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Abstract- Like many forms of microstrip patches, the annular ring has received considerable attention. When operated in its fundamental (TM^{11}) mode, this printed antenna is smaller than its rectangular or circular counterparts. The annular ring may also be somewhat broadband in nature when operated near the TM^{12} resonance [5]. It has been shown that the structure is a good resonator (with very little radiation) for TM_{1m} modes (m odd), and a good radiator for TM_{1m} modes (m even) [8]. A circular ring microstrip antenna is designed for TM_{11} mode at the resonance frequency of 2 GHz, and analyzed for different parameters such as return loss, VSWR, input impedance and bandwidth. Analysis shows that the size of designed antenna is small at the cost of low bandwidth.

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DESIGN AND ANALYSIS OF CIRCULAR RING MICRO STRIP ANTENNA

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Design and Analysis of Circular Ring Microstrip Antenna

Rajesh Kumar[1], Dr. D. C. Dhubkarya[2]

Abstract-Like many forms of microstrip patches, the annular ring has received considerable attention. When operated in its fundamental (TM^{11}) mode, this printed antenna is smaller than its rectangular or circular counterparts. The annular ring may also be somewhat broadband in nature when operated near the TM^{12} resonance [5]. It has been shown that the structure is a good resonator (with very little radiation) for TM_{1m} modes (m odd), and a good radiator for TM_{1m} modes (m even) [8]. A circular ring microstrip antenna is designed for TM_{11} mode at the resonance frequency of 2 GHz, and analyzed for different parameters such as return loss, VSWR, input impedance and bandwidth. Analysis shows that the size of designed antenna is small at the cost of low bandwidth.

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I. INTRODUCTION

Microstrip antennas, often referred to as patch antennas consists of a very thin metallic patch (usually gold or copper) placed a small fraction of a wavelength above a conducting ground plane, separated by a dielectric substrate. The radiating patch can be of any planar geometry e.g. rectangle, circle, square, thin strip (dipole), elliptical, ring, circular ring, disc sector and triangular. The radiating elements and the feed lines are usually photo etched on the dielectric substrate.

Microstrip antennas have some advantages such as light weight, low cost etc. and some disadvantages such as low bandwidth and efficiency. However there are different methods by which their efficiency and bandwidth may be improved. These antennas are low-profile, conformable to planar and non-planar surfaces, simple and inexpensive to manufacture using modern printed circuit technology, mechanically robust when mounted on rigid surfaces, compatible with microwave monolithic integrated circuits (MMIC) designs, and when particular patch shape and mode are selected they are very versatile in terms of resonant frequency, polarization, pattern, and impedance. In addition, by adding loads between the patch and the ground plane, such as pins and varactor diodes, microstrip antennas with variable resonant frequency, impedance, polarization, and pattern can be designed [4].

The microstrip antennas find application in high-performance spacecraft, aircraft, missile and satellite, mobile applications, where size, weight, cost, performance, ease of installation, and aerodynamic profile are constraints, and low profile antennas are required. Presently, there are many government and commercial applications, such as mobile radio and wireless communications that have similar specifications where micro strip antennas can be used. They are also used in Wireless Local Area Networks (WLANs) to provide short range high-speed data connections between mobile devices and wireless access points.

The annular-ring structure was first studied by Bergman and Schultz in 1955 as a travelling wave antenna. It has also been used as a resonator and as a radiator in medical applications [3]. Like many forms of microstrip patches, the annular ring has received considerable attention. When operated in its fundamental (TM11) mode, this printed antenna is smaller than its rectangular or circular counterparts. The annular ring may also be somewhat broadband in nature when operated near the TM12 resonance [5]. It has been shown that the structure is a good resonator (with very little radiation) for TM1m modes (m odd), and a good radiator for TM1m modes (m even) [8].

In this paper a circular ring micro strip antenna is designed for TM11 mode at the resonance frequency of 2 GHz, and analyzed for different parameters such as return loss, VSWR, input impedance and bandwidth. Analysis shows that the size of designed antenna is small at the cost of low bandwidth. Fig.1. shows a circular ring microstip antenna.

