International Journal of Advances in Engineering & Technology, May 2011.
©IJAET **ISSN: 2231-1963**

DESIGN AND SIMULATION OF A DUAL BAND GAP COUPLED ANNULAR RING MICROSTRIP ANTENNA

Shuchita Saxena[1] and B.K. Kanaujia[2]
[1]Department of E&C Engineering, MIT, Moradabad
shuchita1210@gmail.com
[2] Department of E&C Engineering, AIT, Bareilly

ABSTRACT

The bandwidth enhancement technique using coplanar parasitic element is presented in this paper. This paper presents the analysis of gap coupled annular ring microstrip antenna. The proposed antenna is designed to operate at 6.2 GHz. Details of the proposed antenna and measured results are presented and discussed. The various parameters of the patch antenna are calculated and the antenna impedance is matched to 50 ohm of coaxial feed. The simulated impedance bandwidth of the proposed antenna is 4.8% for lower band (5.07-5.32 GHz) and 2.13% for higher band (6.05-6.18 GHz).

Keywords: *Microstrip antenna, Gap-coupled antenna, Annular ring antenna, impedance, return loss, VSWR.*

1. INTRODUCTION

Although antenna engineering has a history of over 60 years, it remains as a vibrant field which is bursting with activity, and is likely to remain so in the foreseeable future. Within this field, microstrip antenna forms one of the most innovative areas of current antenna work. An antenna is an element used for radiating or receiving electromagnetic wave. Although antennas may seem to be available in numerous different shapes and sizes, they all operate according to the same basic principles of electromagnetic.

Micro strip antenna consists of a path of metallization on a grounded substrate. A microstrip patch antenna is a type of antenna that offers a low profile, i.e. thin and easy manufacturability, which provides a great advantage over traditional antennas. Patch antennas are planar antennas used in wireless links and other microwave applications. The microstrip technique uses conductive strips and/or patches formed on the top surface of a thin dielectric substrate separating them from a conductive layer on the bottom surface of the substrate and constituting a ground for the line or antenna. A patch is typically wider than a strip and its shape and dimensions are important features of the antenna. Microstrip patch antennas are attractive due to their compact structure; light weight due to the absence of heavy metal stamped or machined parts, and low manufacturing cost using printed circuit technology. They also provide low profiles, conformity to surfaces and direct integration with microwave circuitry.

The patch can take many different configurations. However, the rectangular and circular are the most popular because of ease of analysis and fabrication, and their attractive radiation characteristics. These antennas can be mounted on the surface of high performance aircraft, spacecraft, satellite, missiles and even hand-held mobile telephones. The annular ring microstrip antenna has been studied from a long time by a number of the investigators [1]-[4] because the bandwidth is larger as compared to the other conventional microstrip patch antenna. There are several interesting features associated with this patch.

- For a given frequency, the size is substantially smaller than that of the circular patch when both operated in the lowest order mode. In application to arrays, this allows the element to be more densely situated, thereby reducing the grating-lobe problem.
- It is possible to combine the annular ring with a second microstrip element, such as another co planer parasitic antenna, to form a compact dual band antenna system.
- The separation of the mode can be controlled by the ratio of outer to inner radii.

- As compared to a circular disk, the angular ring has less stored energy and thus a lower ‘Q’ factor. This implies a wider bandwidth for the antenna.
- Finally, it has been found that, by operating in one of the higher- order broadside mode, i.e. TM, the impedance bandwidth is several times larger than is achievable in other patch of comparable dielectric thickness.

The antenna is designed using transmission and cavity model approach. The details of the designing are given in section III. Section IV shows the even and odd mode technique used for the analysis of gap-coupled antennas. Using this technique, the proposed design for calculating the impedance of gap coupled ARMSA is given in section V. Section VI shows the results and discussion and the conclusion is given in section VII.

2. Theoretical considerations

Microstrip antennas have a number of useful properties, but one of the serious limitations of these antennas has been their narrow bandwidth characteristics. Researchers have been engaged in removing this limitation for the past 20 years, and have been successful in achieving an improved impedance bandwidth for different antennas. Since many wide-band applications require a low-profile conformal antenna, much work has gone into designing wide-band MSA elements or producing MSAs with a dual resonance characteristic. The philosophy behind this technique is that if the resonant frequency of the coupled element or elements is slightly different to that of the driven patch, then the bandwidth of the entire antenna may be increased.

