# MAGNETIZED CIRCULAR FERRITE MICROSTRIP ANTENNA

JIBENDU SEKHAR ROY, PATRICK VAUDON,
FRANÇOISE JECKO AND BERNARD JECKO

IRCOM, Faculté des Sciences, 123, Avenue Albert-Thomas,
Université de Limoges, 87060 LIMOGES Cédex, FRANCE

## ABSTRACT

Axially magnetized ferrite microstrip antennas can generate circularly polarized radiation pattern and can show the property of magnetic tuning. These properties drawing interest towards magnetically biased ferrite microstrip antenna (FMA), investigations on which are relatively undeveloped at this moment. The theoretical investigations on the circular ferrite microstrip antenna, biased axially by a steady magnetic field, are presented in this paper. The computed resonant frequency, gain and circularly polarized radiation pattern are verified, comparing those with the experimental results.

## INTRODUCTION

The microstrip antennas, fabricated on ferrite substrates and biased by steady magnetic field, are gaining increasing importance in antenna technology ; because this type of antennas can generate circularly polarized far fields using only a single feed and operating frequency of a single patch can be tuned by varying the bias magnetic field. Very few reports on magnetically biased FMA, can be found in literature [1 - 7], which confirm that using the controllable magnetic field, unattainable with other substrates, the beam scanning, antenna pattern, radar cross-section etc can also be controlled. Sufficient theoretical and experimental studies on magnetized FMA have not been reported.

In this article, theoretical and experimental investigations on a circular FMA, biased axially by a steady magnetic field, are reported. The ferrite medium is partially magnetized to generate good circular polarization. The simple cavity model is used for the analysis of the circular FMA. The resonance condition of circular FMA is obtained. The magnetic tuning can be understood from this resonance condition. The circularly polarized far fields are derived. The total radiated power and the dielectric, conductor and magnetic losses are calculated in order to obtain the gain of the circular FMA. The resonant frequency, gain and circularly polarized radiation pattern, computed theoretically, for a circular FMA, are verified experimentally.

## PERMEABILITY TENSOR

For a ferrite magnetized in the z-direction, the tensor permeability is given by :

$$(\mu) = \begin{pmatrix} \mu & -j\kappa & 0 \\ j\kappa & \mu & 0 \\ 0 & 0 & \mu_z \end{pmatrix} \mu_o$$

where, $\mu = \mu' - j\mu''$, $\kappa = \kappa' - j\kappa''$, $\mu_z = \mu_z' - j\mu_z''$ and, $\mu_o$ is the permeability of free space.

In this report, the FMA is partially magnetized by a steady axial (along z-direction) magnetic field and consequently, the complex components $\mu$, $\kappa$ and $\mu_z$ of the permeability tensor, described by Green and Sandy [8, 9], are adopted for the analysis.

## THEORY

The circular FMA geometry consists of a conducting, thin circular patch on a thin ferrite substrate backed by a ground plane. The ferrite is partially magnetized axially, as shown in figure 1. Considering the circular FMA as a cylindrical cavity, bounded at its top and bottom by perfect electric walls and on its side by a perfect magnetic wall, and assuming the fields inside the cavity are independent of z-direction, the time harmonic electric field in the cavity, for TM mode of propagation, can be written as :

$$E_z(\rho, \phi') = E_o F_n(\gamma\rho) \exp\{j(\omega t + n\phi')\} \tag{1}$$

where $(\rho, \phi', z)$ are the cylindrical co-ordinates, $E_o$ is a constant and :

$$F_n(\gamma\rho) = J_n(\gamma\rho) \quad \text{if} \quad \gamma^2 > 0$$
$$= I_n(\gamma\rho) \quad \text{if} \quad \gamma^2 < 0$$

$J_n$, $I_n$ are the Bessel function and modified Bessel function of order n. Positive and negative values of n give left and right circular polarizations respectively.

Here, $$\gamma^2 = \omega^2 \varepsilon_o \mu_o \varepsilon_f \mu_{eff}$$

where $\varepsilon_f$ is the relative permittivity of the ferrite substrate, $\varepsilon_o$ and $\mu_o$ are the free-space permittivity and permeability.

