Simplified Design Formulae for Annular Ring Shape Patch Antenna

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Abstract: **Microstrip Antennas (MSA) finds wide applications in modern communication gadgets because of their light weight, small size and low cost. Annular Ring Microstrip antenna (ARMSA) also received considerable attention. This printed antenna is smaller in size in comparison with rectangular, circular and triangular patch antenna. For designing of the Annular Ring Microstrip patch antenna, researchers have given many formulae to calculate the parameters of antenna like inner and outer radius of antenna at a given frequency. But these formulae are very complex and have very large calculation and have no uniformity in the formulae. As the shape of the antenna changes the design formulae change completely. This paper presents a simple formula for the physical dimensions of the annular ring patch antenna. These set of formulae is validated by comparing the simulated and measured results for different substrates.**

Keywords: microstrip antenna, annular ring microstrip antenna, substrate.

1. INTRODUCTION

Rectangle microstrip antennas are designed for many applications. RF energy harvesting is the novel field for this. Many structures have been presented for this purpose by the author [1-4]. The annular ring shape antenna is also a useful shape of patch for microstrip antenna. The Annular ring has been analyzed extensively using the cavity model because the cavity model analysis is found to be quite simple with significant accuracy. This can be accomplished using a procedure similar to that for the rectangular patch but for annular ring patch we use cylindrical coordinates [5]. As we know that due to fringing effect the electrical radii of the ring are different from the physical radii of the ring and researcher have given many empirical formulae for relating the electrical radii of the ring to physical radii of the annular ring. The most commonly used formulae are available in the literature [6] and known as classical formulae. Designing the annular ring patch antenna from these set of classical formulae are very lengthy and time consuming. The disadvantage of using these formulae is that whenever there is a need of changing the material /substrate, all the calculations should be repeated. And this consumes time. Equivalent design concept was the solution of this problem [7]. Many works were presented by using this equivalent design concept [8-9]. These transformation formulae are very easy to remember and have very easy calculations.

The annular ring patch was designed first by using conventional formula [6] and simulated for a frequency 2.4 GHz and by using this structure as basic design derived a simplified transformation set of formulae for annular ring shape patch antenna. This transformation design formulae for annular ring patch antenna were presented by the author [10].

In this paper a simplified formulae are presented for calculating the inner and outer radius of annular ring shape patch antenna for designing the structure of antenna. The evaluation process and validation of these proposed formulae are also described in the preceding section.

For validating these formulae, many sets of antennas having different substrate material of different thicknesses are designed and simulated on the software HFSS. Further one simulated result and one standard measured result are given under the section results and discussion section.

2. PROPOSED FORMULAE FOR ANNULAR RING SHAPE PATCH ANTENNA

Due to fringing effect the electrical radii of the patch are different from the physical radii of the patch by a small amount. Mathematically [6]:

$$a = a_e + \Delta a \quad (1.1)$$

$$b = b_e + \Delta b \quad (1.2)$$

Where a and b are the outer and inner physical dimensions of ring. a_e and b_e are the electrical dimensions respectively. Δa and Δb are the extensions in the diameters due to the fringing fields. The physical structure dimensions are as shown in the Fig.1.

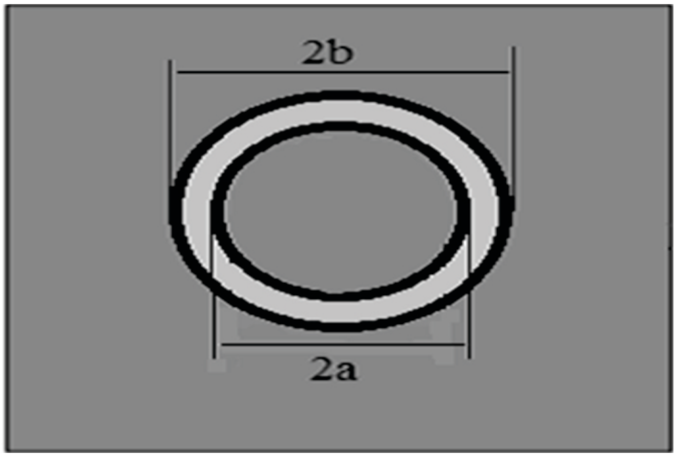

Figure 1 Physical dimensions of the annular ring shape patch antenna.

