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RESEARCH ARTICLE

BANDWIDTH ENHANCEMENT OF BIRD NEST ANTENNA WITH DIELECTRIC RESONATOR RING

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ABSTRACT

A wideband circularly polarized bird nest antenna with dielectric resonator ring is designed. This structure consists of a dielectric resonator ring with probe at the center of the circular ground plane which act as a monopole and it surrounded by a number of dielectric slabs. Here the dielectric slabs are used to convert the linearly polarized wave produced by the monopole to the circularly polarized wave. Since the structure of antenna look like a bird nest, it is called bird nest antenna. The reflection coefficient, axial ratio (AR), radiation pattern, gain and VSWR of the antenna were simulated using Ansoft HFSS. The 10 dB impedance bandwidth and 3 dB axial ratio bandwidth provided by the antenna is 57% and 48% respectively. Maximum gain provided by this antenna is 5.25dBi.

Key words:

Monopole antenna, wave polarizer, circular polarization, dielectric resonator antenna

INTRODUCTION

Due to the rapid development of wireless technology, mobile satellite communications have become popular. Antennas mounted on the top of a moving vehicle should be circularly polarized to communicate with the geostationary satellite. Circularly polarized antennas avoids the interferences to the communication channels from the multipath propagations. Because the reflected waves will be attenuated due to the change of polarization direction and only the directed wave is received by receiver antenna. Therefore there is less fading and flutter when circular polarized antenna is used at each end of the link. Usually microstrip antennas are used for far field applications due to their properties like light weight, ease of fabrication, low production cost. But the use of these antennas are limited due to its low impedance bandwidth.

So bandwidth enhancement techniques are needed in order to fulfill the requirement of today's communication systems. There are many techniques are used for enhancing the bandwidth provided by antenna by changing its structure. A rectangular microstrip patch antenna having bandwidth of 831.5MHz is improved to 5070.2MHz and 8947.5MHz by cutting corners of patch by straight edges and circular edges respectively (Swapnil S. Thorat, R.C. Jaiswal, Dr. Rajkumar and Dr. S.D.Lokhande, 2012). The bandwidth of a patch antenna can increased to 8.33% by increasing the thickness of the substrate (Manteghi, M., 2008). Here the circular polarization is achieved by exciting two orthogonal modes of the patch with 90^0 out of phase signals. Metamaterial bilayered substrates can also be used to increase the bandwidth (Yang, R., Y. Xie, D. Li, J. Zhang, and J. Jiang, 2007). An impedance bandwidth of eight times that of a conventional patch antenna of the same size can be achieved by using a gap coupled microstrip patch antenna (Aanandan, C. K., P. Mohanan, and K. G. Nair, 1990).

In this paper, the 10 dB impedance bandwidth provided by a monopole dielectric resonator antenna is improved to 57% by adding inclined dielectric slabs on the circumference of the ground plane. Here the dielectric slabs are used to convert the linearly polarized wave produced by the monopole dielectric resonator antenna to the circularly polarized wave. As compared to the microstrip antenna, dielectric resonator antenna (DRA) has a wider impedance bandwidth. Because, DRA radiates through the whole DRA surface except the grounded part. In high frequency applications, conductor loss of metallic antennas become severe and the antenna efficiency

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decreases while in DRA the only loss is due to the imperfect material which is very small. Avoidance of surface waves is another advantage of the DRA. Therefore DRAs have high radiation efficiency. DRAs of different shapes are available in which ring DRA is used here. The reflection coefficient, axial ratio (AR), radiation pattern, and VSWR of the antenna were simulated using Ansoft HFSS. The 3 dB axial ratio bandwidth provided by the antenna is 48%.

Design Of Proposed Antenna

This proposed structure consists of a probe with ring dielectric resonator on the center of the circular ground plane. Here source is a coaxial probe with ring dielectric which also act as a monopole dielectric resonator antenna. Since the field excited by the probe is vertically polarized, inclined dielectric slabs are required to provide the circular polarization. So the basic working of this antenna depends upon the wave polarizer constituted in dielectric slabs. A linearly polarized (LP) wave can be converted into an circularly polarized wave by using a wave polarizer[5]. If a linearly polarized wave traveling in the z direction has a polarization angle of 45^0 with respect to the positive axis is incident on the dielectric slabs, it is resolved into two components. One is parallel to x axis (E_x) and other parallel to y axis (E_y). The x component is unaffected by the slabs. However E_y will be retarded. The depth of the slab is tuned to retard E_y by 90^0, then the wave emerging from the back side of the slab is circularly polarized if $|E_x|=|E_y|$.