$\mu_{eff} = \dfrac{\mu^2 - \kappa^2}{\mu}$ is the effective permeability of the ferrite substrate. The magnetic field components inside the cavity are deduced from the electric field.

The resonance condition for circular FMA is obtained using the magnetic wall condition at $\rho = a$ (where "a" is the radius of the patch), and given by :

$$(\mu + \kappa) F_{n+1}(\gamma a) - (\mu - \kappa) F_{n-1}(\gamma a) = 0 \tag{2}$$

In magnetized ferrite the resonant frequencies are different for two opposite values of n and the difference between two frequencies depends on the bias strength and the material property. In eqn. (2), $\mu$, $\kappa$ and $\gamma$ are the functions of bias magnetic field. So by changing the bias strength, different resonance frequencies can be obtained for the same microstrip patch. The range of this frequency-tuning depends on the bias strength and on the material of the ferrite used.

The circularly polarized far fields in $(r, \theta, \phi)$ co-ordinates are obtained as,

$$E_\theta = j^n \frac{V_o a \kappa_o}{2} \frac{e^{-j\kappa_o r}}{r} e^{j\omega t} e^{jn\phi} \left[J_{n+1}(\kappa_o a \sin\theta) - J_{n-1}(\kappa_o a \sin\theta)\right] \tag{3}$$

$$E_\phi = j^n \frac{V_o a \kappa_o}{2} \frac{e^{-j\kappa_o r}}{r} e^{j\omega t} e^{j(n\phi - \pi/2)} \cos\theta \left[J_{n+1}(\kappa_o a \sin\theta) + J_{n-1}(\kappa_o a \sin\theta)\right] \tag{4}$$

where $\kappa_o$ is the free-space propagation vector, h is the thickness of the ferrite substrate and $V_o = h E_o F_n(\gamma a)$ is the edge voltage at $\phi' = 0$. The far field components depend on the bias strength. The gain of the circular FMA is calculated.

## EXPERIMENTAL RESULTS

In order to verify the theoretical results, a circular FMA with design specifications $a = 6.5$ mm, $h = 3.0$ mm, $\varepsilon_f = 14.3$, was designed and the resonant frequency, gain and circular polarization was measured by a Wiltron 360 network analyser exciting the antenna by a co-axial probe. Good agreement between theoretical and experimental results is achieved. Experimentally, ellipticity of circular polarization lower than -3 dB is obtained for $-40° < \theta < 40°$ whereas theoretically it is obtained for $-50° < \theta < 50°$ ; because the coupling between two opposite circular polarizations are not taken into account in the theory. The circular polarizations obtained theoretically and experimentally are shown in figures 2 and 3 respectively. The experimental details will be presented.

## CONCLUSION

The theoretical and experimental studies on circular ferrite microstrip antenna are reported in this communication. More results on circular FMA will be presented. The advantage of circular polarization and magnetic tuning of magnetized FMA can be used in application in near future. The theoretical and experimental results can not be compared very accurately because in the measurement, the internal field of the ferrite was not obtained accurately .

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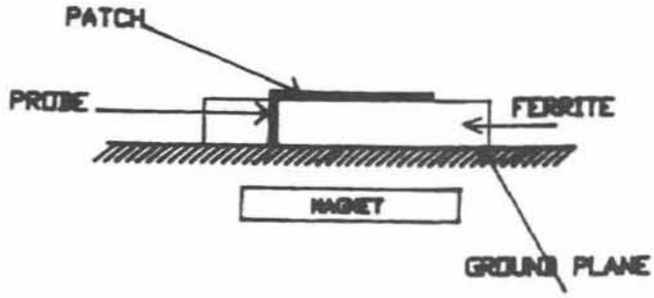


