Design and Analysis of Ultra Wide Band Spiral Dielectric Antenna in Wireless Communications

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Abstract— The ultra wide band planar dielectric antennas developed give almost omni directional radiation pattern along with a huge impedance bandwidth. These antennas are investigated from 6 GHz to 14 GHz (in case of planar log periodic dielectric antenna) and 3 GHz to 8 GHz (for the planar spiral dielectric antenna). All these antennas are very useful in blue-tooth, WI-FI, personal wareless communications equipment, as all these antennas give good omnidirectional radiation patterns with ultra wide band impedance bandwidth. For wireless mobile or blue tooth applications at the higher end of the spectrum, small omni directional antennas are required which are capable of providing almost equal radiation to all directions over a very wide frequency range. Though microstrip, PIFA and other planar antennas can provide rather broad radiation pattern at these frequency ranges, they suffer from extremely narrow bandwidth of operation .

Moreover, another limitation of such antennas is hemispherical radiation pattern. To eliminate these problems, we investigate a planar dielectric toothed log periodic antenna and a dielectric spiral antenna, which are defined by angle dependent geometry and hence are suitable for frequency independent operation. The feeding is done by a 50 ohm coaxial type SMA connector at the centre.

Keywords—component; formatting; style; styling; insert (key words)

I. INTRODUCTION

Frequency independent antennas had been proposed and devised for working over huge band widths. According to Rumsay , solely angle dependent geometries are amenable to such operation. This principle had so far been applied to metallic antennas only. Here we report theoretical and experimental investigations on novel planar dielectric antennas like, ultra wide band log-periodic and spiral angle dependent dielectric antennas. The first dielectric log periodic planar antennas is of the form of two arms forming a bowtie and then the spiral dielectric antenna is of the form of two arms forming an angle dependent equiangular structure, whose dimensions vary exponentially with constant periodicity.

Ultra Wide Band Spiral Dielectric Antenna

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The dielectric spiral has been designed using the same concept as the case of its metallic counter parts. But according to its dielectric constant ($\varepsilon_r = 2.4$, Teflon material) we model its arms length for the case of specified operating frequency range considering the guided wavelength. After fabrication we excited this structure through a 50Ω SMA connector and measured its impedance and radiation pattern.

Unlike the metallic spiral [2 and 3] antenna it is not showing self complimentary nature but due to angle dependent nature it gives a wide band frequency range for its operation. In addition it has many advantages over its metallic counterpart. For example it is totally non corrosive and can be used without application of radome in free space, it has no metallic loss. Unlike the microstrip spiral antenna or the slotted spiral antenna [4] it has no ground plane, so we can get forward and backward radiation at the same time, which makes this antenna unique in its own series. We may use it where omni pattern coverage is necessary.

II. DESIGN METHODOLOGY

In spherical co-ordinates (r, θ, Φ), the shape of a typicalspiral structure is given in [2-4]. The shape of an equiangular planar spiral can be derived by letting the derivative of an arbitrary function f w.r.t. the angle θ as $\frac{df}{d\theta} = f'(\theta) = A\delta(\frac{\pi}{2}-\theta)$, where A is a constant and δ is the Dirac delta function. Expressing the radial variable r as $r = F(\theta,\phi) = e^{a\phi} f(\theta)$, (where $f(\theta)$ is chosen arbitrarily), we get the governing equation of the spiral as

$$\rho = Ae^{a\phi} = \rho_0 e^{a(\phi-\phi_0)} \, for \theta = \tfrac{\pi}{2} \quad \text{where } A = \rho_0 e^{-a\phi_0}$$

= 0 elsewhere.

In terms of wave length we can write, $\rho_\lambda = \frac{\rho}{\lambda} = \frac{A}{\lambda} e^{a\lambda} = Ae^{a[\phi = \ln(\lambda)/a]} = Ae^{a(\phi - \phi_1)}$ where $\phi_1 = \frac{1}{a}\ln(\lambda)$.

Another from of this equation may be written as $\phi = \frac{1}{a}\ln\left(\frac{\rho}{A}\right) = \tan\psi \ln\left(\frac{\rho}{A}\right) = \tan\psi(\ln\rho - \ln A)$.

Here $\frac{1}{a}$ is the rate of expansion of the spiral and Ψ is the angle between the radial distance ρ and the tangent to the spiral, as shown in the figure 5.5(a).

