Single to Multiband Frequency Technique for Wireless and Telecomm Microstrip Antenna Design

Shelly Chawla, Jagtar Singh, Paras Chawla

Abstract— In this article, the variations of changing the number of rings, diameter and patch material are studied for circular ring-shape planar antenna and explore the possibility of converting a single band antenna to multiband. While doing so retain the compactness of multiband antenna. Such type of planar structure has wide potential with multiband support which is to be sight for different aerospace and telecommunication applications. A circular conductor is placed centered in the narrow annular ring having inner radius (R_i) and outer radius (R_o). These patterns are printed on polytetraflouroethlene (PTFE) substrate having dielectric constant 4.4, a thickness of 1.59mm, and a loss tangent of 0.020. The design laminate antenna structure consists of, a ring-shape radiating conducting material and a 50 ohm matching coaxial type feed line which work well for common resonating frequency 7.5 GHz bands. In single band the return loss value is -12.96dB and in case of dual ring the return loss value is -20.32dB at 7.5 GHz. The other band achieved in two ring is 6.5 GHz having return loss value is -21.45dB.

Keywords- Single to multiband; RF device; Microstrip antenna; Ring-shape, PTFE.

I. INTRODUCTION

In telecommunication and aerospace, there are several types of planar antennas, the most common of which is the laminate patch antenna or planar [1]. Common laminate antenna shapes are rectangular, H-shape, E-shape and circular, as conclusion any continuous geometrical patch is possible. The dielectric loading of a planar antenna affects both its impedance bandwidth and radiation pattern [2-3]. Because the ease of designing of physical dimension and shape, laminates planar microstrip are also inexpensive to manufacture and design. With the increase in the value of dielectric constant of the substrate, the bandwidth of antenna decreases which increases the Q factor of the antenna and therefore decreases the impedance bandwidth [4].

The most popular types of planar resonator are the patch, loop, slotted, PIFA, meander line and fractal. However the basic half-wavelength ($\lambda/2$) coaxial center-fed dipole and quarter-wavelength ($\lambda/4$) monopole along with ground plane are extensively used [3,9].

The main aim for miniaturisation for a laminate is the maximum use of volume available for a given geometry. Such maximum volume will theoretically provide the upper bound for both bandwidth as well gain [5].

The art of planar structure miniaturization for the antenna volume allotted for any given application is to find the best trade-off between gain and bandwidth. The radiation characteristics of a planar will be affected by miniaturizing process. Planar microstrip structure miniaturization affects gain, bandwidth and efficiency, but in some cases, it also affects polarization. The efficient way to make microstrip antennas smaller is to bend their geometrical shape so that it force the current to the meander and as a result structure seem electrically larger than it actual shape [3,6-9].

A limitation in microstrip miniaturization in small sized antennas is the difficulty of finding the exact point of feeding. The correct feeding technique of a very small size planar is often neither unbalanced nor balanced, but lies in between the range. The laminate conducting antenna (a typical case of an unbalanced antenna) is a simple example that illustrates this effect, which can be made electrically small by using a substrate with a high permittivity. However, the size of the planar antenna also depends on the size of its ground plane [3,9].

II. DESIGN FOR SINGLE TO DUAL BAND APPLICATION

In order to reduce the antenna size and provide a suitable input impedance match, two techniques are employed; the insertion of strips into the annular ring and placing a cross-slot into the ground plane [2,10]. The objective of choosing ring is that, size of the resonant ring is smaller than that of the corresponding patch and depends on the width of the microstrip implemented. Input impedance of a ring operated in the TM_{11} mode is considerably higher, whereas its impedance bandwidth is smaller, in comparison with the dimension of patch. As the width of strip is increased, the characteristics of a ring approach that of the patch. The mean circumference of ring equals the guide wavelength of the microstrip used [11].

The proposed design annular-ring patch antennas with a cross-slotted ground plane yield a much smaller size for a given frequency and are easily matched to 50 ohms [12].

Depending on parameter selection, the planar antenna can be designed for single band circular-polarization, dual-band circular polarization or further modification for multi-band/wide band operation. Some significant advantages are evident for these shapes, such as nearly good circularly polarized properties are obtained for these compact shapes. The multi-frequency can provide small frequency ratios. The center-frequency has less dependence on the location of the feed point and small size of antenna [14].

The most popular configuration is the circular patch or disk. By treating the patch, ground plane, and the material between

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the two as a circular cavity the mode supported by the circular patch antenna can be found. The modes that are supported primarily by a circular planar antenna whose substrate height is small (h <<λ) are TM^z where z is perpendicular to the conducting patch [13, 15].

