MICROSTRIP SCANNED ARRAY ANTENNA ON YIG FERRITE SUBSTRATE

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Abstract:

The beam scanning properties of a 4×4 element planar array of circular patch microstrip antenna printed on a YIG ferrite substrate with a normal bias field are presented. Two hands of circular polarisation are generated when the magnetic bias is applied. The calculated values of antenna parameters of array geometry as radiation conductance, directive gain and efficiency are presented for both the modes of circular polarisation.

1. Introduction:

Ferrite substrates have been the subject of much interest for microstrip antennas recently. The reason for using ferrite materials in microstrip structures is that the applied magnetic field changes the permeability and thus, the electrical properties of the material, which in turn changes the antenna properties. Beam steering, gain and band width enhancement, RCS control, surface wave reduction, switchable and electronic tunability are some of the unique and inherent features of ferrite based microstrip antennas and array, which have been discussed by number of investigators in recent years [1-5].

On applying a DC magnetic bias normal to the ferrite substrate the resonance splits into two separate frequency modes one right hand, the other left-hand circular polarisation. The explicit dependence of the propagation constant of the two modes is given as [6].

$$\frac{K_\pm}{K_d} = \left(\frac{\omega_0 + \omega_m \mp \omega}{\omega_0 \mp \omega}\right)^{1/2} \qquad \text{....(1)}$$

$$K_d = \frac{2\pi f}{C}\sqrt{\epsilon_r} \qquad \text{....(2)}$$

where K_+ and K_- are the propagation constants for right handed and left handed circularly polarised mode (RHCP & LHCP) respectively.

Here $\omega_0 = \gamma H_0$ & $\omega_m = \gamma\, 4\pi M_s$

H_0 is the bias field, $4\pi M_s$ is the saturation magnetization, γ is the gyromagnetic ratio as $\gamma = 2.8$ MHz/Oe.

In the present paper concept of beam steering has been explained by taking two values of biasing field with 4×4 element circular array geometry printed and designed on YIG ferrite substrate at 3GHz in S band of microwave frequency range.

2. Theory:

The array geometry and its co-ordinate system is shown in figure-1. It consists 16 identical elements of radius 'a' printed on YIG ferrite substrate of thickness 1.27mm. and substrate permittivity ϵ_r=15, tanδ=0.0002 4πMs=1720 Gauss, H_0=1500 Oe & H_0=2000 Oe. Each patch can be excited by a microstrip line connected to the edge or by a co-axial line from the back at the plane of ϕ=o. Bias field is taken normal to the plane of substrate.

The expressions for total radiated fields for the array geometry are obtained using pattern multiplication approach [7-8].

3. Field Patterns:

The value of R(θ, ϕ) are computed for a case taking source frequency f=3GHz, ε_r=15 h=0.127 cm. element separation $d_x=d_y=\lambda_0/2$=5 cm, progressive phase excitation difference $\beta_x=\beta_y=\pi/2$ for two values of biasing field i.e. 1500 Oe & 2000 Oe. The results are calculated and plotted for both RHCP & LHCP mode in two different planes i.e. E-plane and H-plane. which are shown in fig. 2, 3, 4 & 5.

It is observed from these plots that there is a steering of beams in pattern on application of biasing fields. We have computed different pattern characteristics of array geometry for two values of biasing fields for RHCP & LHCP modes and are given in table-1.

4. Antenna Parameters:

The important antenna parameter namely radiation conductance, directive gain and efficiency have been computed for the array geometry for RHCP & LHCP modes considering two values of biasing field i.e. H_0 = 1500 Oe & H_0 =2000 Oe and are presented in table-2. It is observed from the table that there is a change in the values of antenna parameters on changing the biasing field.

5. Conclusion:

The principle of beam steering of a 4×4 element planar array of CPMA on a biased ferrite has been demonstrated. Some salient features of this array geometry are summarized as follows:

1. On application of biasing field H_0=1500 Oe the position of maximum radiations in RHCP & LHCP modes are found at 10° and 45° respectively. While at H_0=2000 Oe these positions of maximum radiations changed to 15° and 20°. Thus by proper selection of a biasing field, a scanned antenna can be designed.

2. At H_0=1500 Oe the values of directive gain of the array geometry in RHCP & LHCP modes are 12.0dB and 9.0dB respectively. These values changed to 12.5dB and 9.5dB where applied biasing field is 2000 Oe.

3. The radiation efficiency (η) of the array geometry is found to be 79.9% and 71.0% in RHCP & LHCP mode at H_0=1500 Oe. In another case when biasing field, H_0=2000 Oe, the efficiency is recorded 65% for RHCP mode & 75.6% for LHCP mode. Obviously the radiation efficiency is significantly affected on application of biasing field.