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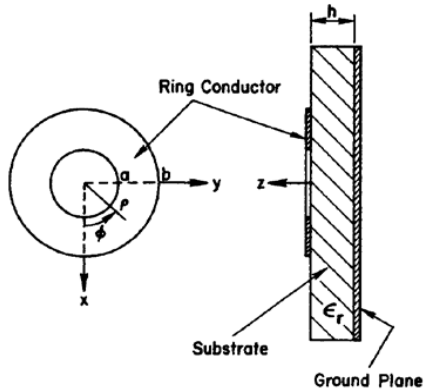

Fig.1. A circular ring microstip antenna [8]

II. Analytical Model

For designing the proposed antenna, cavity model analysis is used. The cavity model of the ring is obtained by replacing its peripheries with magnetic walls. Because there is no variation of the fields along the z direction for thin substrates, the modes are designated as TM_{nm} modes. With no excitation current, the wave equation for electrical field can be written as-

$$(\nabla^2 + k^2)\vec{E} = 0 \qquad (1)$$

Where

$$k = 2\pi\sqrt{\varepsilon_r/\lambda_0} \qquad (2)$$

The general solution for the wave equation (1) in cylindrical coordinates is given as-

$$E_z = E_0[J_n(k\rho)Y_n'(ka) - Jn'kaYnk\rho \cos n\emptyset \qquad (3)$$

and

$$H_\rho = \frac{j}{\omega\mu\rho}\frac{\partial E_z}{\partial \emptyset}, \qquad H_\emptyset = \frac{-j}{\omega\mu}\frac{\partial E_z}{\partial \rho} \qquad (4)$$

Where $J_n(.)$ and $Y_n(.)$ are the Bessel functions of the first and second kind, and of order n, respectively. The other field components are zero inside the cavity. The surface current on the lower surface of ring metallization is given by-

$$\vec{J}_S = -\hat{z} \times \vec{H} = -\widehat{\emptyset}H_\rho + \hat{\rho}H_\emptyset \qquad (5)$$

Or

$$J_\emptyset = \frac{jnE_0}{\omega\mu\rho}[J_n(k\rho)Y_n'(ka) - J_n'(ka)Y_n(k\rho)] \sin n\emptyset \qquad (6a)$$

$$J_\rho = \frac{-jnE_0}{\omega\mu}[J_n'(k\rho)Y_n'(ka) - \ Jn'kaYn'k\rho \cos n\emptyset \qquad (6b)$$

The radial component of the surface current must vanish along the edges at $\rho = a$ and $\rho = b$ to satisfy the magnetic wall boundary conditions. This gives

$$J_\rho(\rho = b) = H_\emptyset(\rho = b) = 0 \qquad (7)$$

Application of this boundary condition leads to the well- known characteristic equation for the resonant modes:

$$J_n'(kb)Y_n'(ka) - J_n'(ka)Y_n'(kb) = 0 \qquad (8)$$

For the given values of a, b, ε_r and n, the frequency is varied and the roots of Equation (8) are determined. These roots are denoted by k_{nm} for the resonant TM_{nm} modes and form X_{nm} such that

$$X_{nm} = k_{nm}\, a \qquad (9)$$

The integer n denotes the azimuthal variation as per $\cos n\emptyset$, while the integer m represents the mth zero of Equation (8) and denotes the variation of fields across the width of the ring.

