ANTENNA MINIATURIZATION USING EPOXY-FERRITE NANOCOMPOSITE MATERIAL*

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Abstract: *This paper reports experimental characterization of aperture coupled microstrip patch antenna (ACMSA) for size reduction (miniaturization), increased bandwidth and improved return loss at Microwave C-band frequency using epoxy-ferrite nanocomposite (Magneto-Dielectric) material. Development of miniaturized antenna is validated by loading epoxy-ferrite nanocomposite magneto-dielectric material in an aperture coupled microstrip patch antenna, which results in lower frequency shift with increased bandwidth and improvements in return loss, thus demonstrating miniaturization capability.*

Keywords: *Antenna Miniaturization, Epoxy-ferrite Nanocomposite, Magneto-dielectric, Aperture Coupled MSA*

1. INTRODUCTION

Antenna is a device designed for radiating or receiving radio waves [1]. The Microstrip antennas also referred to as microstrip patch antennas (MSA) have several advantages like small size, light weight, low cost, low volume and easy to fabricate using printed circuit technology over conventional microwave antennas and therefore are widely used in many practical applications like aircraft, spacecraft, satellite, missile, mobile, GPS, RFID, WiMax and Radar etc. The radiating elements and the feed lines are usually photo etched on the dielectric substrate. The radiating patch may be square, rectangular, thin strip, circular, elliptical, triangular or any other configuration as illustrated in figure 1. A feedline is used to excite MSA to radiate by direct or indirect contact. There are many configurations that can be used to feed microstrip antennas. There are many different techniques of feeding and the four most popular are the microstrip line, coaxial probe, aperture coupling and proximity coupling. However, MSAs suffer from disadvantages like low radiation efficiency, low gain, high Q, narrow impedance bandwidth etc. Moreover, now a day's smaller physical size (miniaturized), wide bandwidth, and higher efficiency are desired characteristics of antenna for wireless systems.

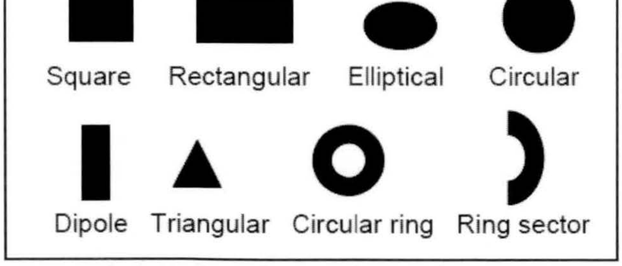

Fig 1. Various Shapes of MSA Elements

Antenna miniaturization using high permittivity materials as substrates have been attempted in the past [2]. The use of high dielectric material with $\mu_r = 1$ are frequently used as a substrate to miniaturize the antenna and is often restricted to antennas operating at a single narrow band (e.g. Bluetooth and GPS). Such high permittivity non magnetodielectric material increases the Q-factor, which reduces available bandwidth of the antenna. To avoid the bandwidth limitation, magneto-dielectrics having not only relative permittivity, but also permeability have been concerned as an antenna substrate. An experimental study of thick films formed by ferrite-epoxy and Co-Silica-BCB nanocomposite pastes characterized to assess their suitability for inductor and antenna applications carried out in [3]. These experimental results show that nanocomposites with high permittivity and permeability (ε_r , $\mu_r > 1$) making it a good candidature for miniaturized antennas.

2. BACKGROUND

Many literatures have shown that combination of epoxy-ferrite nanocomposite material provide increased permeability (magnetic property) > 1 in addition to permittivity [3]. This property makes epoxyferrite nanocomposite material as Magneto-Dielectric material (MD). Magneto-dielectrics provide a unique opportunity for achieving $\mu_r > 1$. With magneto-dielectric loading the resonant wavelength reduced by

$$\lambda = \frac{\lambda_o}{\sqrt{\varepsilon_r \mu_r}} \quad (1)$$

Where λ_o is the free space wavelength. In Eq. (1), $n = \sqrt{\varepsilon_r \mu_r}$ is called miniaturization factor. The higher the value of this factor, the smaller the size (miniaturize) of antenna. As it can be seen in the denominator, the antenna miniaturization is achieved by controlling both ε_r and μ_r. This gives antenna miniaturization i.e. lower shifting of resonant frequency [4]. This paper demonstrates the miniaturization capability of epoxy-ferrite nanocomposite material in addition to enhancement of return loss and improved bandwidth. For antenna miniaturization, aperture coupled microstrip antenna (ACMSA) is preferred and selected as it offers greater design flexibility.

