Design and Analysis of Annular Ring Slot MSA for wireless and UHF Applications

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***Abstract*— In this paper the design and analysis of annular ring slot microstrip antenna is presented. The design frequency of antenna is 2.1 GHz and used substrate for the fabrication of the proposed antenna is FR4. After simulation and testing return losses of about -14 dB, -14 dB, -19 dB and -10 dB are obtained at frequencies approximately 0.6 GHz, 1.6 GHz, 2.2 GHz and 2.7 GHz respectively. The measured and simulated results of the optimal design of the proposed antenna are found out with the aid of network analyzer and IE3D software. The obtained impedance bandwidth covers the frequency band of wireless systems. Therefore this design can be useful in wireless communication and UHF (L and S Band) communication applications.**

Keywords: ***annular ring slot, L and S band, IE3D, spectrum analyzer***.

I. INTRODUCTION

The advancement of science and technology has accelerated the use of microwaves and millimeter waves in the area of communication engineering. However, the demand of miniaturization has given the concept of microwave integrated circuit and printed circuit components and devices. This has led to the development of microstrip antenna. An antenna is a device that provides a means for radiating or receiving radio waves. In other words, it provides a transition from guided waves on a transmission line to a "free space" wave (and vice versa in the receiving case). Thus information can be transferred between different locations without any intervening structure [1,2].

The numerous advantages of microstrip antenna, such as its low weight, small volume, and easy of fabrication using printed-circuit technology led to the design of several configurations for various applications. With increasing requirements for personal and mobile communications, the demand for smaller and low-profile antennas has brought the microstrip antenna to the forefront.

Microstrip antenna consist of a very thin ($t << \lambda_0$, where λ_0 is the free-space wavelength) metallic strip (patch) placed on a small fraction of a wavelength ($h << \lambda_0$, usually $0.003\ \lambda_0 \leq h \leq 0.05\ \lambda_0$) above a ground plane[3]. The microstrip patch is designed so its pattern maximum is normal to the patch (broadside radiator). This is accomplished by properly choosing the mode (field configuration) of excitation beneath the patch. End-fire radiation can also be accomplished by judicious mode selection. For a rectangular patch, the length L of the element is usually $\lambda_0/3 < L < \lambda_0/2$. The strip (patch) and the ground plane are separated by a dielectric sheet.

II. THEORETICAL CONSIDERATIONS

Resonant frequency (f_r) can be found using equations, $h<0.05\ \lambda_o$; E_z= Constant; $k_z=0$; f_r for TM^z_{mno} mode is given by[4]

$$(f_r)_{mno} = \frac{1}{2\pi\sqrt{\mu\varepsilon}}\left(\frac{X'_{mn}}{a}\right) \quad (1)$$

TM^z_{110} mode is dominant mode. Thus using,

$$(K_\rho)^2 + (K_z)^2 = K_r^2 = \omega_r^2\mu\epsilon \quad (K_z=0 \text{ and } K_\rho=X'_{mn}/a) \quad (1a)$$

where a is the radius of the patch. We have,

$$\frac{(X'_{mn})^2}{a^2} + 0 = (2\pi f_r)^2\mu\varepsilon \quad (2)$$

$$=(4\pi^2 f_r)^2\mu\varepsilon$$

So, $$f_r^2 = \frac{X'^2_{mn}}{a^2 4\pi^2\mu\varepsilon}$$

or $$f_r = \frac{X'_{mn}}{2\pi a\sqrt{\mu\varepsilon}} \quad (3)$$

the value of X'_{mn} for m=1 and n=1 is equal to X'_{11}=1.8412

$$(f_r)_{110} = \frac{1.8412}{2\pi a\sqrt{\mu\varepsilon}}$$

or $$(f_r)_{110} = \frac{1.8412c}{2\pi a\sqrt{\varepsilon_r}}$$

Where c is the speed of light.The effective radius a_e is used in place of actual radius (due to fringing effect)

$$a_e = a\left\{1+\frac{2h}{\pi a\varepsilon_r}\left[\ln\left(\frac{\pi a}{2h}\right)+1.7726\right]\right\}^{\frac{1}{2}} \qquad (4)$$

Thus, $(f_r)_{110} = \dfrac{1.8412c}{2\pi a_e\sqrt{\varepsilon_r}}$ (5)

The basic shape of the design is circular and a slot of annular ring shape is incorporated in the design (Fig. 1). Therefore, the design equations for circular microstrip antenna are also taken into consideration. The fields for a circular microstrip antenna are defined in terms of Bessel function [5].

