Multiband Annular ring patch antenna for super high frequency (SHF) application

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Abstract –*Here a multi band annular ring patch antenna is presented for super high frequency application. The antenna adopt two annular ring connected with a single strip line feeding and has the radiation pattern for E-plane and for H-plane is unidirectional with some side lobe. The best result is obtained when the thickness of the rings is 1mm and inner radiusof 3mm. the antenna is very small in size and resonate at multi frequency in supper high frequency band. In addition, the bandwidth is (302.3MHz, 397.5MHz, 933.6MHz, and 1977.1MHz) it is also known as impedance bandwidth. And the considerable bandwidth is (4.4%, 3.2%, 6.8%, and 10.5%) respectively.*

Index Terms-annular ring, microstrip antenna, super high frequency.

I. Introduction

Super high frequency band is most popular band it ranges from 3GHz to 30GHz. The conventional boundary between UHF and SHF at 3GHz. The first band of SHF is S-band ranging from (2GHz-4GHz) and it is last band of UHF.SHF band is sub divided in S, C, X, K_u and K. It is most popular for its application in satellite as well as it is used in Radio astronomy, wireless communication, most modern radar, satellite television broadcasting, DBS, mobile communication and many other applications also. From few decades the annular ring antenna gets a wide attention due to some advantage [1-6]. The dimension of annular ring is smaller than the circular patch at fixed frequency application. This is due to surface current path is increased [1]. Using this feature antenna array can be used. However, facing of large input impedance is an obstacle on its uses. And to overcome on this obstacle many technique is developed, 1) The electromagnetic coupling feeding [3, 4]; 2) adding parasitic patch [1]; 3) The aperture Coupling feeding [5]; 4) the impedance-transformer line feeding [2].

For Mobile-Satellite application, it is needed that antenna has uniform radiation pattern in the upper half space as well as at low elevation angle. For improving low-elevation gain there are two methods, 1) changing the shape of patch and the ground to enhance the gain at low elevation angle. 2) Increasing the dielectric constant and thickness of the substrate for increasing the surface radiation [7]. And the improvement of low-elevation gain is limited. And the low profile is discarded.

In the proposed work, the antenna has unidirectional radiation pattern shape which is most acceptable for radar, satellite, wireless communication and mobile application.

II. Antenna configuration and design

The geometry of transmission line feeding annular ring is shown in figure 1. There are two annular ring as a radiating element and substrate with dielectric constant of 4.4 (FR4-epoxy) and metallic ground. The inner and outer radius of both ring are same and represented by a and b respectively.

If the wave propagation mood in annular ring is TM_{nm}then the resonant frequency of the annular ring microstrip patch antenna is given by,

$$f_{nm} = \frac{X_{nm} c}{2\pi a \sqrt{\varepsilon_e}} \qquad (1)$$

Where f_{nm} is resonant frequency for annular ring patch, $\varepsilon_e$is effectivepermittivity that is permittivity after consideration of fringing effect, c is speed of light in vacuum and X_{nm} is the roots of the characteristics equation given by equation 2.

$$J_n'(2X_{nm})Y_n'(X_{nm}) - J_n'(X_{nm})Y_n'(2X_{nm}) = 0 \qquad (2)$$

From equation 1 it is understood that resonant frequency can be change by changing the substrate, changing by

radius or by changing both. The impedance of annular ring patch for TM_{11} TM_{12} is very high, and it depends on the ratio of outer radius to inner radius i.e. (a/b).
As the ratio increase the impedance increases. The separation of resonance frequency is controlled by a/b. For TM_{11} it is hardly to match impedance by adjusting the ratio a/b. that's why for this impedance transfer line is used [2]. For annular ring on increasing the thickness of the substrate the impedance gets decrease as well as the bandwidth gets enhanced. Impedance at outer boundary of annular ring is larger than impedance at inner boundary therefore the 50Ω impedance matching is possible for TM_{12} mode.

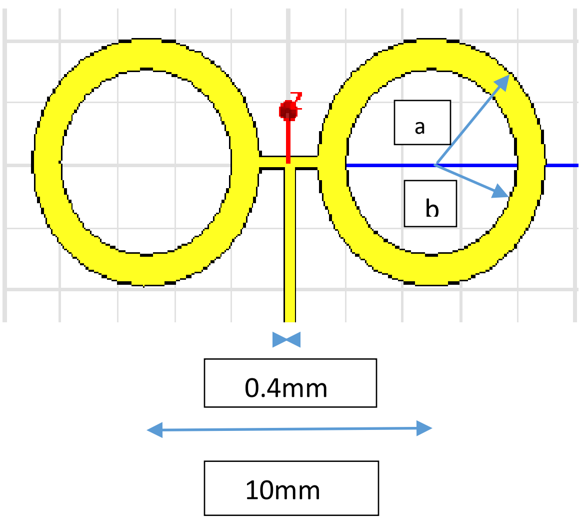

Figure 1: patch geometry

When annular ring is operated in $TM_{12,}$ it is found that its impedance bandwidth is several times achieved by other patches [12].