If $C = b/a$ then Equation (8) can be written as-

$$J_n'(CX_{nm})Y_n'(X_{nm}) - J_n'(X_{nm})Y_n'(CX_{nm}) = 0 \qquad (10)$$

Using zeroth-order approximation, the resonant frequency is obtained as-

$$f_{nm} = \frac{X_{nm}\, c}{2\pi a\sqrt{\varepsilon_r}} \qquad (11)$$

Where

c = velocity of light in free space
a = Inner radii of ring
ε_r = dielectric constant of substrate

In Equation (11), the effect of the fringing fields has not been considered. Thus the frequency calculated by this formula is lower than the measured value. The accuracy can be improved by using effective dielectric constant (ε_{re}).

$$f_{nm} = \frac{X_{nm}\, c}{2\pi a\sqrt{\varepsilon_{re}}} \qquad (12)$$

To determine the value of ε_{re}, the ring resonator is modeled as a microstrip line bent in a circular shape. The effect of the curvature on the resonant frequency is expected to be small provided the radius of curvature is large compared with the width of the strip conductor. The effective dielectric constant can be determined as-

$$\varepsilon_{re} = \frac{1}{2}(\varepsilon_r + 1) + \frac{1}{2}(\varepsilon_r - 1)\left(1 + \frac{10h}{W}\right)^{-\frac{1}{2}} \qquad (13)$$

Where

$W = b - a$
b = Outer radii of the ring
h = thickness of dielectric

The modified values of the inner and outer radii of the ring can be determined using parallel plate waveguide model of a microstrip line and are given by-

Where W_e is the effective width of the ring and can be given by-

$$W_e(f) = W + \frac{(W_e(0) - W)}{\left[1 + (f/f_p)^2\right]} \qquad (15)$$

$$W_e(0) = 120\pi h/z_0\sqrt{\varepsilon_r} \qquad (16)$$

$$f_p = z_0/2\mu_0 h \qquad (17)$$

Where μ_0 is the permeability and z_0 is the quasi-static characteristic impedance of microstrip line of width W. A pair of empirical formulas for the modified radii of the ring are-

$$a_e = a - \frac{3h}{4} \quad (18a)$$

$$b_e = b + \frac{3h}{4} \quad (18b)$$

The above model gives reasonably accurate results as long as W_e is less than the mean diameter of the ring, i.e. $(a+b)$.

An approximate value of $X_{n1} = k_{n1}a$ can be obtained using the equation (19). This expression gives reasonably accurate value of k_{n1} for $n \leq 5$ and $[(b-a)/(b+a)] < 0.35$

$$X_{n1} = k_{n1}a = 2an/(a+b) \quad (19)$$

III. Design Specificatons

To design the proposed microstrip antenna, glass epoxy (quartz) dielectric material having dielectric constant (ε_r) of 4.2 and dielectric loss tangent (tanδ) of 0.0005 is selected with the substrate of height 1.6 mm. Outer to inner radius ratio (b/a) of the patch is selected as 2. The parameters calculated using cavity model are- effective dielectric constant (ε_{re}) = 3.52, inner radius (a) = 8.6 mm, outer radius (b) = 17.2 mm, width of the patch (W) = 8.6 mm.

IV. Simulation Results

IE3D v. 14.2 is used as a tool for the simulation purpose. A trial and error method is used to locate the feed point. For different location of the feed point, the return loss (RL) is compared and that feed point is selected, where the return loss is most negative (or minimum) or where the input impedance is 50 ohms for the resonant frequency. From Return Loss v/s frequency plot (RL = -24.9 dB at 2.0 GHz) and VSWR v/s frequency plot (VSWR = 1.121 at 2.0 GHz), the bandwidth of the designed circular ring microstrip antenna is found to be 21 MHz. From Magnitude v/s frequency plot, the value of antenna impedance is 49.14 Ω at frequency of 1.999 GHz which is very close to resonant frequency 2.0 GHz.