Fig. 1 Circular FMA configuration

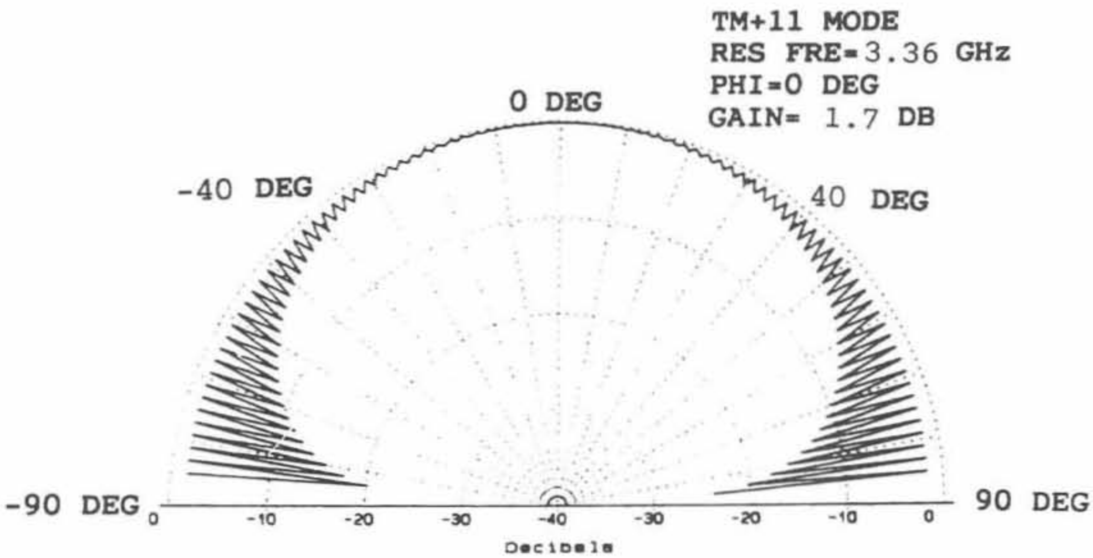


Fig. 2 Circular polarization (Theoretical)

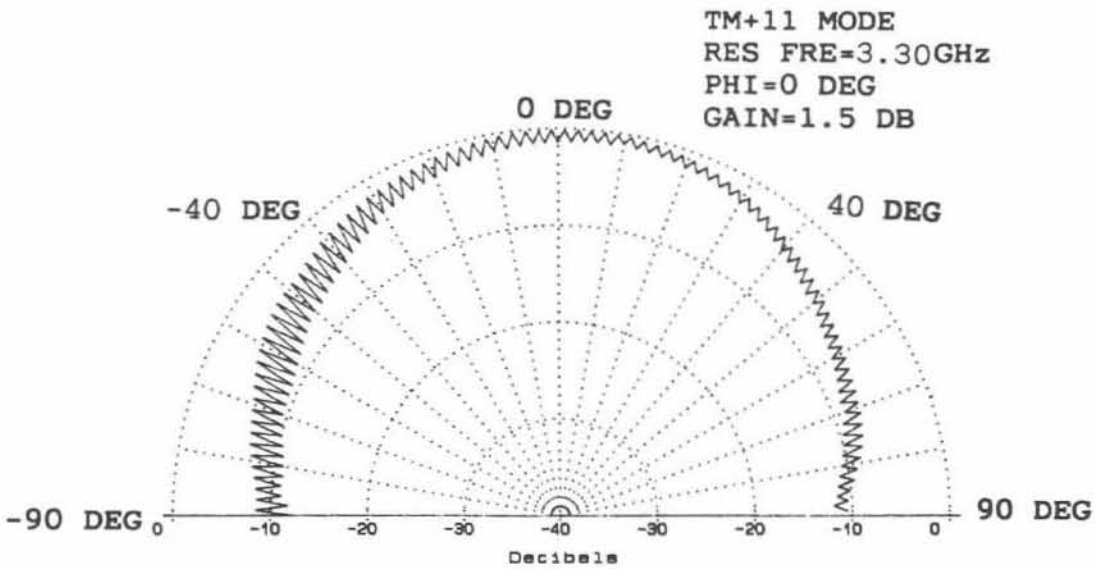


Fig. 3 Circular polarization (Experimental)