The Gap coupled ARMSA can be represented as the two parallel microstrip lines as shown in figure 1 and 2.

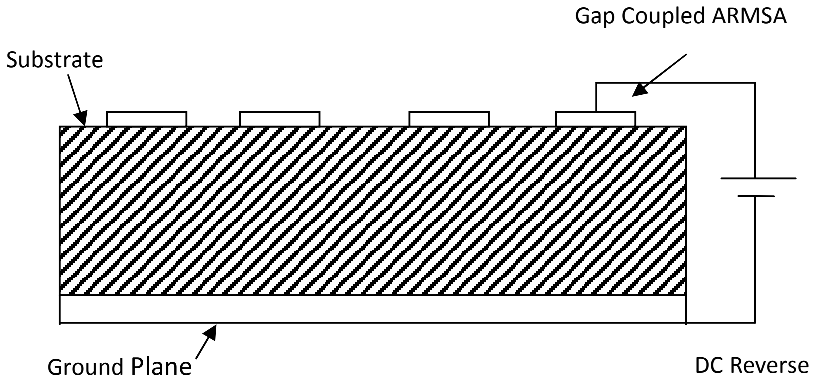


Figure1: Side view of the gap-coupled ARMSA

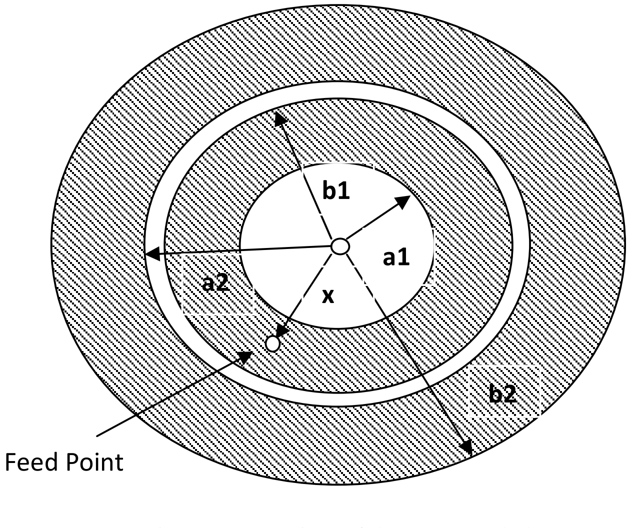


Figure2: Top view of the gap-coupled ARMSA

Figure.2 shows two gap coupled annular ring antennas in which inner one is feeded at point(c, 0) by a coaxial cable (a1<c<b2) where a_1 and b_1 is inner and outer radius of the inner ring and a_2 and b_2 is inner and outer radius of the outer ring. The inner ring is fed with the coaxial cable while the outer ring is kept parasitic. The thickness of the substrate h is small as compared to the difference between the inner and outer radius of the inner ring. The analysis is done using only one parasitic antenna.

The equivalent circuit for gap coupled ARMSA is shown in figure 3 and 4.