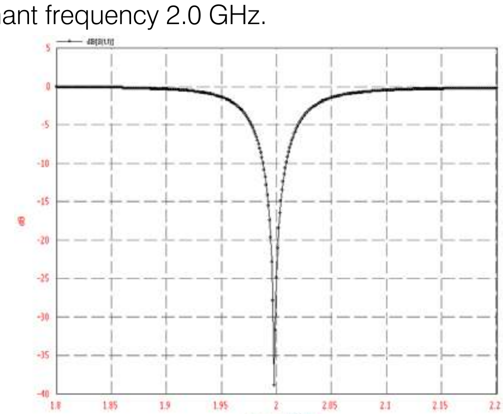

Fig.2. S-parameter plot for Return loss v/s Frequency for 1.8 2.2 GHz

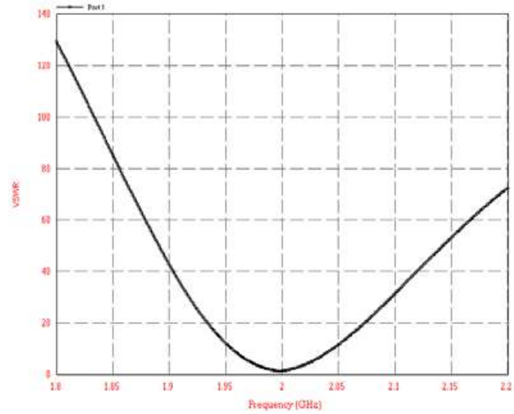

Fig.3. VSWR v/s Frequency plot for 1.8 -2.2 GHz.

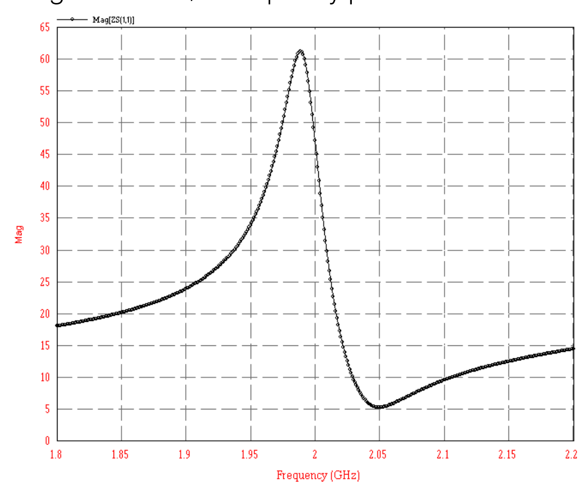

Fig.4. Magnitude v/s Frequency plot for Z Parameter for 1.8-2.2 GHz

V. Testing results

After simulation the designed antenna is fabricated with given specifications and tested on spectrum analyzer using coaxial probe feed. On testing the fabricated antenna the return loss of -13.5 dB is obtained at 1.989 GHz, which is very close to desired frequency of operation for the designed antenna i.e. (2.0 GHz). Also the bandwidth obtained is 25 MHz.

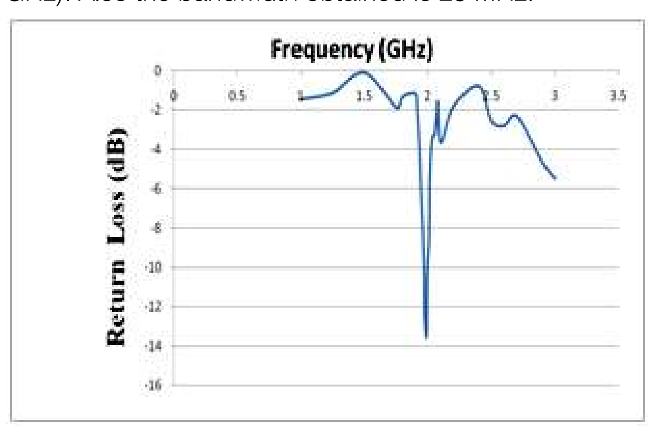

Fig.5. Return loss v/s Frequency plotted in excel based on testing results

VI. Conclusion

If we compare the simulated and tested values of designed antenna, we find that the return loss is lower than -10 dB in both the cases, for desired frequency of the designed antenna. This states that the losses are minimum during the transmission. The tested and simulated bandwidth has the ratio of 1.23, so we can say that the level of mismatch is not so high. The BW of the designed hardware was found to be small of the order of 21 MHz, which matches the theoretical background of CRMSAs operating in dominant modes. Thus it is found practically that the ring microstrip antennas have smaller dimensions at the cost of low bandwidth when operated in TM_{11} mode.

VII. Acknowledgement

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