Figure 1 shows the geometry of the dielectric slab, dielectric resonator ring and probe. Dielectric slab is made up of material having dielectric constant ε_r and has a length of l, a width of w, a depth of d, and an inclination angle of α. L_p and r_p are the length and radius of probe. The ring resonator around the probe is made up of material having dielectric constant ε_d. The height and thickness of ring is h_r and t_r respectively.

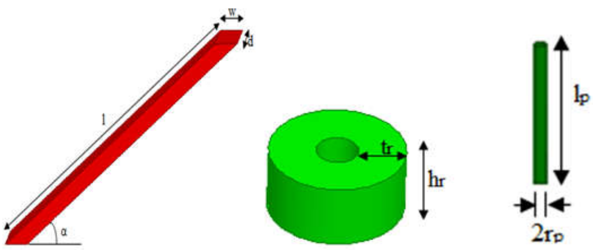

Figure 1 Geometry of the dielectric slab, dielectric resonator ring and probe

In this paper, eight inclined dielectric slabs are used. Figure 2 shows the configuration of the proposed circularly polarized bird nest antenna with dielectric resonator ring. The radius of ground plane is R and each dielectric slabs are uniformly distributed along the circumference of the ground plane having displacement of S_0 from the center with an angular interval of 360/N.

SIMULATED RESULTS

A CP bird-nest antenna operating in C band was designed. The parameters are ε_r=15, N=8, l=62mm, w=6mm, d=9.7mm, α=31^0, R=33mm, S_0=28mm, ε_d=20, h_r=5mm, t_r=3.5mm, l_p=13.3mm and r_p=0.6mm. The operating frequency of antenna is 5.3GHz. Figure 3 shows the simulated reflection coefficients of the proposed antenna. In figure 3, the measured 10dB impedance bandwidth is 57%. Here antenna has three resonant frequencies in which first resonant frequency mainly depends on monopole, second due to slab and the third depends only on the DRA.

When dielectric slabs and dielectric resonator ring are vanished by setting ε_r=1 and ε_d=1 respectively, it looks like a simple monopole antenna which only contains a probe at the center of ground plane. The impedance bandwidth provided by this antenna is 31% and has a single resonant frequency at 5.2GHz. By setting ε_d=1 and increasing ε_r from 1 to 15, this resonant frequency decrease from 5.2GHz to 4.71GHz indicate that this resonance depends on probe. Simultaneously a second resonant frequency become stronger as ε_r increases which is depends on the dielectric slab. This can be verified in the figure 4. Because of these two resonances, the bandwidth improves from 31% to 44%.

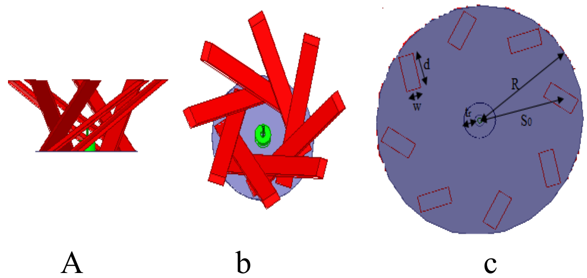

Figure 2 (a) Front view, (b) top view, (c) bottom view of the bird nest antenna with dielectric resonator ring

This bandwidth can be further improved by increasing ε_d from 1 to 20. It can be shown in figure 5. The first resonant frequency has small variation from 4.71GHz (ε_d=1) to 4.76GHz (ε_d=20). So it can be verified that the first resonant frequency entirely depends on the monopole. Second resonance frequency increases from 6.44GHz (ε_d=1) to 6.87GHz (ε_d=20) indicate that this resonance is due to the effect of slab. Simultaneously a third resonant frequency become stronger as ε_d increases which is only depends on the DRA. So the impedance bandwidth of this antenna further improves from 44% to 57%. This same bandwidth is also obtained from VSWR plot. In the figure 6, the impedance bandwidth when VSWR<2 is 57%.