3. ANTENNA DESIGN

The base antenna, ACMSA is designed, fabricated and tested at 8 GHz using FR4 substrate with a thickness of 1.6 mm, dielectric constant of 4.4, and material loss of 0.0245 [5]. In aperture coupled microstrip antennas, the field is coupled from the microstrip line feed to the radiating patch through an electrically small aperture or slot cut in the ground plane. The coupling aperture is usually centered under the patch, providing low cross-polarization due to the symmetry. The shape, size, and location of the aperture decide the amount of coupling from the fed line to the patch. The antenna design was undertaken through simulations using the IE3D software version 14.65. Figure 2(a) shows the arrangement of the ACMSA.

4. PREPARATION OF EPOXY-FERRITE NANOCOMPOSITE MATERIAL

Epoxy-ferrite nanocomposite thick film was prepared by mixing 50 vol% of zinc-ferrite nano powder and 50 vol% of epoxy resin with continuous hand stirring. A small quantity of hardener in the ratio 1/10 of epoxy resin was added to harden

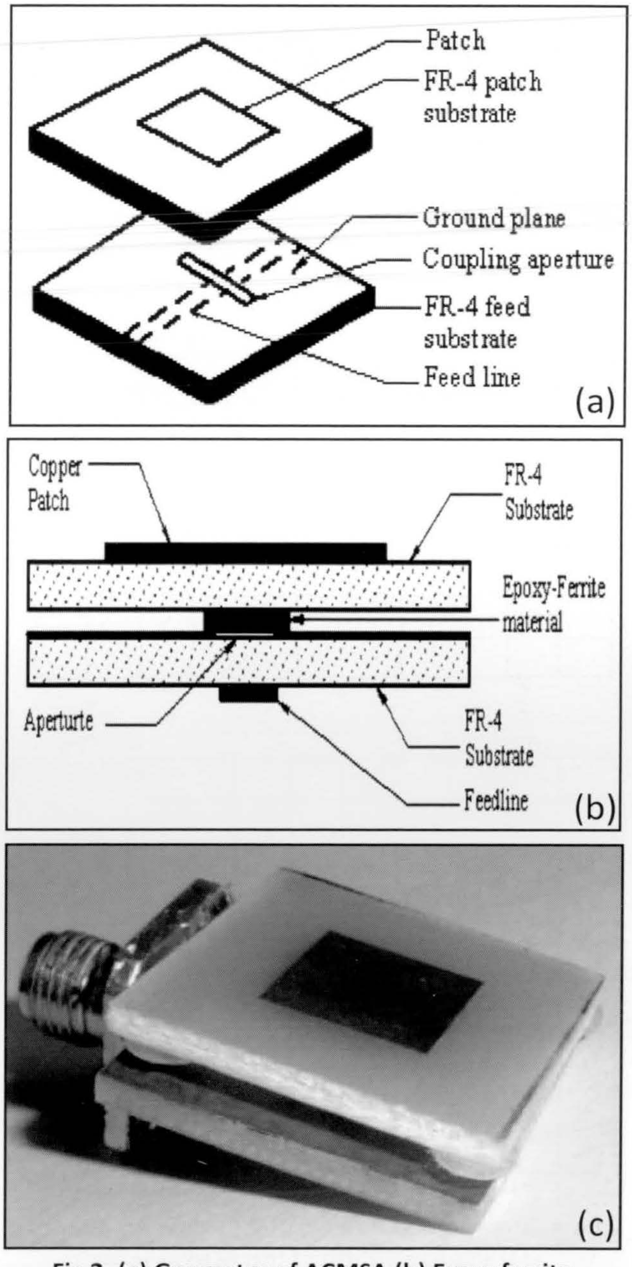

Fig 2. (a) Geometry of ACMSA (b) Epoxyferrite Loading Illustration (c) Fabricated Rectangular ACMSA

the epoxy-ferrite mixture so as to obtain solid composites [6]. The mixture is then transferred to a metal mold. The mold is then left for curing inside an oven at 140 °C for 50-60 minutes. A sample of 10 mm (w) x 1 mm (l) x 1.2 mm (h) thick film, see figure 3, is prepared and then placed above the slot of the feeding structure of the fabricated ACMSA [7], is as shown in figure 2(b) and 2(c).