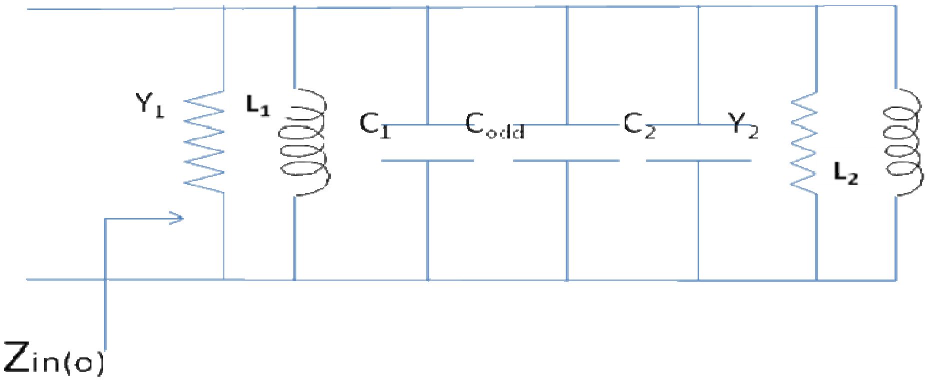


Figure3: Modified equivalent circuit of gap-coupled ARMSA for odd mode

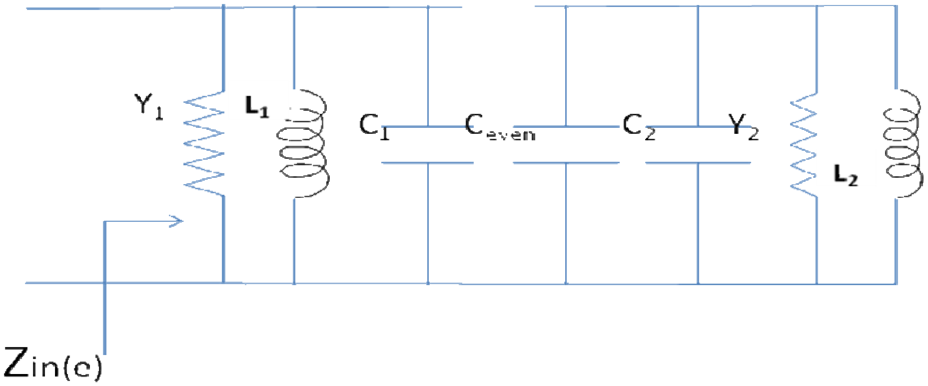


Figure4: Modified equivalent circuit of gap-coupled ARMSA for even mode

It can be expressed as the parallel combination of Y_1, L_1, C_1 and Y_2, L_2, C_2 where the subscript 1 represent for inner ring and 2 for the outer parasitic ring. The component L represents the stored magnetic energies while C represents electric energies, which occur at below patch metallization and the fringing fields around the radiating apertures of inner and outer ring. The admittance Y shows the power loss through coupling and radiating apertures. The parasitic patch is excited by the gap coupling whereas the feed patch is excited by the coaxial probe feeding technique.
The value of Y_1, L_1, and C_1 is calculated using cavity model as,

$$L_1 = \frac{\mu h}{\pi k_1^2 [n,m]} \left[J_n(k_1 c) Y_n^{'}(k_1 a_e) - Y_n(k_1 c) J_n^{'}(k_1 a_e) \right]^2 \qquad \text{----------(1)}$$

$$C_1 = \frac{\mu \varepsilon_0 \varepsilon_r}{L k_1^2} \qquad \text{----------(2)}$$

$$Y_1 = \frac{\pi}{h}\left[\left(\frac{E_a}{E_c}\right)^2 g(a,a) + \left(\frac{E_b}{E_c}\right)^2 g(b,b) - 2\frac{E_a E_b}{E_c^2} y(a,b)\right] \quad \text{----------(3)}$$

Where

$$[n,m] = \frac{1}{2k_1^2}\left[\left(k_1^2 b_e^2 - 1\right)\left\{J_n\left(k_1 b_e\right) Y_n'\left(k_1 a_e\right) - Y_n\left(k_1 b_e\right) J_n'\left(k_1 a_e\right)\right\}^2 - \frac{4}{\pi^2 k_1^2 a_e}\left(k_1^2 a_e^2 - 1\right)\right] .(4)$$

$$E_a = E_{nm}(a,\phi) \quad \text{....(5)}$$

$$E_b = E_{nm}(b,\phi) \quad \text{.....(6)}$$

$$E_c = E_{nm}(c,\phi) \quad \text{.....(7)}$$

In which (c, 0) is the feed location and denotes the electric field distribution for ARMSA for TMmn mode and given by

$$E_{nm}(\rho,\phi) = \hat{z}\left\{J_n\left(k_1 b_e\right) Y_n'\left(k_1 a_e\right) - Y_n\left(k_1 b_e\right) J_n'\left(k_1 a_e\right)\right\}\cos n\phi \quad \text{..............(8)}$$