In this paper the work reported an extension of the Bhatnagar's postulate [7] for the case of an annular ring patch. For this, many designs for different frequencies and different substrate were simulated on the HFSS software. And by evaluating the results, it is concluded that the extensions in the radii of the patch (Δa and Δb) are directly proportional to the electrical radii a_e and b_e of an annular ring patch and it is given by:

$$\Delta a = \beta \times H \times a_e \quad (1.3)$$

$$\Delta b = \beta \times H \times b_e \quad (1.4)$$

$$\text{Where } H = \frac{\lambda g}{h}$$

Where β is the Bhatnagar constant and H is the normalized thickness of the substrate. λg is the guided wavelength and h is the physical height of the substrate.

By combining above equations (1.3) and (1.4) we get new simplified formulae for the designing of the annular ring patch antenna which is proposed as simplified formulae for the designing annular ring patch antenna. These are given as below:

$$a = a_e\,(1+ \beta H) + \quad (1.6)$$

$$b = b_e\,(1- \beta H) + \quad (1.7)$$

The value of β is 1 for all shape of patch. And H is dependent on the designed frequency.

There are a number of formulae to design the annular ring microstrip patch antenna. Some are simple and some are quite complex to calculate. There is no uniformity in these available formulae. This new simplified formulae are used to find the physical radii of the annular ring patch and gives appropriate results in designing of the antenna and beauty of these new set of formulae is that these are valid for regular shapes of patch antenna like rectangular, equilateral triangular ,circular and annular ring patch antenna.

3. METHODOLOGY

The following steps are used to implement this new formula for physical radii of the annular ring patch.

- All the antennas are designed to resonate on frequency range between 1 – 9 GHz.
- Microstrip feed line is used for all antennas having characteristic impedance of 50Ω.
- Substrate materials are chosen having dielectric constant in range 1 to 10.
- The electrical radii (a_e & b_e) of the annular ring patch antenna are calculated using classical formula given in equation (1.1-1.2) for all designs.
- The classical formulae for calculating the inner and outer radii of the annular rig patch are given in e.
- The proposed formula for calculating the physical inner and outer radius of the annular ring patch is already available [6]. Simulated the designs by using these formulae.
- To validate these new proposed formulae, all antennas are designed using new proposed formula and simulated on HFSSv16 and then simulation results were compared with that of antenna designed using classical formulae.
- For further verification, the experimental results of the design of an antenna using new formula on resonant frequency 2.4 GHZ are also presented in this report.

Licensed Software HFSSv16 (ANSYS) has been used for designing and simulating the antenna. Vector Network Analyzer (Keysight Technologies) of the range 1-14 GHz has been used for measuring the experimental results of the fabricated antenna.

4. RESULTS AND DISCUSSIONS

Many designs are simulated by calculating their dimensions by using these proposed formulae for different dielectric substrate for the frequency 2.4 GHz. Also the same designs are simulated by using the classical formulae [6]. The results were surprisingly same.

The Table 1.1 below gives a comparison of resonant frequency obtained from the simulation of the antenna design for a desired frequency of the 2.4GHz varying the dielectric constant of the substrate material.

TABLE 1.1 Comparison table of simulated results for different substrates structure designed by using classical formulae and proposed formulae

Designed Frequency – 2.4 GHz		
Dielectric constant	Resonant Frequency (Simulated) in GHz	
	Designed by Classical Formulae	Designed by proposed Formulae
2.2	2.36	2.38
3	2.45	2.41
4.4	2.42	2.46
6	2.405	2.41
9.2	2.41	2.39
10.2	2.421	2.42

The simulated results are very large in number so one sample of the simulated results from the classical formulae and proposed formulae are shown in Fig. 2 and Fig. 3 respectively.