The performance of the system is then a function of the logarithm of the frequency. Photograph of the planar equiangular spiral structure investigated is shown in Figure 5.5(b). It consists of two coplanar dielectric arms whose lengths are specified by the equation

$$L = (\rho_1 - \rho_0)\sqrt{1 + \frac{1}{a^2}}\ .$$

An equiangular dielectric surface, designated as P, can be created by defining the curves of its edges as

$$\rho_2 = \rho'_2 e^{a\phi}, \rho_3 = \rho'_3 e^{a\phi} = \rho'_2 e^{a(\phi - \delta)}$$

where $\rho'_3 = \rho'_2 e^{-a\delta}$, such that

$$K = \frac{\rho_3}{\rho_2} = e^{-a\delta} \langle 1\ .$$

The two curves, which specify the edges, are of identical relative shape with one magnified relative to the other or rotated by an angle δ with respect to the other. The magnification or rotation allows the arm of conductor P to have a width, as shown in Figure 1(c).

A second equiangular dielectric surface, designed as Q, can be defined by

$$\rho_4 = \rho'_4 e^{a\phi} = \rho'_2 e^{a(\phi - \pi)}$$

where $\rho'_4 = \rho'_2 e^{-a\pi}$,

and $\rho_5 = \rho'_5 e^{a\phi} = \rho'_4 e^{a(\phi - \delta)} = \rho'_2 e^{a(\phi - \pi - \delta)}$,

where $\rho'_5 = \rho'_4 e^{-a\delta} = \rho'_2 e^{-a(\pi + \delta)}$.

The system composed of the two radiating arms, P and Q, constitutes a balanced system, and it is shown in Figure 5.5(c). The finite size of the structure is specified by the fixed spiraling length L_0 along the centre of the arm. The entire structure can be completely specified by the rotation angle δ, the arm length L_0, the rate of spiral 1/a, and the terminal size ρ'_2. With reference to Figure 5.5(a), we choose at 0 degree the inner and outer arm radii to be 0.9 mm and 3.1 mm respectively [6], whereas at 360 degrees the inner and outer arm radii are chosen to be 147.8 mm is 534.5mm respectively.

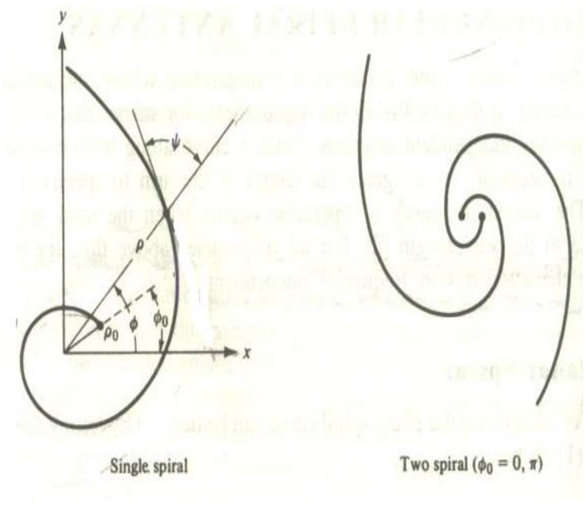

Figure 5.5(a) Generation of equiangular spiral curve

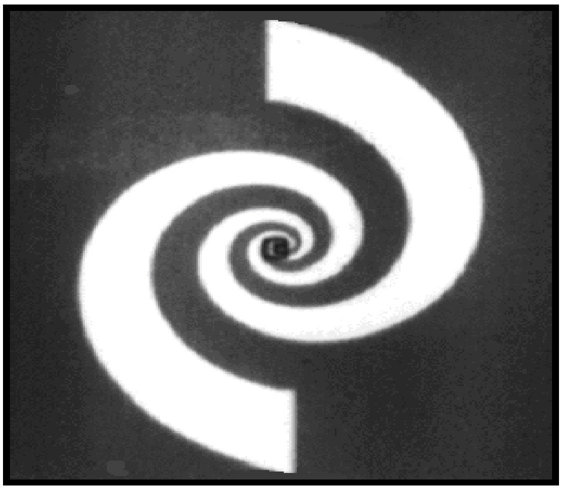

Figure 5.5(b) Top view of dielectric spiral antenna

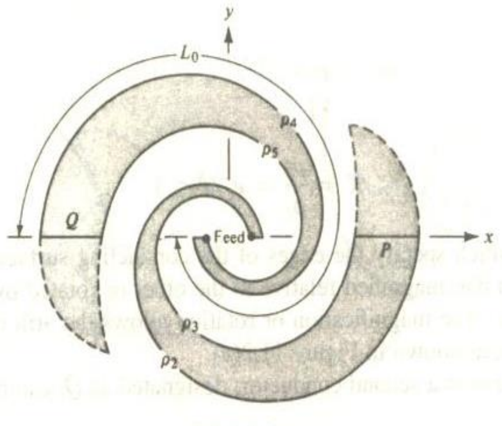

Figure 5.5(c) Top view of dielectric spiral antenna

III. **RESULTS**

Experimentally measured return loss plot against frequency is shown in Figure 5.6. It shows that the minimum return loss of about –11 dB occurs at 5 GHz. In addition, it maintains ultra wide band spectrum with < -6 dB return loss i.e. nearly 3:1 VSWR bandwidth extending from 3.08 to 7.31 GHz. It is to be noted that this is the standard definition used for ultra wide band antennas [5]. Experimental radiation patterns had been also measured and are shown in Figures (5.7 and 5.8). In all four principal planes the patterns are almost omni directional and as a whole the antenna gives an almost isotropic pattern.