4. The high permittivity of the substrate reduces the dimensions of the patches. This reduction would certainly have wide utility to create miniaturization of antenna system, which has potential application in space and cellular communication.

The overall results show that the array geometry can be used to obtain scanned and compact antennas which are applicable in radar for search and track operations and space communication.

References:

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Table-1: PATTERN CHARACTERISTICS OF ARRAY GEOMETRY.

Pattern characteristics	H_0=1500 Oe				H_0=2000 Oe			
	E-plane		H-plane		E-plane		H-plane	
	RHCP Mode	LHCP Mode	RHCP Mode	LHCP Mode	RHCP Mode	LHCP Mode	RHCP Mode	LHCP Mode
1. Direction of Max. radiation (major lobe)	10°	45°	10°	45°	15°	20°	15°	20°
2. Half power beam width (HPBW)	5°	6°	5°	8°	8°	7°	8°	6°
3. Direction of Max. radiation (minor lobe)	30°	16°	30°	16°	36°	50°	36°	46°
4. Half power beam width (HPBW)	8°	12°	11°	10°	9°	14°	9°	14°
5. Side lobe level (SLL) dB	-15	-9	-15	-5	-5	-9	-4	-7

Table-2: COMPUTED VALUES OF ANTENNA PARAMETERS.

Antenna parameters	H_0=1500 Oe		H_0=2000 Oe	
	RHCP Mode	LHCP Mode	RHCP Mode	LHCP Mode
1. Radiation conductance (G)	6.489×10^{-4} ohm^{-1}	4.672×10^{-4} ohm^{-1}	3.42×10^{-4} ohm^{-1}	7.764×10^{-4} ohm^{-1}
2. Directive gain (Dg)	12.0 dB	9.0 dB	12.5dB	9.5 dB
3. Efficiency (η)	79.9%	71.0%	65.0%	75.6%

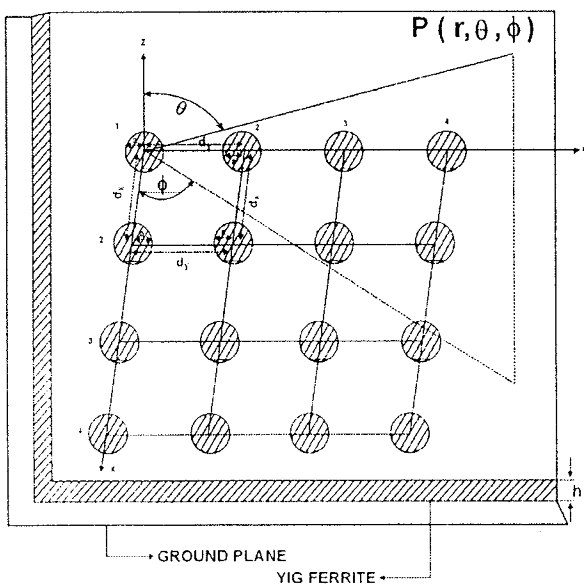

Fig. 1: Array geometry and co-ordinate system of 4×4 element planar array of circular patch microstrip antenna on YIG ferrite substrate.

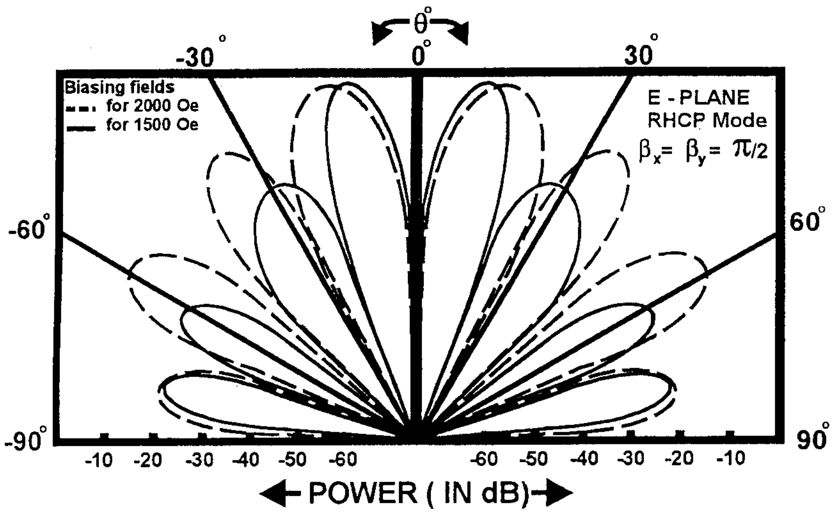

Fig. 2 : E-Plane radiation pattern of 4x4 CPMA on YIG ferrite for RHCP mode for two biasing fields.

