A Wideband Bi-Semicircular Slot Antenna

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1. Introduction

Power efficient and high data rate communication systems are envisioned for numerous civilian and military applications. Hence design of wideband, miniaturized, and efficient radiating elements has become a subject of intense investigation over the past decade. Ring antennas are considered to be among the narrowband resonant antennas and occupy an area of $\lambda^2/4\pi$ at their first resonance [1]. However, like many other printed antennas, ring antennas do not make efficient use this area. In this paper we present a modified topology for the ring antenna in order to obtain larger bandwidth without increasing the occupied area. One such topology, based on annular ring slot antennas is proposed. It is shown that the modified antenna topology has a much gentler input reactance as a function of frequency, which is exploited to achieve much higher bandwidth. This increase in the bandwidth is obtained without putting any constraints radiation patterns, antenna efficiency (gain), or adversely affecting the antenna polarization purity. Numerical and experimental results are used to demonstrate that the new topology presents a bandwidth that is by a factor of 7.3 (730%) higher than that of an ordinary annular ring slot antenna. In what follows, the design procedure and measurement results are presented and discussed.

2. Antenna Design and Simulation

A ring slot antenna resonates when its circumference is approximately one wavelength. A microstrip-fed narrow ring slot antenna is a relatively narrow-band antenna with only a few percent of usable bandwidth. The geometry of an annular ring slot antenna is shown in Figure 1, where a 50Ω microstrip line connected to a 110 Ω open circuited microstrip line is used for feeding the antenna and obtaining a good match. The length of the open circuited stub, L_m, can be adjusted to obtain a good match to the line impedance. In order to increase the antenna bandwidth, the structure can be modified as shown in Figure 2. This significantly decreases the spectral variations of the input resistance and reactance of the antenna as is seen in Figures 3 and 4. This way, a wideband match can easily be obtained and the antenna bandwidth can be increased significantly. The proposed antenna is shown in Figure 2 where a similar microstrip feed and matching scheme is used. The antenna has an inner radius of 12mm and a width of 1mm. As can be seen from Figures 3 and 4, by increasing the width of the connecting slot (t_l) the input impedance variations decrease and a wider bandwidth can be obtained. In this prototype, t_l is chosen to be 1.4 mm wide and the feed line consists of a 50Ω microstrip line connected to a 110Ω open circuited line. The narrow feed line is used to obtain a localized feed and also provide an additional factor of flexibility in obtaining a wideband match. Both structures of Figures 1 and 2 are simulated using IE3D and the simulation results predict that a wideband impedance match can be obtained for the second antenna by only tuning L_m.

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3. Results and Discussion

The modified ring slot and the simple slot antennas are fabricated on a 0.5mm thick, 11cm × 10 cm, RO4350B substrate with a dielectric constant of ε_R=3.4 and loss tangent of 0.003. Figures 5 and 6 show the simulated and measured return losses of the simple and modified slot antennas. It is seen that the ordinary ring antenna has a -10 dB bandwidth of 6.2% whereas the modified ring shows a VSWR of better than 2 over a 1.6:1 bandwidth ratio or equivalently 45.8%. This shows a bandwidth improvement by a factor of 7.3 without increasing the area occupied by the antenna or introducing any difficulty in the design of the feed network. The discrepancy between the measured and simulated return losses of Figure 6 are mostly attributed to finite size of the antenna ground plane. The radiation patterns of the ordinary and modified ring antennas are measured in the anechoic chamber of the University of Michigan and are presented in Figures 7, 8, and 9. Figure 7 shows the measured pattern of the ordinary ring antenna which can be used as a reference for comparison. Figures 8 and 9 show the measured E- and H-plane radiation patterns of the modified slot antenna at four different frequencies. It is shown that the antenna patterns over the entire bandwidth are similar to each other and to that of the ordinary ring antenna. It is also shown that the cross polarization levels are very small at bore-sight. They however, intensify around $\theta=\pm 45^\circ$, which is also observed in the radiation patterns of the ordinary ring slot antenna and is attributed to the circular radiating current distribution. The cross polarization levels at these angles are very close to those of the ordinary ring, which shows that the proposed topology does not have any adverse affect on the cross polarization levels.

The antenna gain is also measured using a double ridge horn reference antenna. The measured gain and calculated directivity of the antenna are given in Figure 10. It is shown that the antenna gain and directivity increase with frequency in a similar fashion. It should be noted that the antenna directivity is calculated from a full-wave method of moments (MoM) simulation [2]. In this simulation the antenna ground plane is considered to be infinitely large, which is not a valid assumption. It has been shown that having a small ground plane reduces the antenna efficiency considerably [3]. This is one of the reasons behind the difference between the two graphs in Figure 7. Another reason for this discrepancy is the ohmic losses in the substrate and the ground plane of the antenna that decrease the antenna efficiency and are not accounted for in the full-wave simulation.

4. Conclusions

A new method for improving the bandwidth of narrow, annular ring slot antennas is presented, which results in bandwidth improvements by a factor of 7.3 (730%) without increasing the occupied area of the antenna or putting any constraints on the radiation patterns, impedance matching, or cross polarization of the antenna. Measured results show acceptable gain values and radiation parameters from this compact circular ring antenna over the entire band of operation.

References

[1] Batchelor, J.C.; Langley, R.J., "*Microstrip annular ring slot antennas for mobile applications*", Electronics Letters, Vol. 32, Issue 18 , 29 Aug. 1996, pp. 1635-1636.
[2] IE3D *Electromagnetic Simulation and Optimization Software,* Zeland Software, Inc.
[3] K. Sarabandi and R. Azadegan, "Design of an efficient miniaturized UHF planar antenna", *Antennas and Propagation Society, 2001 IEEE International Symposium,* Vol. 4, 2001 pp:446-449.