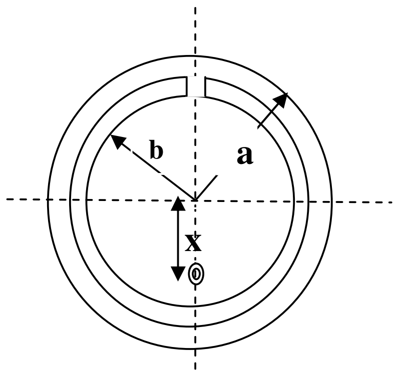

Fig.1 Base Geometry of design (Circular MSA)

III. CALCULATIONS

(i)Resonant frequency

The resonance frequency of a CMSA is obtained using the given formula [3].

$$f_o = \frac{K_{mn}c}{2\pi a_e\sqrt{\varepsilon_e}}$$

where K_{nm} is the *m*th root of the derivative of the Bessel function of order n . For the fundamental TM_{11} mode, the value of K_{nm} is 1.84118. The a_e and ε_e are the effective radius and the effective dielectric constant of the MSA, respectively. The fringing fields along the circumference of the given MSA are taken into account by replacing the patch radius *a* by the effective radius a_e.

$$a_e = a\left[1+\frac{2h}{\pi a\varepsilon_r}\left\{\ln\left(\frac{a}{2h}\right)+1.41\varepsilon_r+1.77+\frac{h}{a}(0.268\varepsilon_r+1.65)\right\}\right]^{\frac{1}{2}} \qquad (6)$$

The value of ε_e is obtained using

$$\varepsilon_e = C(a, h, \varepsilon_e, \varepsilon_r)/C(a, h, \varepsilon_e) \qquad (7)$$

where $C(a, h, \varepsilon_e, \varepsilon_r)$ and $C(a, h, \varepsilon_e)$ are the total capacitances of the dominant TM_{11} mode of MSA with and without a dielectric substrate respectively. These can be calculated as [3]

$$C(a.h,\varepsilon_o,\varepsilon_r) = \frac{0.8525\varepsilon_o\varepsilon_r\pi a^2}{h}+0.5C_f \qquad (8)$$

In (8), the first term is the main capacitance of the disc and the second term is the fringing capacitance, C_f, which is given by

$$C_f = 2a\varepsilon_o\left[\ln\left(\frac{a}{2h}\right)+1.41\varepsilon_r+1.77+\frac{h}{a}(0.268\varepsilon_r+1.65)\right] \qquad (9)$$

$C(a, h, \varepsilon_e)$ is calculated by putting $\varepsilon_r = 1$ in (8) and (9). For thin substrates, ε_r should be used instead of ε_e in (6.1), and for thick substrates ($h > 0.05\lambda_o$), ε_e should be used.

(ii)Actual radius of the Patch

Using equations 6 to 9 and taking the values of different parameters as follows, we can calculate the value of actual radius of the patch.

K_{mn}=1.84118; c=3x10^{8}m/s;
ε_o= 8.86x10^{-12}F/m; ε_r=4.2;
h=1.6 mm; Frequency(f_o)=2.1GHz

We can now calculate the value of the fringing capacitance C_f, $C(a, h, \varepsilon_e, \varepsilon_r)$, $C(a,h, \varepsilon_e)$, ε_e and effective radius a_e followed by the value of the actual radius 'a' which come out to be 24mm.

IV. EXPERIMENTAL SETUP

Experimental setup is shown in fig. 2 for the determination of the return loss of the proposed antenna. In this experiment the designed antenna is connected to the SWR Bridge (50Ω, 5-300MHz) and the network analyzer. This is attached to the available network analyzer of range 0-3 GHz. This analyzer determines the return loss of the designed annular ring slot shaped microstrip antenna and demonstrate the return loss versus frequency pattern.

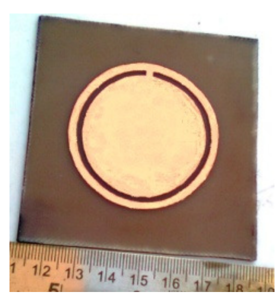

Fig. 2 Experimental Setup and network analyzer

V. Result and Discussion

An annular ring slot shape microstrip patch antenna at operating frequency with the slot inner and outer radius 20 and 22 mm respectively which is multiple resonant at various frequencies in the range from 0.5GHz to 3.0GHz is designed. The effects on different types of antenna parameters like return loss, VSWR, impedance and radiation pattern is found out. The results shows the multiband performance of annular ring slot antenna as improved impedance, improved SWR(standing wave ratio) performance on a reduced physical area when compared to basic geometries.

After simulation the return losses of about -14 dB, -14 dB, -19 dB and -10 dB are obtained at frequencies approximately 0.6 GHz, 1.6 GHz, 2.2 GHz and 2.7 GHz respectively which are shown in figure 3.