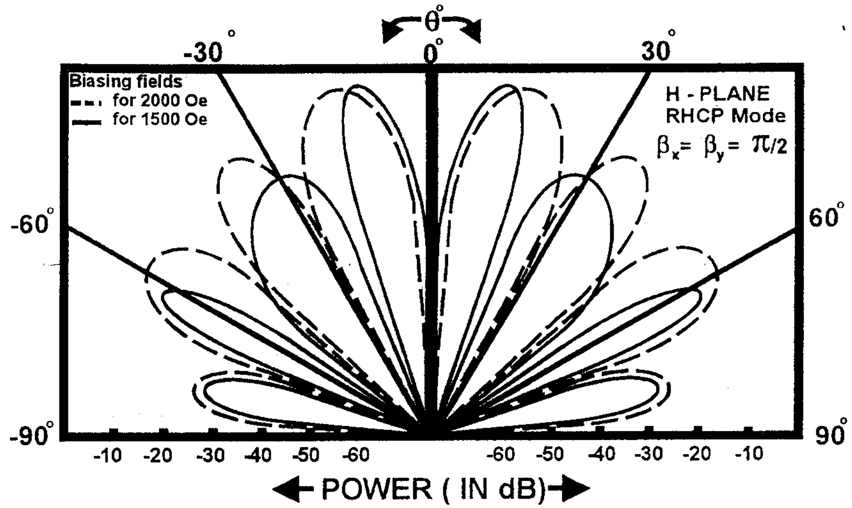

Fig. 3 : H-Plane radiation pattern of 4x4 CPMA on YIG ferrite for RHCP mode for two biasing fields.

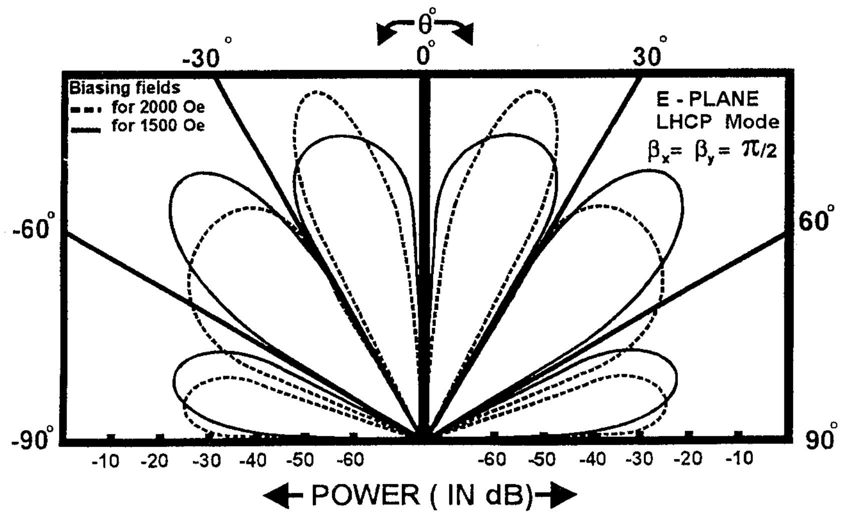

Fig. 4. :E-Plane radiation pattern of 4x4 CPMA on YIG ferrite for LHCP mode for two biasing fields.

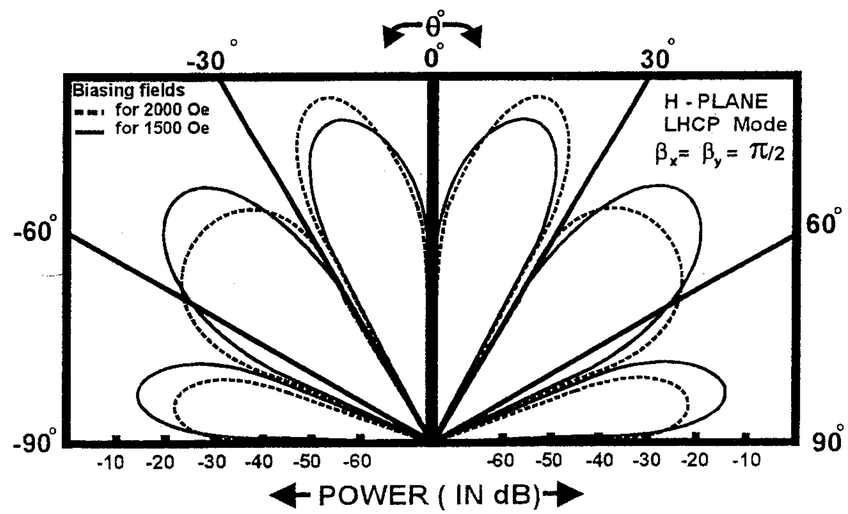

Fig. 5 : H-Plane radiation pattern of 4x4 CPMA on YIG ferrite for LHCP mode for two biasing fields.