And

y(a,b) = mutual apertures between the apertures
g(a,a) = edge conductance at inner radius
g(b,b) = edge conductance at outer radius

Where

a = inner radius of ARMSA
a_e = effective inner radius of ARMSA
b = outer radius of ARMSA
b_e = effective inner radius of ARMSA
μ = permeability of the substrate
h = thickness of the dielectric substrate
k_1 = resonant wavenumber
ε_e = effective relative permittivity
ε_r = relative permittivity of the substrate

3.0 Input Impedance of gap coupled ARMSA

Input impedance for gap coupled ARMSA is given as

$$Z_{in} = Z_{in(e)} + Z_{in(o)} \quad \text{....(9)}$$

Where,

Zin(e) = input impedance for even mode
Zin(o) = input impedance for odd mode

From above fig:

$$Z_{in(e)} = \frac{1}{Z_{in1}} + \frac{1}{Z_{in2}} + \frac{1}{j2\pi f_{12} C_e} \quad (10)$$

$$Z_{in(o)} = \frac{1}{Z_{in1}} + \frac{1}{Z_{in2}} + \frac{1}{j2\pi f_{12} C_o} \quad (11)$$

Z_{in1} is the input impedance of the inner ring and is expressed as the parallel combination of R, L and C. Z_{in2} is the input impedance of the outer ring and is given as:

$$Z_{in1} = \frac{1}{\frac{1}{R_1} + j\omega C_1 + \frac{1}{j\omega L_1}} \quad (12)$$

$$Z_{in2} = \frac{1}{\frac{1}{R_2} + j\omega C_2 + \frac{1}{j\omega L_2}} \qquad (13)$$

4.0 Results and Discussion

4.1 Design specifications for microstrip patch

- Substrate material used = RT Duroid 5870
- Relative permittivity of the substrate ε_r = 2.32
- Effective relative permittivity ε_{eff} = 2.1936
- Thickness of dielectric substrate h = 0.159 cm
- Inner radius of the inner ring a_1 = 1.518
- Outer radius of the inner ring b_1 = 3.187cm
- Effective Inner radius of the inner ring a_{e1} = 1.816 cm
- Effective Outer radius of the inner ring $b_{e1=}$ 3.514 cm
- Inner radius of the outer ring $a_{2\,=}$ 3.282 cm
- Outer radius of the outer ring b_2 = 6.892cm
- Effective Inner radius of the outer ring a_{e2} = 3.608cm
- Effective outer radius of outer ring b_{e2} = 7.248 cm
- Centre design frequency ,f = 6.2 GHz

The simulation of the proposed antenna is performed using CST software. The model was designed to match 50 ohm of the coaxial probe feed. A glance at the model designed in CST software can be done in figure 5, 6 and 7 given below.

