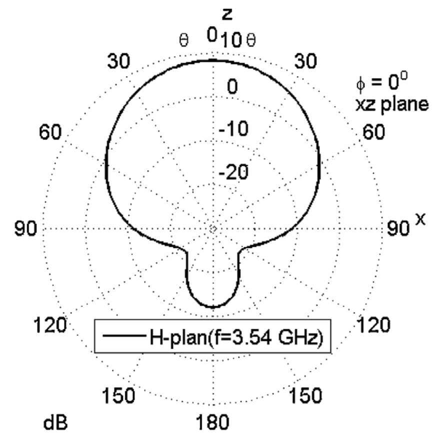

Fig. 5. H-plan direction patterns of the microstrip antenna.

electromagnetic field in the ferrite iterative. The Maxwell equations in the magnetized anisotropic medium are written as [11]:

$$\left.\begin{aligned} \varepsilon\frac{\partial \mathbf{E}}{\partial t} &= \nabla\times\mathbf{H} \\ \frac{\partial \mathbf{B}}{\partial t} &= -\nabla\times\mathbf{E} \\ \mathbf{B}(\omega) &= \mu_0\mu_r(\omega)\cdot\mathbf{H}(\omega) \end{aligned}\right\} \tag{1}$$

Suppose the outside magnetic field is according to z's positive direction, the relative permeability of magnetized anisotropic material can be written as the tensor form below.

$$\mu_r(\omega) = \begin{bmatrix} \mu_{xx} & \mu_{xy} & 0 \\ \mu_{yx} & \mu_{yy} & 0 \\ 0 & 0 & \mu_{zz} \end{bmatrix} = \begin{bmatrix} \mu_r & j\mu_{rg} & 0 \\ -j\mu_{rg} & \mu_r & 0 \\ 0 & 0 & \mu_{rz} \end{bmatrix} \tag{2}$$

$$\text{Where,}\quad \left.\begin{aligned} \mu_r &= 1+\left(\frac{T\omega_m}{T^2-\omega^2}\right) \\ \mu_{rg} &= \left(\frac{\omega\omega_m}{T^2-\omega^2}\right) \\ \mu_{rz} &= 1 \end{aligned}\right\},\quad T=\omega_0+j\omega\alpha \tag{3}$$

$\omega_0=\gamma H_0$ is precession angular frequency of electrons, γ is magnetogyric ratio, H_0 is the magnetic field strength outside. $\omega_m=\gamma 4\pi M_s$, M_s is saturation magnetization and α is damping factor.

Put the 3rd equation of Eq. (1) into scalar form

$$\begin{bmatrix} B_x(\omega) \\ B_y(\omega) \\ B_z(\omega) \end{bmatrix} = \mu_0\cdot\begin{bmatrix} \mu_{xx}H_x(\omega)+\mu_{xy}H_y(\omega) \\ \mu_{yx}H_x(\omega)+\mu_{yy}H_y(\omega) \\ H_z(\omega) \end{bmatrix} \tag{4}$$

From Eq. (4), we can see that H_z component of the magnetic field of ferromagnetic can be obtained by iterates while x, y components are mutual coupling and need to solve them in the same time. Next, we will introduce the solving method of H_x and H_y.