DIFFERENT FERRITE MATERIAL USED AS SUBSTRATE IN MICROSTRIP PATCH ANTENNA

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Abstract

it is shown how the radiation characteristic of a patch antenna can be manipulated by a small number of normally magnetized ferrite disks inserted in the resonant region of the patch. It is shown that a one- and dual-band circular polarized microstrip antenna can be obtained by taking advantage of the interaction of the antenna cavity field with the magnetized ferrite disks. . The dependence of the axial ratio and the return loss of the antenna on the position and the number of ferrite disks underneath the patch are analyzed. We discuss patch antenna miniaturization using magneto dielectric substrates. Recent results found in the literature reveal that with passive substrates advantages over conventional dielectric substrates can only be achieved if natural magnetic inclusions are embedded into the substrate. Patch antennas on ferrite substrates allow for pattern control, frequency shifting, and scattering reduction. This is achieved by external magnetic field biasing coupled with the inherent magnetization of the ferrite substrate. Measurements of rectangular microstrip patch antennas on a ferrite LTCC substrate display a maximum tuning range of 610 MHz near 12 GHz.

Keywords*— Ferrite Material , Microstrip Antenna, CBS Antenna.*

1 INTRODUCTION

MICROSTRIP patch antennas have found extensive application in wireless communication systems due to their low profile, low cost, and relatively simple fabrication. antenna miniaturization is extremely important for modern wireless communication systems. with the rapid growth of wireless markets [mobile communication, wireless local area network (WLAN) networking, global positioning system (GPS) services, and radio-frequency identification (RFID) applications], radio-frequency (RF) engineers are facing continuing challenges of small-volume, wide-bandwidth, power efficient, and low-cost system designs. a low-profile, small-size antenna integrated into rf front ends with sufficient bandwidth is essential in wireless systems. their novel electromagnetic characteristics have found useful applications in antennas and microwave circuits. ebg printed circuit structures are thin composite dielectric layers with periodic metallic patterns (usually backed by a metal ground plane), and have one or multiple frequency bandgaps in which no substrate mode can exist.

There is an increasing interest in studying the performance of microstrip antennas and microstrip circuits fabricated on magnetized ferrite substrates. in the case of microstrip antennas on ferrite substrates, these antennas present certain useful properties which are not found in conventional microstrip antennas fabricated on dielectrics. also, antennas printed on normally biased ferrites have been found to radiate circular polarization with one single feed [5], and the state of polarization has been found to be switchable between left-hand circular polarization (lhcp) and right-hand circular polarization (RHCP) as the direction of the bias magnetic field is reversed.

Finally, several researchers have reported that the radar cross section of microstrip antennas fabricated on magnetized ferrites can be substantially reduced over a frequency range which can be tuned by means of the bias magnetic field (this is the frequency range where magnetostatic wave propagation is allowed along the ferrite substrates supporting the antennas) [14], [15] unbiased ferrite substrates and self-magnetized thin films have been investigated as a means of reducing the size of antennas owing to the high permittivity of the ferrite medium [6]–[8]. pattern and polarization control of ferrite-based antennas have also been successfully achieved [16]–[18]. in [19], patch antennas on non-uniformly biased ferromagnetic substrates have been analyzed. recently, a switchable ferrite microstrip antenna has been presented [20]. ferrite-based antennas typically use a variable magnetostatic bias to achieve tunability and re configurability. for such antennas, the resonance frequency variation is dependent on the bias direction and strength. usually, ferrite materials at microwave frequencies are used in the saturated state.

1.1 THEORETICAL BACKGROUND AND MICROSTRIP PATCH ANTENNA DESIGN PROCEDURE

In the proposed measurement technique, a rectangular microstrip patch radiator utilizing the given fabric material as its substrate is to be designed assuming an approximate value of dielectric constant. The value of the dielectric constant of this fabric substratematerial may be computed by simply measuring the resonant frequency of the patch radiator. The design of the microstrip patch radiator involves the computation of its patch dimensions. The patch width (*W*) has a minor effect on the resonant frequency (*fr*), and it is calculated using the following formula [8]:

$$W = \frac{c}{(2fr)}\sqrt{\frac{2}{(\varepsilon r+1)}} \ldots\ldots\ldots\ldots\ldots(1)$$

where c is the speed of light in free space and εr is the relative permittivity of the fabric material under test. The microstrip patch lies between air and the dielectric material, and thus, the EM wave sees an effective permittivity (εreff) given by [8]:

$$\varepsilon reff = \left[\frac{(\varepsilon r+1)}{2}\right] + \left[\frac{(\varepsilon r-1)}{2}\right]\left[1 + 12hW-12 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(2)\right.$$