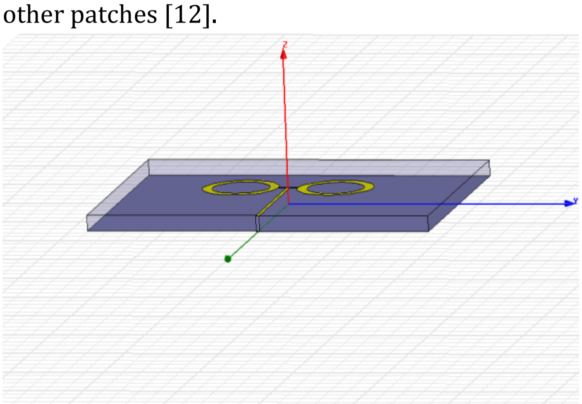

Figure 2: 3D geometry of patch antenna.

Thickness of the substrate h=1.6mm
Dielectric constante ε_e =4.4
Outer radius a=4mm
Inner radius b=3mm
Thickness of strip line and joining line of both rings is = 0.4mm
Center distance between both circle is =10mm
Dimenssion of ground and substrate is = (36mm x 30mm).

The results can be varied by using different substrate but FR4-epoxy is cheaper that's why FR4-epoxy is most widely used as substrate. The center of annular ing is at (0mm,-5mm,1.6mm) and the other annular ring is 180^0 rotation of the frist annular ring. The center distance of the anuular patch is 10mm.

Figure 3: Photo of the propotype

III. Results and discussion

Figure 3 shows the return-loss of the proposed antenna. And the return loss is calculated by the equation given below.

$$Return\ loss = -10\log(\Gamma)^2 \quad (3)$$

The impedance bandwidth for S_{11} <-10dB is 302.3MHz, 397.5MHz, 933.6MHz, and 1977.1MHz which ranges from (6.6995GHz-7.0018GHz), (12.1034GHz-12.5009GHz), (13.208GHz-14.1416GHz), and (17.7907GHz-19.7678GHz) Andtheir considerable bandwidth is 4.4%, 3.2%, 6.8%, and 10.5%) respectively. The first two bandwidths is not wide while other two is wide, that's why the antenna can be used for satellite communication for short capacity messages or satellite position services [7] on the other hand larger bandwidth can be used for large data transfer or can be used as modern Radar technique.

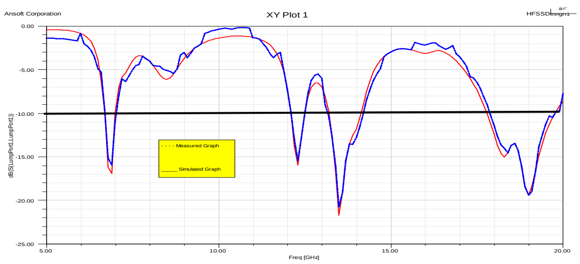

Figure 3: Measured and simulated return-loss.

Fig. 3, fig. 4 show a good agreement between measured and simulated value.

The VSWR of the proposed antenna is shown in the figure 4 which is calculated by the equation given below.

$$S = \frac{1+|\Gamma|}{1-|\Gamma|} \qquad (4)$$

Comparison of Simulated and Measured VSWR

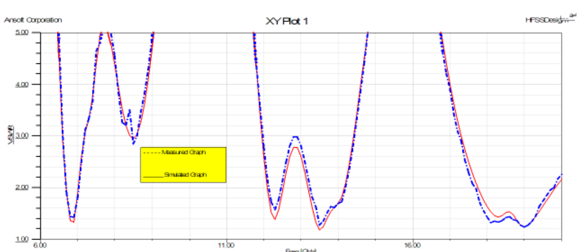

Figure 4: Measured and Simulated VSWR.

At some angle the directivity of the antenna is very less for lower resonance frequency but high at high resonance frequency.

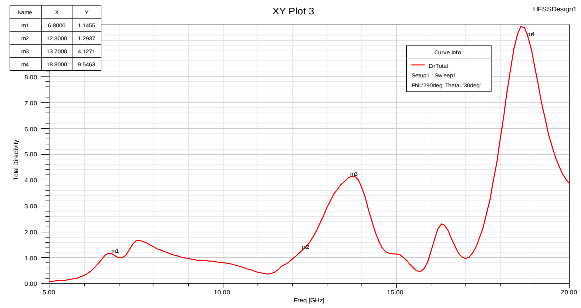

Figure 5: Total directivity at resonance frequency.

