A Circularly Polarized Magneto-dielectric Resonator Antenna with Wideband, Multi-resonant Response

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A unique design employing layered magneto-dielectric materials exhibits simultaneous compact size, high bandwidth, moderate efficiency, and circular polarization operation at UHF. A prototype antenna operating over 240MHz-420MHz with a linear dimension smaller than 0.15λ at the lowest frequency is fabricated and tested.

Introduction

The design begins with a dielectric resonator antenna (DRA) which, being a volumetric source, has inherently wider bandwidth than a linear or surface radiator [1]. In an effort to reduce the size, the DRA is composed of layers of magneto-dielectric and dielectric materials, forming the magneto-dielectric resonator antenna (MDRA). Finally, a previously developed method to improve the bandwidth of a DRA using a double resonant structure is used [2]. Extending this approach, parasitic elements are also included yielding a multi-resonant design.

Design and Fabrication

Antenna size is generally determined by the wavelength in the antenna material, $\lambda_d = \lambda_o/\sqrt{\mu_r\varepsilon_r}$. Incorporating artificial materials with both μ_r and ε_r greater than unity can result in the same $\mu_r\varepsilon_r$ product without the adverse effects of using high permittivity materials [3]. In this design the magneto-dielectric is an aligned Z-type hexaferrite ceramic. [1] Over the frequency range of interest, the magnetic loss tangent ($\tan\delta_m$) is approximately 0.04 but increases at higher frequencies; $\tan\delta_e$ is estimated to be five to ten times smaller than $\tan\delta_m$. The relative permittivity and permeability are approximately 16 and 8.5, respectively.

A probe feed, which allows for easier CP implementation, is used to achieve a double resonant design. The double resonant technique presented in [2] combines a resonant slot feed and a DRA to effectively double the available bandwidth; this design also maintains the same polarization and pattern over the bandwidth of operation. Here, the resonance of the probe is designed to be adjacent to that of the MDRA. The concept of merging resonances to augment bandwidth is extended to include additional resonances from parasitic elements. If properly designed the parasitic element yields a third resonance at an adjacent frequency. In this design a parasitic probe is short circuited to the ground plane opposite from the fed probe, as shown in Figure 1(a). Additional parasitic probes can be added to achieve more resonances that would lead to increased bandwidth.

This multi-resonance approach is used to design a circularly polarized antenna. A square MDRA is ideal for CP implementation because two orthogonal modes can be excited using two probes along adjacent walls, as shown in Figure 1(b). At the MDRA resonance E_z has a null at the midpoint of the MDRA length in the y direction so the presence of the second

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[1] TransTech, Inc., Adamstown, MD. *http://www.trans-techinc.com/*

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probe should not affect the return loss at this frequency.

Currently, the manufacturing process limits the hexaferrite layer thickness. A layered design of alternating hexaferrite and regular dielectric layers is adopted; this also allows for greater control over the effective parameters, $\mu_{r,eff}$ and $\varepsilon_{r,eff}$. The dielectric is Roger's TMM4 which has relative permittivity of 4.5 with $\tan\delta_e < 0.002$. [2] The dimensions of the resonator are determined with the familiar DRA expressions (see, for example, [2]) with effective parameters $\mu_{r,eff}$ and $\varepsilon_{r,eff}$ derived using effective medium theory. The antenna has fourteen layers, each of which is 0.54 cm thick and 17.2 cm square. The total height is about 7 cm. Probe lengths are determined, to first-order, as one-quarter the wavelength in the material at the desired resonant frequency. The fabricated antenna with feed and parasitic elements is shown in Figure 2(a); the design is symmetric with respect to the MDRA diagonal. Label l_F refers to the feed probe while labels l_{p1-p4} refer to the parasitic probes. The parasitic elements shown provide additional resonances as well as improve matching and isolation. The wide, external probes seen in Figure 2(a) exhibit better coupling to the antenna than internal, wire probes.

Measurements

The return loss of the CP design is measured; a $3dB$ coupler is used to split power between the two input ports. The second port of the network analyzer is connected to the isolated port of the coupler and is used to monitor the power reflected from the antenna ports. The result is shown in Figure 2(b). The return loss is about -10 dB over the entire band; a minimum of $-7.6dB$ occurs at 248 MHz indicating 17% reflected power. The wideband matching is expected because power reflected from the antenna feeds goes to the isolated port of the coupler and shows up in S_{21}. The antenna operates when both S_{11} and S_{21} are below -10 dB, above roughly 240 MHz.

The patterns of a dual linearly polarized design, i.e. with one antenna port fed and the other terminated in a matched load, are measured; the CP feed network is not used in pattern measurements. The ground plane is about 30 cm square The E plane of the first port, E_1, and H plane of the second, H_2, coincide as do the E_2 and H_1 planes. It is noted that the anechoic chamber performs best at frequencies above 400MHz. The patterns measured at 265 MHz and 285 MHz are shown in Figures 3 and 4. Patterns measured at 246 MHz and 310 MHz look similar except for slightly increased cross-pol in the H-plane at 310 MHz. The symmetry in the design is evident in the pattern symmetry about $\theta = 0$.

The gain of the dual linearly polarized design is also measured on a 50 cm square ground plane. The gain ranges from -1 dBi at 250 MHz to -3 dBi at 310 MHz. The gain at higher frequencies is limited by the magnetic loss of the hexaferrite material which increases with increasing frequency. Current efforts are underway to reduce the magnetic loss tangent to values better than 10^{-2}.

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[2] Rogers Corporation, Rogers, CT. *http://www.rogers-corp.com*

Conclusion

A unique MDRA design has been described and a sample of the measured results given. At this time, the efficiency is limited by loss in the magneto-dielectric material. Additional details and measured results will be presented at the symposium.

References

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[2] A. Buerkle, K. Sarabandi, and H. Mosallaei, *IEEE Antennas and Propagat. Society Symposium*, vol.2A, pp.1359-1362, June 2004.

[3] H. Mosallaei and K. Sarabandi, *IEEE Trans. on Antennas and Propagation*, vol.52, pp.1558-1567, June 2004.

(a) (b)

Figure 1: Probe fed DRA (a) with parasitic probe (b) for CP design.

(a) (b)

Figure 2: (a) Fabricated antenna in measurement setup with feed and parasitic elements. (b) Measured return loss and isolation with CP feed network.

(a) E plane pattern at $f = 265MHz$.

(b) H plane pattern at $f = 265MHz$.

Figure 3: E and H plane patterns at $f = 265MHz$.

(a) E plane pattern at $f = 285MHz$.

(b) H plane pattern at $f = 285MHz$.

Figure 4: E and H plane patterns at $f = 285MHz$.