The patch length (*L*) determines the resonant frequency and is a critical parameter in design because of the inherent narrow bandwidth of the patch. The design value for *L* is given by [8]:

$$L = \left[\frac{c}{(2fr\sqrt{\varepsilon reff})}\right] - 2\Delta L \ldots\ldots\ldots(3)$$

where εreff is the effective permittivity of the material under test. The additional line length on ΔL both ends of the patch length, due to the effect of fringing fields, is given by [8]:

$$\frac{\Delta L}{h} = 0.412\left[\frac{(\varepsilon reff+0.3)}{(\varepsilon reff-0.258)}\right] \ldots\ldots\ldots(4)$$

The effective patch length *Le* is written as:

$$Le = L + 2\Delta L \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Hence, the knowledge of the actual (measured) resonant frequency paves way for extracting the value of εr of the fabric material.

1.2 CBS ANTENNA WITH NON UNIFORM BAISED FERRITE MATERIAL

Fig -1 CBS slot antenna with non uniform baised ferrite material[2]

Cavity Backed slot (CBS) antennas belong to the family of aperture antennas. Such antennas usually consist of a metallic enclosure (cavity), part of which is opento allow radiation of the electromagnetic waves. Examples of aperture antennas are slots, open waveguides and horns [3]. The applied field is produced by the sources such as permanent magnet and/or electromagnet. The demagnetizing field is due to the magnetization of the ferrite material, and is usually in the opposite direction to the applied field. Theinternal field is the actual magnetic field inside the ferrite material which, in general, depends on the other two fields Depending on the mathematical model for the internal magnetic field, the applied and demagnetizing fields may have to be determined explicitly. At this point it is important to make a distinction between three magnetic fields which will be mentioned in the paper:[4]

- Applied (external) magnetic field;
- Demagnetizing magnetic field;
- Internal (biasing) magnetic field.

The cavity is loaded with one layer (1.27 cm thick) of ferrite material. Two different ferrites are used in the simulations and measurements:

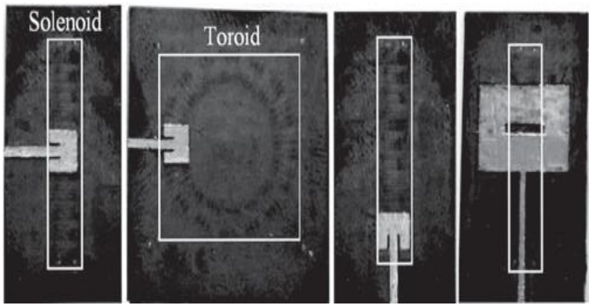
- G-475 (aluminum doped)
- G-1006 (gadolinium-aluminum doped).

Table-1 Material Specification[2]

Ferrite	Parameters
G-475	$\epsilon_r = 13.4$, $M_s = 39.79$ kA/m, $\Delta H = 3.581$ kA/
G-1006	$\epsilon_r = 13.5$, $M_s = 31.83$ kA/m, $\Delta H = 6.207$ kA/

Ferrite Material With Their Specification[2]

1.3 FERRITE LOW TEMPERATURE CO-FIRED CERAMIC(LTCC) TUNABLE ANTENNA:



(a) (b) (c) (d)

Fig.2 Fabricated antennas on ESL 40012 ferrite LTCC, where the white boxes show the locations of the embedded windings. (a) Transverse small patch on solenoid. (b) Transverse small patch on toroid. (c) Longitudinal small patch on solenoid. (d) Longitudinal large slotted patch on solenoid.[3]

Different antenna designs and orientations have been investigated, as shown in Fig. 2. Microstrip-fed patch antennas operating at their first resonance have been placed transversally over both the solenoid [Fig. 2(a)] and toroid [Fig. 2(b)] windings. An identical patch has also been placed longitudinally over the solenoid [Fig. 2(c)]. In order to investigate the performance of a larger-sized antenna that can completely cover the solenoid winding beneath it, a second patch design operating in its 3rd resonance at 12 GHz is shown in Fig. 2(d), where the slot in the center of the patch is used to increase its electrical length such that the patch fits it in the available substrate space.