And at θ=30⁰ and at ϕ= 290⁰ the gain at lower resonance become considerable and somewhat reduce at high resonance frequency as shown in figure 5.

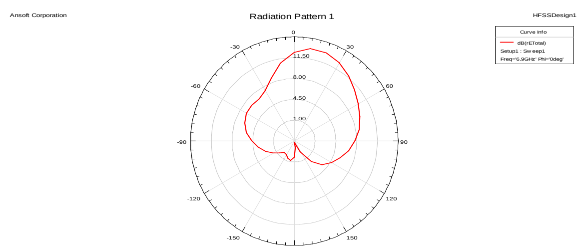

Figure 6: E-Plane radiation pattern

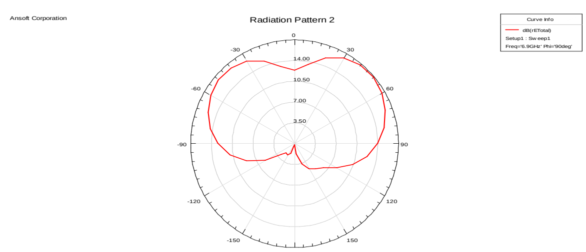

Figure 7: H-Plane radiation pattern

Figure 6 and figure 7 shows that the antenna is somewhat like directional antenna. But some side lobe is present. And these side lobe are mainly responsible for interference.

IV. Conclusion

By changing the outer and inner radius of the patch the 50Ω impedance matching can be found or by changing the width of the feeding line the impedance is matched for single feeding. The result indicate that the proposed antenna resonate at multi-frequency and the bandwidth of each resonance is large enough to transmit the data. It is used for satellite communication, in modern radar, and as the size of the antenna is also very small due to which it can be used in small devices like cell phone and tracking devices.

References

[1] Saeed I. Latif and LotfollahShafai,"Polarization Characteristics of Multiband Loaded Microstrip Annular Ring Antennas"IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. 57, NO. 9, SEPTEMBER 2009.

[2] Xiaoye Sun, Zhijun Zhang,and Zhenghe Feng,"Dual-Band Circularly Polarized StackedbAnnular-Ring Patch Antenna for GPS Application" IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS, VOL. 10, 2011

[3] Row, J. S., "Dual-frequency circularly polarised annular-ring microstrip antenna," *Electron. Lett*, Vol. 40, No. 3, 153-154, 2004.

[4] Garg, R., Bhartia, P., Bahl, I., and Ittipiboon, A.: 'Microstrip antenna design handbook' (Artech House, Norwood, MA, USA, 2001).

[5] Lin, Y. F., Chen, H. M. and Lin, S. C., "A new coupling mechanism for circularly polarized annular-ring patch antenna," *IEEE Trans.Antennas Propag.*, Vol. 56, No. 1, 11 15, 2008.

[6] Row, J. S., "Design of aperture-coupled annular-ring microstrip antennas for circular polarization," *IEEE Trans. Antennas Propag.*, Vol. 53, No. 5, 1779-1784, 2005.

[7] Guo, Y. X., Bian, L. and Shi, X. Q., "Broadband circularly polarized annular-ring microstrip antenna," *IEEE Trans. Antennas Propag.*, Vol. 56, No. 1, 2474-2477, 2009.

[8] Su, C. W., Huang, S. K. and Lee, C. H., "CP microstrip antenna with wide beamwidth for GPS band application," *Electron. Lett.*, Vol. 43, No. 20, 1062-1063, 2007.

[9] Chen, X., Fu, G., Gong, S. -X. and etc., "Single-feeding circularly polarized TM21-mode annular-ring microstrip antenna for mobile satellite communication", *Progress InElectromagnetics Research-Letter* Vol. 20, 147-156, 2011.

[10] Lin, S. Y., Wong, K. L., "A conical-pattern annular-ring microstripantenna with a photonic bandgap ground plane," *Microw. Opt. Technol.Lett.* Vol. 30, No. 3, 159-161, 2001.

[11] Lin, S. Y., Huang, K. C., "A compact microstrip antenna for GPS and DCS application," *IEEE Trans. Antennas Propag.*, Vol. 53, No. 3, 1227-1229, 2005.

[12]ZaipingNie andWeng Cho Chew., "Analysis of the Annular-Ring-Loaded Circular-Disk Microstrip Antenna," IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. 38. NO. *6,* JUNE *1990*

[13]Asem Al-Zoubi, Fan Yang, and Ahmed Kishk., "A Broadband Center-Fed Circular Patch-Ring AntennaWith a Monopole Like Radiation Pattern," IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. 57, NO. 3, MARCH 2009.