5. RESULTS AND DISCUSSION

The antenna without and with epoxy-ferrite film condition was then measured for the

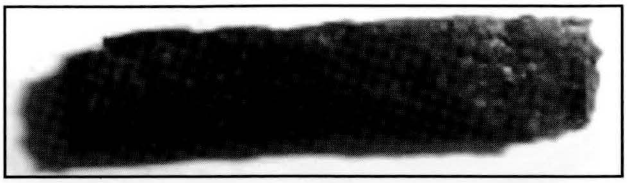

Fig 3. Synthesized Epoxy-Ferrite Composite Film

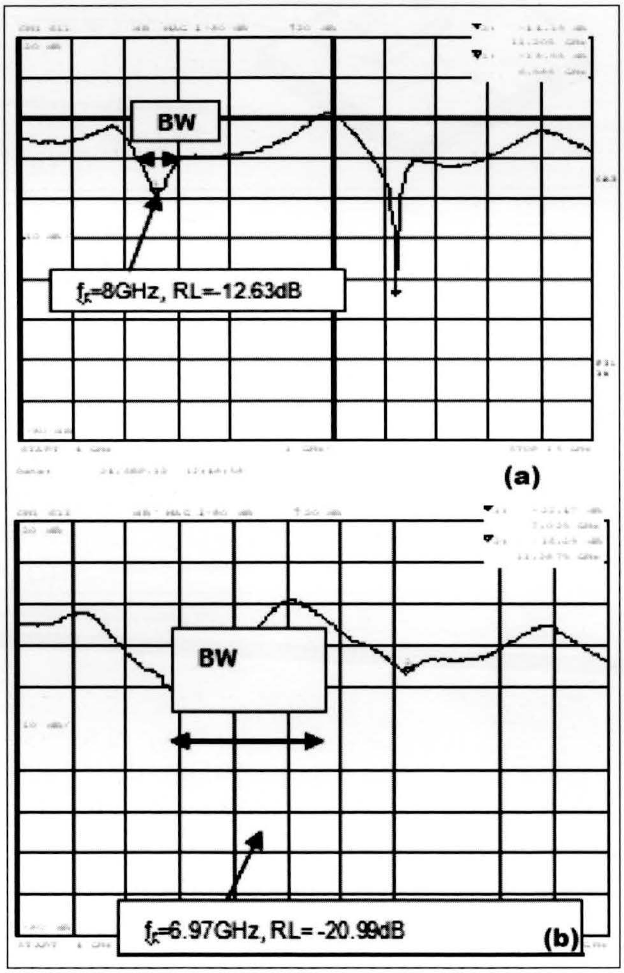

Fig 4. Measured Return Loss (RL) Versus Frequency (f_r), and Bandwidth of the ACMSA using Network Analyzer. (a) Without Material (b) With Epoxy-Ferrite Nanocomposite Material Loaded

resonant frequency, return loss characteristics, and bandwidth using vector network analyzer (Rohde and Schwarz, German make ZVK model 1127.8651). The measured parameters of the antenna are listed in Table 1. The measured results show that the epoxy-ferrite material increases the effective permittivity and permeability of the combinations and hence shifts down the resonant frequency from 8GHz to 6.97GHz resulting in a 16 percent reduction in patch size. The increase in the return loss characteristics from -12.6dB to -20dB, and bandwidth improvement from 0.9GHz to 1.87GHz could also be noted because of epoxy-ferrite nanocomposite.

Table 1: The Measured Parameters of the ACMPA

Sl. No	Parameter of antenna	Without material	With magneto-dielectric material
1	Resonance Frequency (GHz)	*8*	6.97
2	Reflection coefficient (-dB)	*12.6*	20.99
3	Bandwidth (GHz)	*0.9*	1.87
4	Patch size Reduction in %	-	16

6. CONCLUSION

In this paper, aperture coupled microstrip patch antenna loaded with epoxy zinc ferrite nanocomposite magneto-dielectric material is studied. This experiment validates epoxy-ferrite nanocomposite material (magnetic effect by the presence of nano ferrite fillers in the composite material) and its capability to miniaturize antenna. The primary effect of epoxy-ferrite nanocomposite material as magneto-dielectric film on the antenna resonant frequency, return loss, and bandwidth is studied.

5. REFERENCES

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