Ferrite-based antennas typically use a variable magnetostatic bias to achieve tunability and re-configurability [21], [22]. For such antennas, the resonance frequency variation is dependent on the bias direction and strength [23]. Previous characterization efforts have revealed that an internal *H*0-field of over 2500 A/m is required to fully saturate ESL 40012 ferrite LTCC to its magnetization value of $\mu 0Ms$ = 400 MT. Unbiased ferrite substrates and self-magnetized thin films have been investigated as a means of reducing the size of antennas owing to the high permittivity of the ferrite medium [6]–[8]. Pattern and polarization control of ferrite-based antennas have also been successfully achieved [16]–[18]. In [19], patch antennas on no uniformly biased ferromagnetic substrates have been analyzed. Recently, a switchable ferrite microstrip antenna array has been presented [20].

1.3 PATCH ANTENNA WITH EMBEDDED FERRITE DISKS

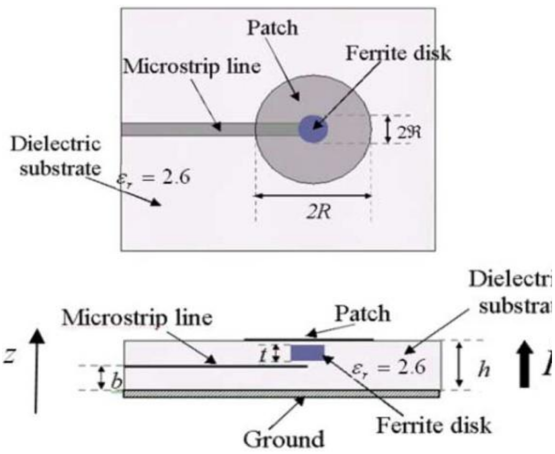


Fig-A[1]

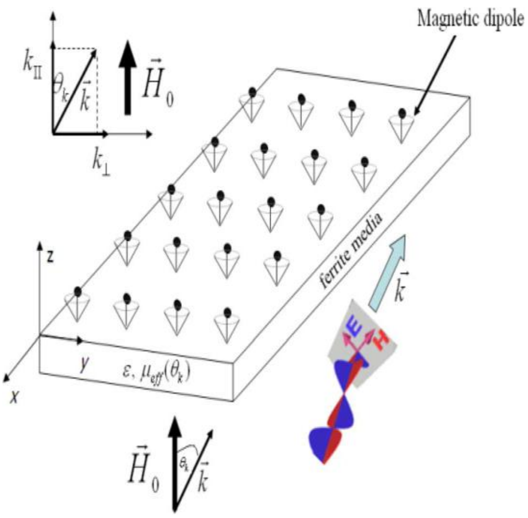


Fig-B[1]

Fig. 3(A) Circular Patch Antenna With Ferrite Disk In The Substrate Region.(B) Ferrite Material Illuminated By An Electromagnetic Wave.[1]

The low-loss dielectric properties of ferrite materials allow the electromagnetic (EM) waves to penetrate into the ferrite and results in an effective interaction between the electromagnetic waves and the ferrite magnetization. In this work, it is proposed to use small particles of ferrite materials embedded into the cavity region of the patch antenna, instead of use of full ferrite substrate, to manipulate its radiation characteristics. In this part, the proposed structure of the patch antenna with an embedded ferrite disk in the cavity region is considered. Fig. 3 shows the proposed antenna configuration with one ferrite disk, which consists of a circular patch with radius 17 mm, printed on a substrate with dielectric constant 2.6, substrate thickness 3.048 mm and is fed by a dielectric loaded microstrip line with substrate thickness 1.524 mm through EM coupling.

Here, Ms is the saturation magnetization of a ferrite material and ΔH is the linewidth near the ferromagnetic resonance. The dimensions of the ferrite disk were selected to avoid the propagation of the magnetic-dipolar modes in its volume and neglect the variation (no homogeneity) of the internal bias magnetic field along the thickness of the disk. Accordingly, a ratio of 1:8 between the ferrite's disk thickness to its diameter was chosen. The ferrite disk is magnetized by an external dc magnetic field $H0$ =2827 Oe in the Z-direction.