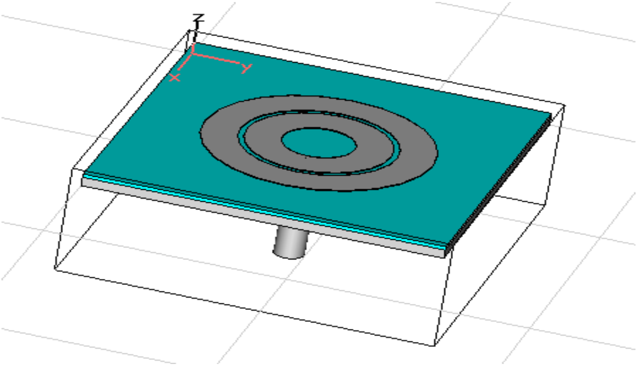


Figure 5: Gap coupled ARMSA model design using CST

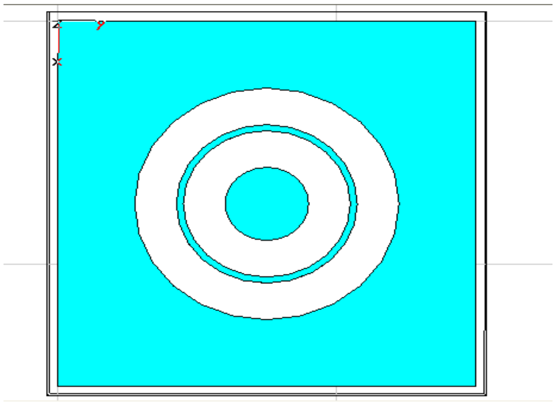


Figure6: Top view showing patch, coaxial feed of the model

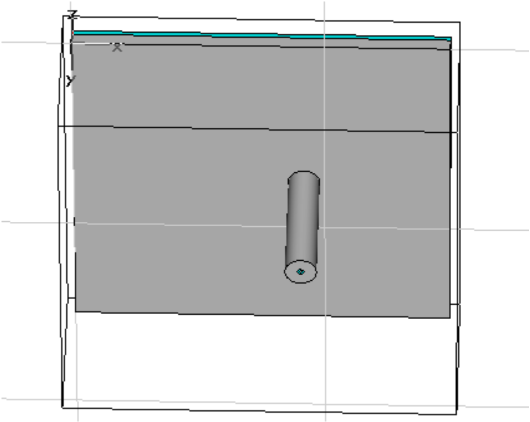


Figure7: Lateral view of the model

The input impedance (real and imaginary part), VSWR, Return loss and radiation pattern for the proposed model are shown in figures below.

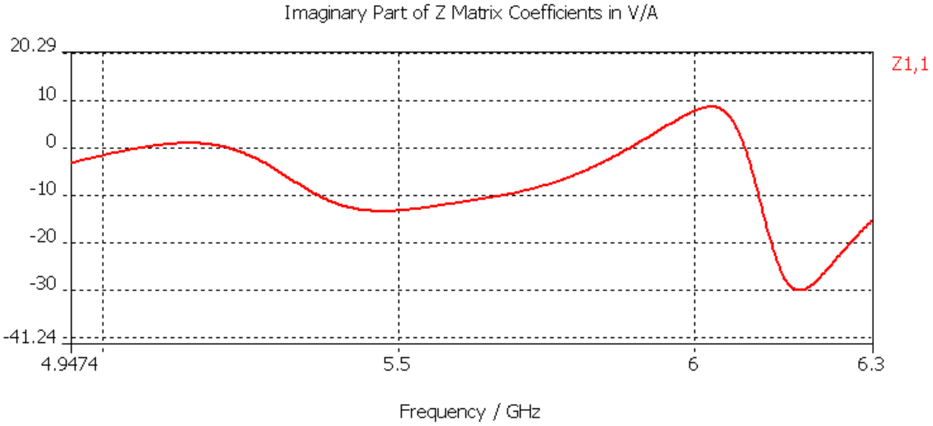


Figure8: Imaginary part of input impedance

The frequency characteristics of the input impedance (real and imaginary part) of the gap coupled concentric annular ring microstrip antenna are shown in figure 8 and 9.

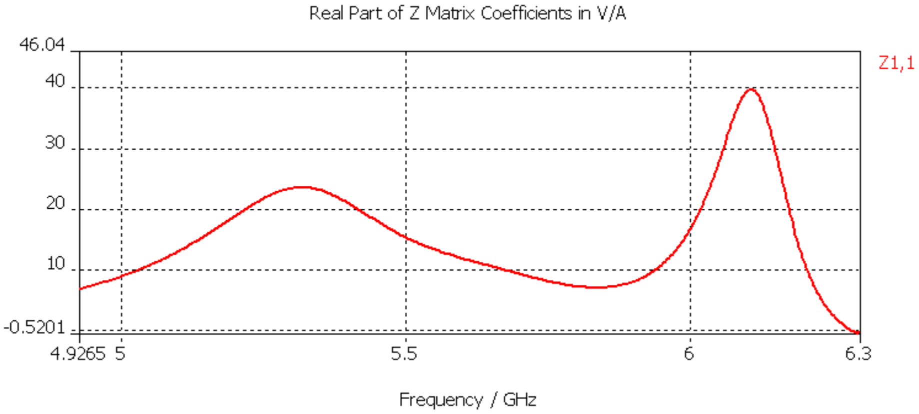


Figure9: Real part of input impedance

The real part of input impedance attains an optimum value of 40 ohms at a particular value (6.1 GHz) and then starts decreasing. On the other hand the imaginary part of input impedance almost always decreases around the resonant frequency.
Two different resonant frequencies are observed at f_1=5.2 GHz and f_2=6.1 GHz as shown in figure 10.