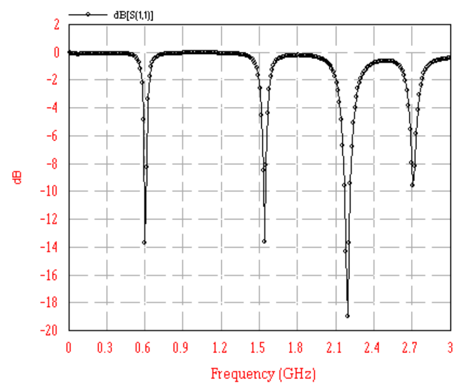

Fig. 3 Frequency vs. return loss plot for annular ring slot MSA

The plot of frequency vs. real part of input impedance obtained on IE3D is shown in figure 4.

The VSWR is shown in figure 4 should be less than 2 as per our simulated result is concerned; it gives at frequency of approximately 0.6 GHz, 1.6 GHz, 2.2 GHz and 2.7 GHz. Result at 2.2GHz is more desirable.

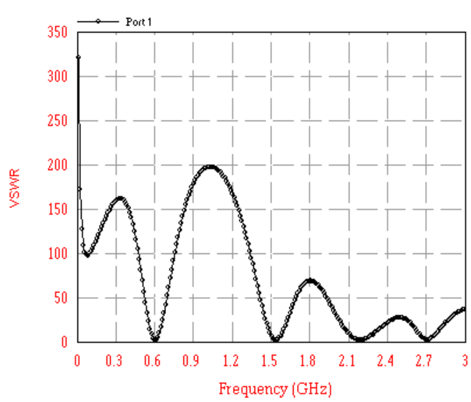

Fig. 4 VSWR vs. frequency plot

As the microstrip patch antenna radiates normal to its surface, the elevation pattern for the θ = 0 and θ=90 degrees is of special interest. The radiation pattern of the antenna is shown in fig. 5 below.

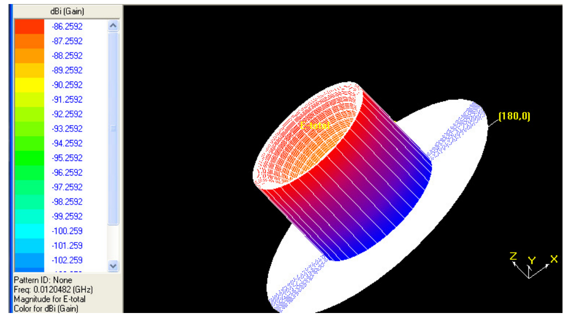

Fig. 5 (a) 3D view of the radiation pattern

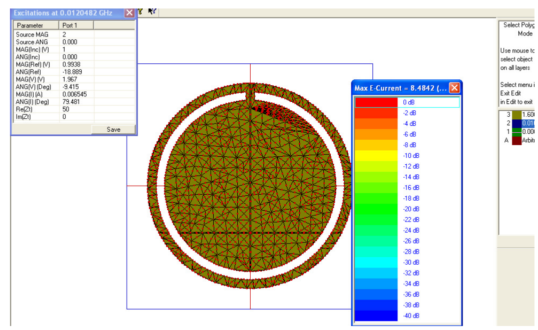

Fig. 5(b) radiation pattern (current distribution)

(i)Comparison between Measured and Simulated Results

Graph of the simulated value & measured value are shown in the Fig. 6 In these graph simulated and measured result are closely matched. Simulated result is -45dB at 2.9GHz resonating frequency and measured result is -40.05dB at 2.7 GHz resonating frequency.

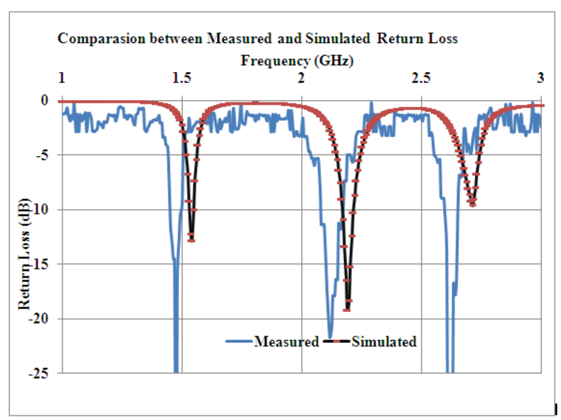

Fig. 6 Graph of the comparison of simulated & measured value

VI. Conclusion

Annular ring slot microstrip antenna offers better bandwidth as compared to other conventional shapes of patch. After simulation and testing return losses of about -14 dB, -14 dB, -19 dB and -10 dB are obtained at frequencies approximately 0.6 GHz, 1.6 GHz, 2.2 GHz and 2.7 GHz respectively. The result obtained through IE3D software yield compatible with experimental results.

The obtained impedance bandwidth covers the frequency band of wireless systems. Therefore this design is useful for wireless communication applications and UHF (L and S Band) communication applications.

ACKNOWLEDGMENT

We are thankful to Prof. P. K. Singhal (Professor and Head, ECE Department) MITS Gwalior (M.P.) for providing the measurement facilities.

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