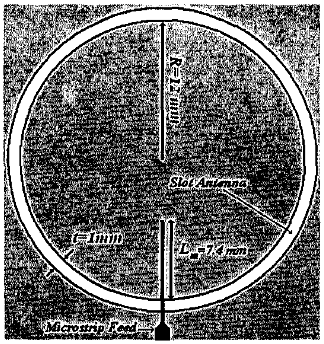

Figure 1. Geometry of the narrowband annular ring slot antenna.

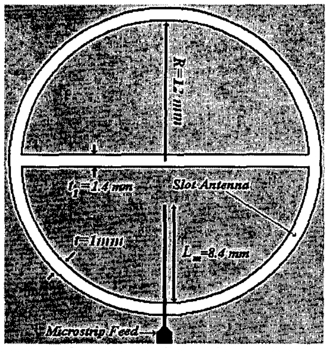

Figure 2. Geometry of the wideband annular ring slot antenna.

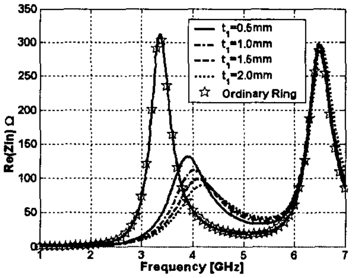

Figure 3. Real part of the input impedance of the modified ring slot antenna for different t_l values.

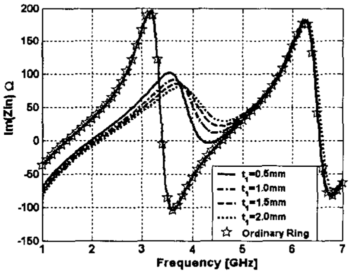

Figure 4. Imaginary part of the input impedance of the modified ring slot antenna for different t_l values.

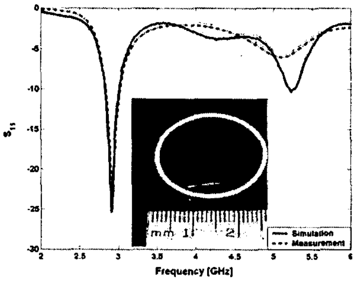

Figure 5. Measured and simulated return losses of the narrowband annular ring slot antenna.

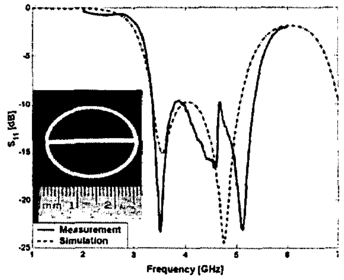

Figure 6. Measured and simulated return loss of the wideband annular ring slot antenna.

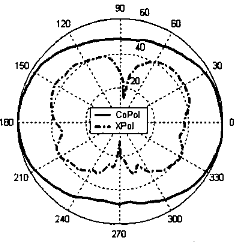

Figure 7a. Measured E-Plane pattern of the narrowband ring antenna.

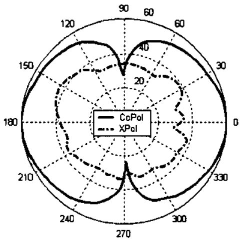

Figure 7b. Measured H-Plane pattern of the narrowband ring antenna.

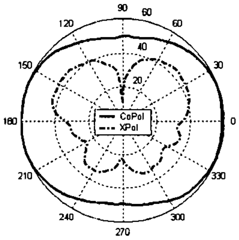

Figure 8a.

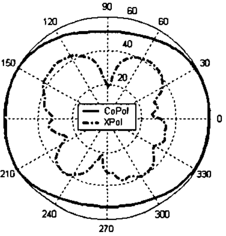

Figure 8b.

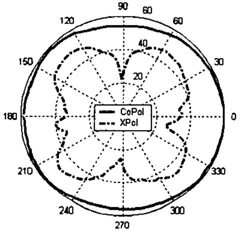

Figure 8c.

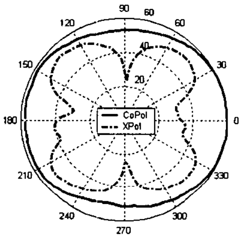

Figure 8d.

Figure 8. E-Plane radiation pattern of the wideband ring slot antenna measured at **a)** 3.5 GHz, **b)** 4 GHz, **c)** 4.5 GHz, and **d)** 5 GHz

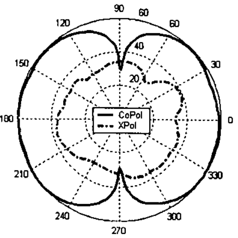

Figure 9a.

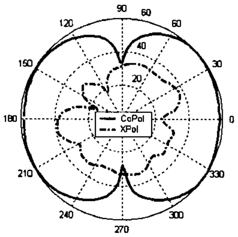

Figure 9b.

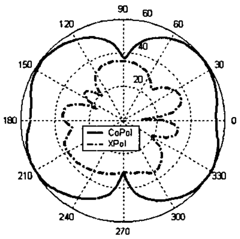

Figure 9c.

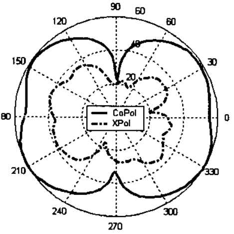

Figure 9d.

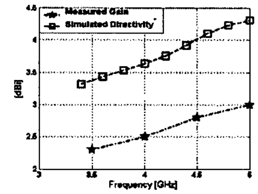

Figure 10. Measured gain and calculated directivity of the modified ring antenna.

Figure 9. H-Plane radiation patterns of the wideband ring slot antenna measured at **a)** 3.5 GHz, **b)** 4 GHz, **c)** 4.5 GHz, and **d)** 5 GHz.