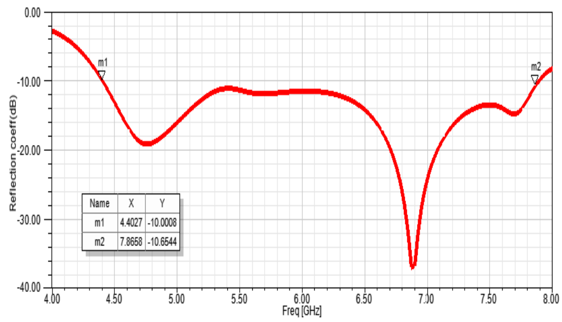

Figure 3 Simulated reflection coefficient of bird nest antenna with ring DRA

Figure 7 shows the simulated ARs of this antenna at θ=40^0 and ϕ=300^0. The axial ratio bandwidth provided by this antenna is 48% from 4.26GHz to 6.95GHz where the impedance bandwidth is from 4.4GHz to 7.88GHz. Here the 44% of simulated impedance passbands (4.4GHz-6.95GHz) are almost fall within their respective AR passbands, so the antenna is circularly polarized within this range. Figure 8 shows the simulated radiation pattern in 2D and 3D polar plot at resonant frequency. With reference to the figure, the pattern has a null in the boresight direction ($\theta=0^0$). That is, along the z axis, which is correspond to the radiation directly overhead the antenna, there is very little power is transmitted. In the xy plane, the radiation is maximum.

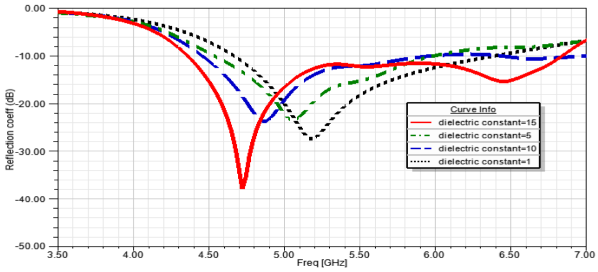

Figure 4 Simulated reflection coefficient of the bird nest antenna with ring DRA for ε_r=1, 5,10, and 15 and ε_d=1

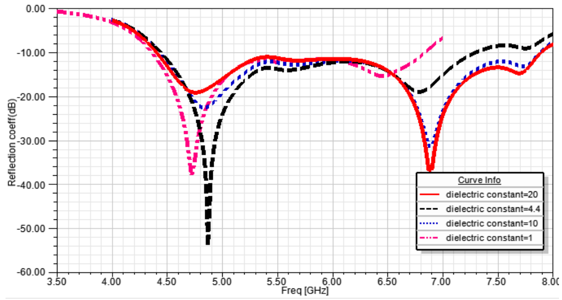

Figure 5 Simulated reflection coefficient of the bird nest antenna with ring DRA for ε_d=1, 4.4,10, and 20 and ε_r=15

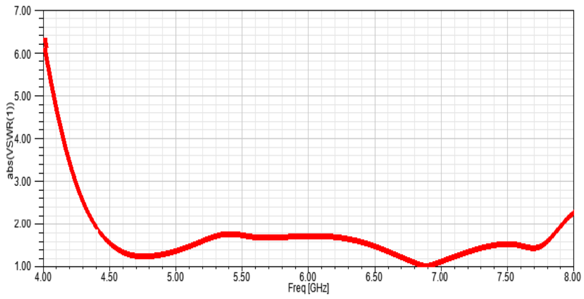

Figure 6 Simulated VSWR of the bird nest antenna with ring DRA

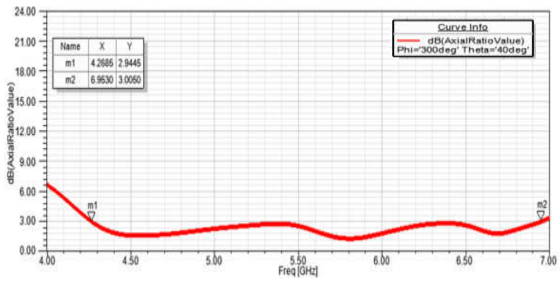

Figure 7 Simulated axial ratio of the bird nest antenna with ring DRA

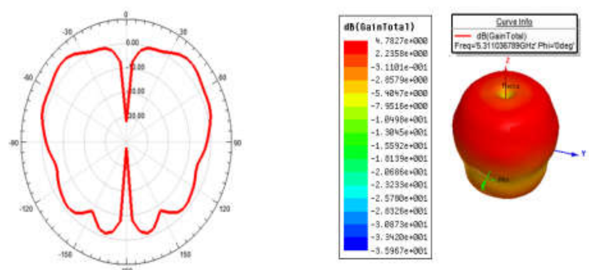

Figure 8 Simulated radiation pattern in 2D and 3D polar plot of the bird nest antenna with ring DRA