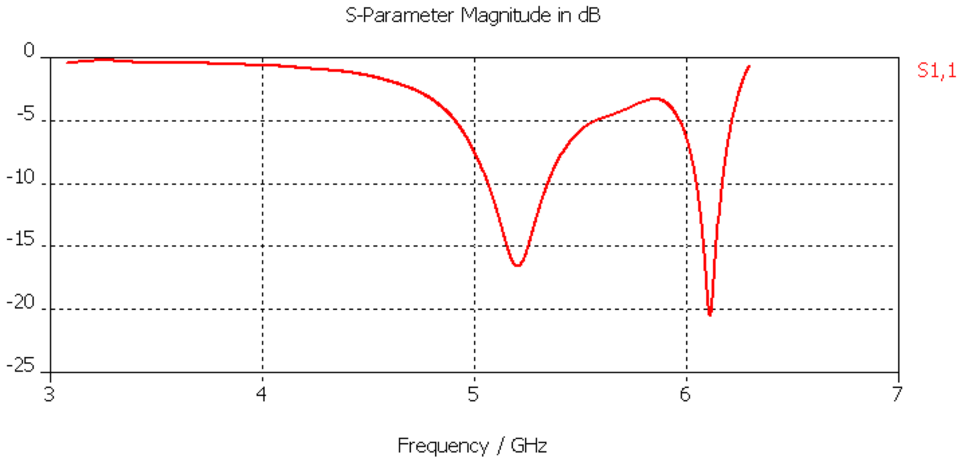


Figure 10. Return Loss of the patch antenna

The figure shows that antenna radiates best at 6.1 GHz, where S_{11}= -20 db. Further, at 3.2 GHz the antenna will radiate virtually nothing as S_{11} is close to 0 db.

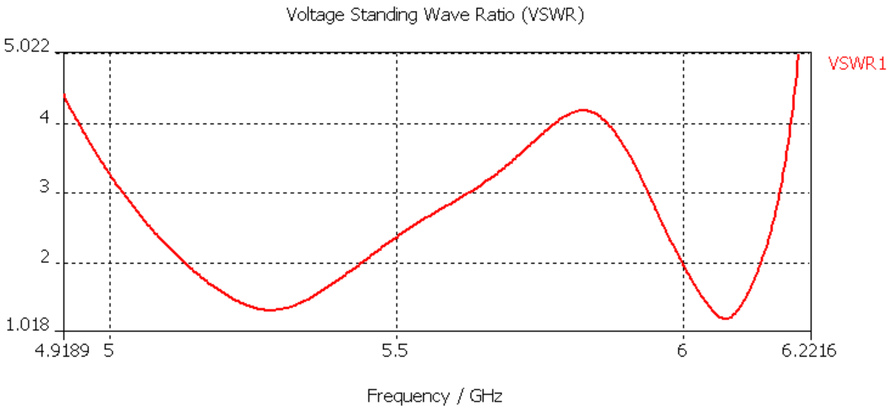
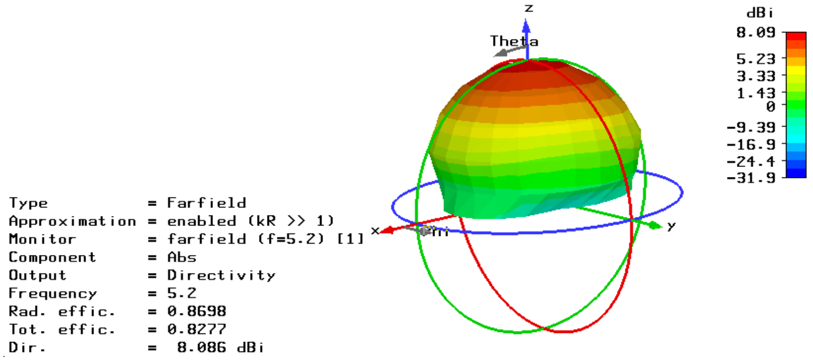


Figure11: VSWR of the Antenna

Variation of VSWR as a function of frequency is shown in figure 11. The VSWR is found to have the minimum value of 1.19 at 6.08 GHz. The VSWR is less than 2 throughout the bandwidth at both the resonant frequencies.