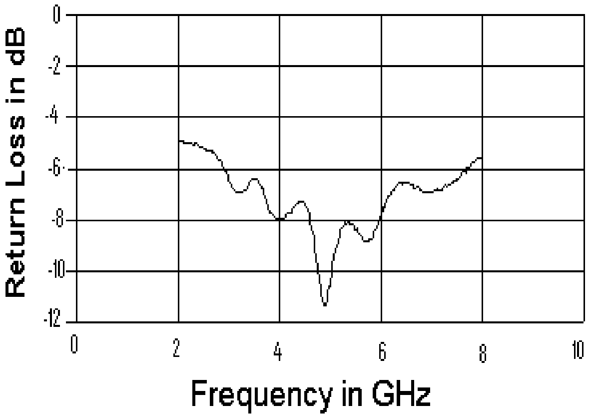

Figure 5.6Return loss vs. frequency plot

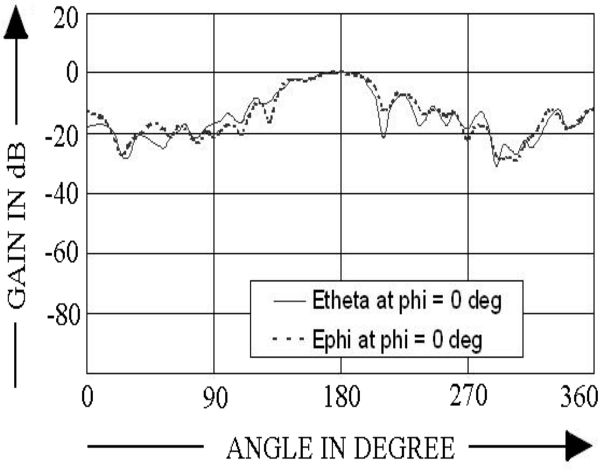

Figure 5.7Radiation patterns for E_{theta} and E_{phi} vs. theta at phi = 0 deg.

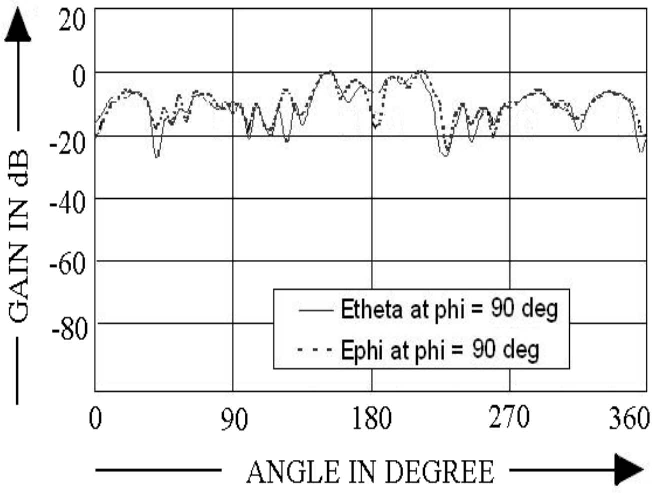

Figure 5.8 Radiation patterns for E_{theta} and E_{phi} vs. theta at phi = 90 deg

IV. CONCLUSION

Measured results indicate suitability of these wide band dielectric antenna for wireless and mobile applications with good omni directional pattern coverage over extremely wide spectral ranges. Another interesting observation has been the small size of the antenna, which makes them ideal for handheld mobile applications where space and weight are at premium.

It is found experimentally that ultra wide 3:1 VSWR impedance bandwidth of about 4.23 GHz (from 3.08 to 7.31 GHz) with the best return loss within the operating band being about -11 dB is obtained for the dielectric spiral antenna and nearly 3:1 VSWR bandwidth extending from 6.1752 GHz to 12.66 GHz is obtained for the dielectric log-periodic antnna. Further, the experimentally measured radiation patterns show rather broad nature suitable for omni directional coverage. Varying the plane of polarization, they are also observed to have an almost polarization independent behavior. All these characteristics make these new antennas developed ideally suited for numerous emerging fields of wireless, blue tooth and mobile communications.

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