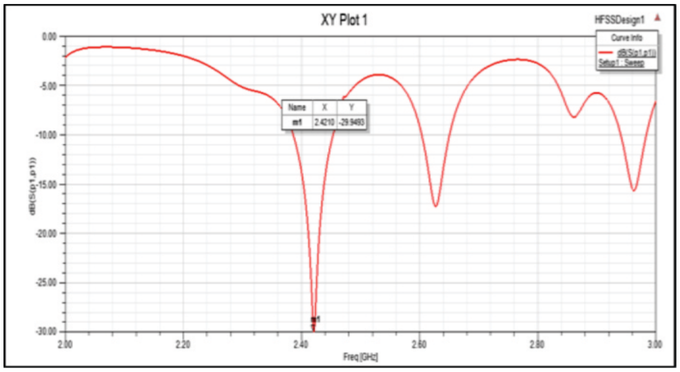

Figure 2 Simulated return Loss versus frequency plot for f_r =2.4 GHz and ε_r=4.4 (designed by classical formulae).

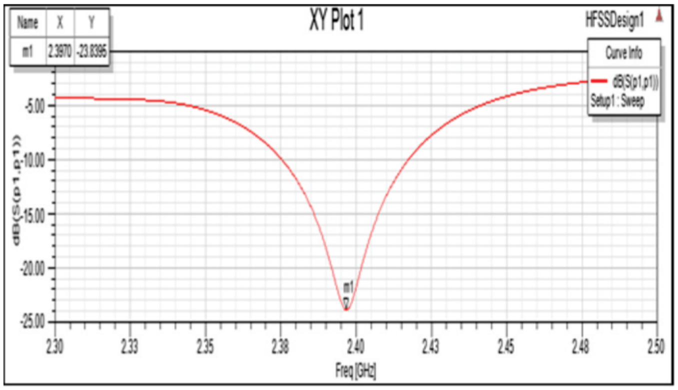

Figure 3 Simulated return loss versus frequency plot for f_r =2.4 GHz and ε_r=4.4 (designed by proposed formulae).

The substrate having dielectric constant 4.4 and thickness 0.298 mm was selected for fabricate the structure designed by the proposed formulae. This design frequency was 2.4 GHz. The fabricated structure of the designed antenna is shown in Fig. 4

Figure 4 Fabricated Structure of the annular ring patch antenna designed by using the proposed formulae (a) front view (b) Back view.

Experimental result also validated the result as shown in Fig.5.

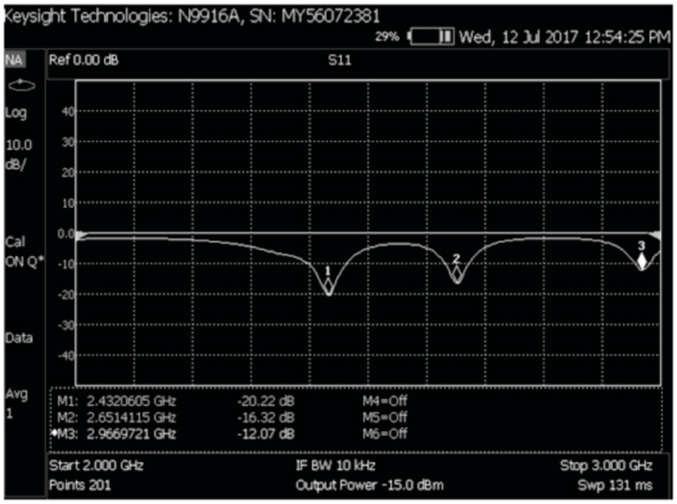

Figure 5 Experimental result of the fabricated structure for f_r =2.4 GHz and ε_r=4.4 (designed by proposed formulae).

All the simulated and measured results validated the proposed formulae.

5. CONCLUSION

The new design formulae can be used as an alternate easy formula for calculating physical dimensions of an annular ring patch antenna. These give simple relation between physical inner and outer radii of the patch of the annular ring patch antenna. For the validation of these formulae various antennas have been designed and their return loss plots have also been studied. The simulated and experimental results validated the new simplified design formulae for annular ring shape patch antenna.

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