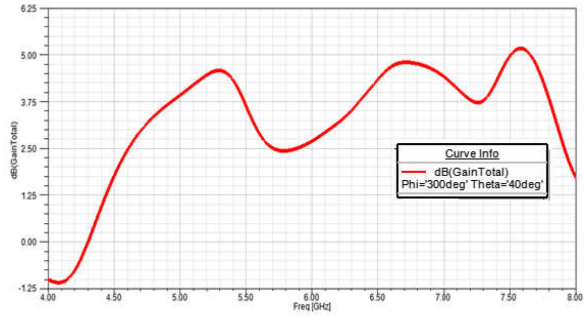

Figure 9 Simulated gain of bird nest antenna with ring DRA

Figure 9 shows the plot of simulated gain vs frequency. Here gain is plotted at $\theta=40^0$ and $\phi=300^0$. Bird nest antenna with ring dielectric resonator provides three peak gains at 5.3GHz, 6.7GHz and 7.57GHz. In these three frequencies, antenna can receive more power than the other frequencies. These three frequencies different than the match point frequencies obtained from reflection coefficient plot. Because peak gain frequency is mainly depend on the directivity rather than the match point. The maximum gain obtained is 5.25dBi.

In this design, the ring is made up of material having dielectric constant=20 and the maximum gain obtained is 5.25dBi. This maximum gain can slightly improved by reducing the dielectric constant of dielectric resonator ring. This can be shown in figure 10. Here ring is made up of three materials having different dielectric constant. When ring is made up of Arlon (dielectric constant=10), the gain increases and the maximum gain obtained is 5.7dBi. When FR4 (dielectric constant=4.4) is used, the gain is decreases to 5.4dBi. This is because, Arlon and FR4 has loss tangent of 0.003 and 0.02 respectively. As loss tangent increases, the power loss increases which reduce the gain.

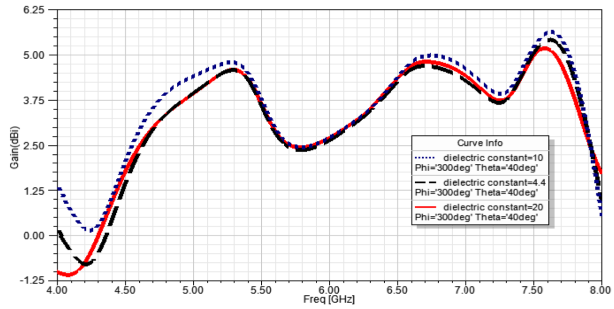

Figure 10 Simulated gain of bird nest antenna with ring DRA for different dielectric constants of ring

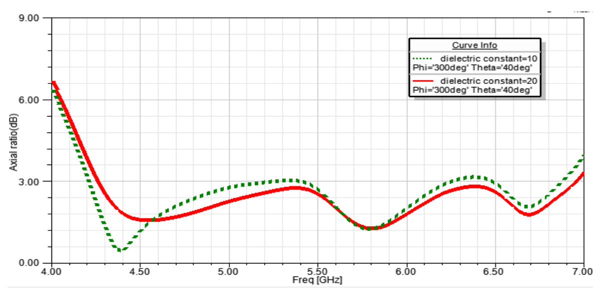

Figure 11 Simulated axial ratio of the bird nest antenna with ring DRA for different dielectric constants of ring

If Arlon is used to design the ring, then the gain increases to 5.7dBi and the impedance bandwidth is 57% from figure 5. But in this case, the antenna provides three narrow axial ratio bands which are separated as shown in figure 11. So to obtain high gain with wide impedance and axial ratio bandwidth, the ring is made up of dielectric constant=20. If gain is the main consideration than bandwidth, ring should be made up of low dielectric constant.

CONCLUSIONS

A wideband circularly polarized dielectric bird nest antenna with DRA has been investigated. This structure consists of a probe with ring resonator at the center of the circular ground plane and it surrounded by a number of dielectric slabs. These dielectric slabs are used to provide circular polarization to the antenna. The simulated impedance bandwidth and axial ratio bandwidth of this antenna are 57% and 48% respectively. The 44% of impedance bandwidth is lies in axial ratio bandwidth indicate that this antenna is circularly polarized in this range. Maximum gain provided by this antenna is 5.25dBi.

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