The radiation pattern of the desired antenna is shown using CST software.



```
Type            = Farfield
Approximation = enabled (kR >> 1)
Monitor         = farfield (f=5.2) [1]
Component       = Abs
Output          = Directivity
Frequency       = 5.2
Rad. effic.     = 0.8698
Tot. effic.     = 0.8277
Dir.            =  8.086 dBi
```

Figure11: Radiation Pattern of the Antenna

5.0 CONCLUSION

The gap coupled annular ring microstrip antenna is designed and various parameters like input impedance, VSWR, return loss and radiation pattern are calculated using CST software. The proposed antenna exhibits dual frequency bands (return loss less than -10db) with impedance bandwidth of 4.8% for lower band (5.07-5.32 GHz) and 2.13% for higher band (6.05-6.18 GHz).

REFERENCES

[1]. W. C. Chew, “A broad band annular ring microstrip antenna”, IEEE Trans. On antenna and propagation, vol. AP-30, no.5, pp 918-922, sept. 1982

[2]. I.J. Bahl, S. S. Stuchly and M. A. Stuchly, “A new microstrip radiator for medical applications”, IEEE Trans. Microwave theory Tech., vol. MTT.-28, pp. 1464-1468, 1980

[3]. J. W. Mink, “Circular ring microstrip antenna elements”, presented in 1980 Antennas propagat. Soc. Int. Symp. , Quebec, Canada, June 1980.

[4]. S. Ali, W. C. Chew and J. A. Kong, “Vector Hankel transform analysis of annular ring microstrip antenna”, IEEE Trans. Antennas propagat., vol. A.P. 30, no. 4, pp.637-644, july1982.

[5]. Bhartia P and Bahal I J, Frequency agile microstrip antennas, Microwave J **25,** , pp. 67- 70,1982.

[6]. B. K.Kanaujia and B. R. Vishvakarma “Analysis of Gunn integrated annular ring microstrip antenna, IEEE trans Antenna Propag. **52(1)** , , pp.88-97, 2004.

[7]. A K Gautam and B R Vishvakarma, Frequency agile microstrip antenna symmetrically loaded with Tunnel diodes, Microwave Opt technol Lett **48**, ,pp. 1807-1810,2006.

[8]. G Kumar and K C Gupta, Broad-band microstrip antennas using additional resonators gap-coupled to the radiating edges, IEEE Trans. Antenna Propag. **32**, , pp. 1375-1379,1984.

[9]. M K Meshram and B R Vishvakarma, Gap coupled microstrip antenna for wide-band operation, Int J Electronics, pp. 1161-1175,2001.

[10]. Ramesh Garg, “Design equations for coupled microstrip lines”, Int. Electronics, vol. 47, no. 6, pp. 587-591, 1979

[11]. C. K. Aanandan, P. Mohanan and K.G. Nair, “Broad band gap coupled microstrip antenna”, IEEE Trans. On antenna and propagation, vol.38, no.10, pp.1581-1585, Oct.1990.

[12]. A.K. Bhattacharya and Ramesh Garg, “A Microstrip Array of concentric Annular rings”, IEEE Trans. on antenna and propagation, vol. A.P.33.no.6, June 1985.

Author biography

Shuchita Saxena received the Bachelor of Technology degree in Electronics and Communication engineering from Moradabad Institute of Technology, Moradabad in 2004.Currently seeking the opportunity for doing M. Tech in Microwave Engineering from Uttar Pradesh Technical University, Lucknow. Her main research interest is in analysis of microstrip antennas.

Dr. Binod Kumar Kanaujia received Degree in Electronics Engineering from KNIT, Sultanpur in 1994, M.Tech. in Microwave Engineering in 1998 from BHU. He Completed PhD in Microwave Engineering in 2004 from BHU. His teaching and research interests are in the areas of MIC, EMT. He is working as Associate Professor in AIT, Delhi.