2 THREE DIFFERENT TYPE OF FERRITE MATERIAL WITH DIFFERENT RADIATION CHARACTERISTICS

2.1 Three Different Type Of Ferrite Material with different radiation characteristics:

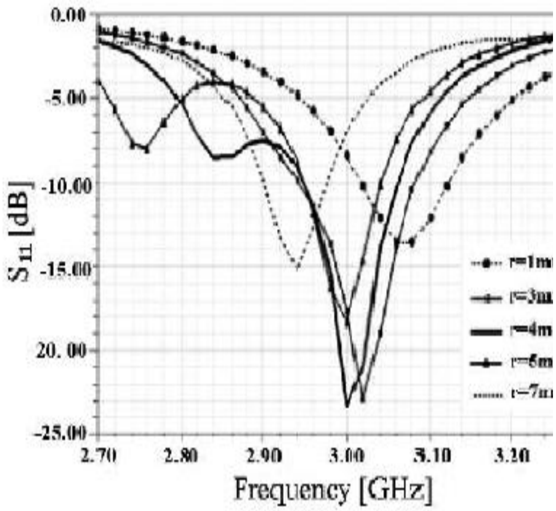


Fig -4: Yttriumiron Garnet (YIG) Ferrite Used In Microstrip Patch Antenna With 3 Ghz Frequency[1]

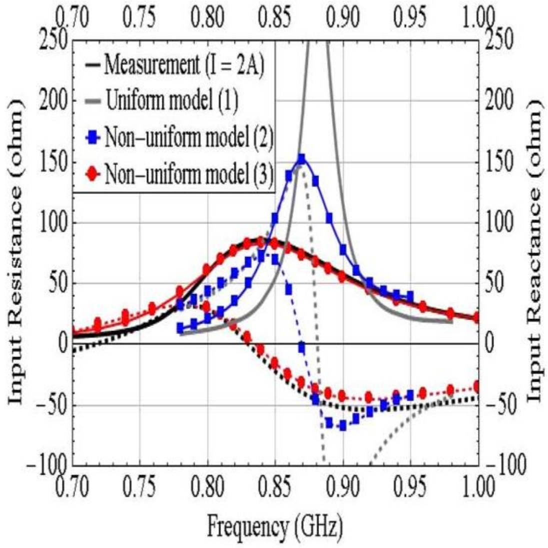


Fig-5: Input Impedance Of The CBS Antenna Loaded With Ferrite Material G-475[3]

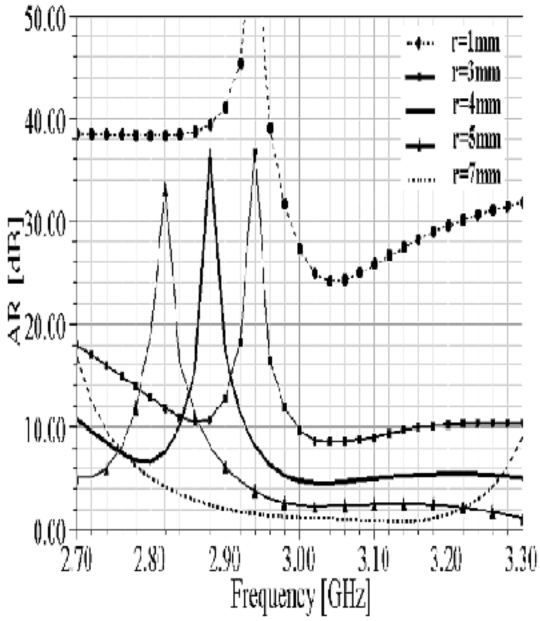


Fig-6: Axial ratio at 3 GHz frequency with LTCC ferrite material [4]

3 CONCLUSION

A new method to manipulate the radiation characteristics of the patch antenna by small normally magnetized ferrite disks inserted in the dielectric region under the patch is proposed. The antenna considered here is loaded with the ferrite material subjected to a severely non-uniform applied magnetic field. Placing the bias windings below the ground plane instead of between the antenna and the ground plane will be beneficial.from this survay we can use ferrite material for improving radiation characteristic upto 12 GHZ.

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