However, for the circular patch there is only one degree of freedom to control (radius of the patch). Doing this does not change the order of the modes, but it does change the absolute value of the resonant frequency [9].

The resonant frequencies of the cavity, and thus of the planar antenna, where the substrate height 'h' is very small, the fields are constant along *z*. Therefore the resonant frequencies for the TM^z_{110} modes are as [3-9, 14]

$$(f_r)_{110} = \frac{1.8412 v_0}{2\pi a_e \sqrt{\in_r}} \tag{1}$$

Where v_o is the velocity of light

A first order approximation of radius of circular Disk to the solution of below equation for 'a' is to find a_e

$$a_e = a\left\{1 + \frac{2h}{\pi a \in_r}\left[\ln\left(\frac{\pi a}{2h}\right) + 1.7726\right]\right\}^{1/2} \tag{2}$$

Where a is calculated from equation (1) & substituting for a_e

$$a = \frac{F}{\left\{1 + \frac{2h}{\pi F \in_r}\left[\ln\left(\frac{\pi F}{2h}\right) + 1.7726\right]\right\}^{1/2}} \tag{3}$$

$$F = \frac{8.791 \times 10^9}{f_r \sqrt{\in_r}} \tag{4}$$

Approximate value of annular ring inner & outer radius resonant frequency can be obtained by the following approaches used for the other patch antennas. To the zeroth-order approximation, the resonant frequency is obtained by setting

$$a = 1 + \frac{1}{49}\ln\left\{\frac{u^4 + (u/52)^2}{u^4 + 0.432}\right\} + \frac{1}{18.7}\ln\left\{1 + \left(\frac{u}{18.1}\right)^3\right\}$$

$$b = 0.564\left(\frac{\varepsilon_r - 0.9}{\varepsilon_r + 0.3}\right)^{0.053} \tag{5}$$

Where u = W/h

The radiation fields of a circular ring antenna can be obtained either from the magnetic current approach or the electric current distribution on the surface of the ring.

The length and width dimension of ground plane and substrate as-

$L_g = 6d + L$ and $W_g = 6d + W$

The location of coaxial wave port is given as

$W_f = W/2$ and $L_f = l/2\sqrt{\varepsilon_{eff}}$

Designing Parameters of single band antenna and results

The geometry of a single band compact circularly polarized antenna is shown in figure 1. A circular patch is centered in the narrow annular-ring, of inner radius R_i and outer radius R_o. These patches are printed on PTFE substrate, of $\varepsilon_r = 4.4$, a thickness of 1.6mm, and a loss tangent of 0.021. The crossed slot in the ground plane has unequal lateral lengths, L_x and L_y, with a slot width w. This structure excites two degenerate orthogonal modes with equal amplitude and 90^0 phase difference by tuning various parameters (R_i, R_p, L_x, and L_y) right-hand circular polarization (RHCP) radiation is obtained.

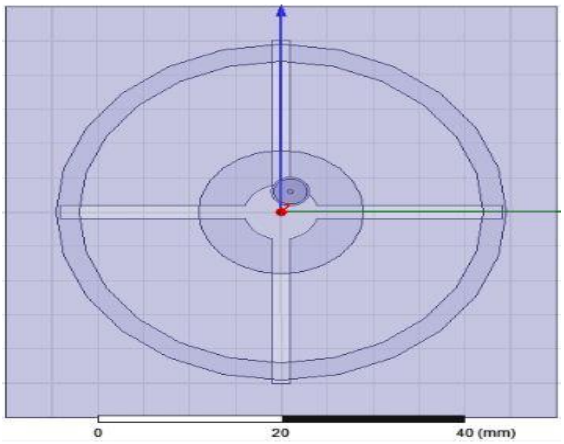

Fig.1 Geometry of single band antenna.

TABLE I. PHYSICAL DIMENSIONS OF SINGLE BAND ANTENNA DESIGN

Parameters	Values (mm)
Ground plane (a)	60
Ground plane (b)	60
Slot horizontal (c)	48
Slot width (d)	2
Slot vertical (e)	50
f	48
feed point in x-direction (f_x)	1.58
feed point in x-direction (f_y)	5
g	2
ro_g1disk	4
ro_gdisk	4
ro_icable	0.325
ro_ocable	2.08
ro_pdisk	9
ro_ring1	24.5
ro_subcable	1.83
ro_g1disk	4
ro_gdisk	4

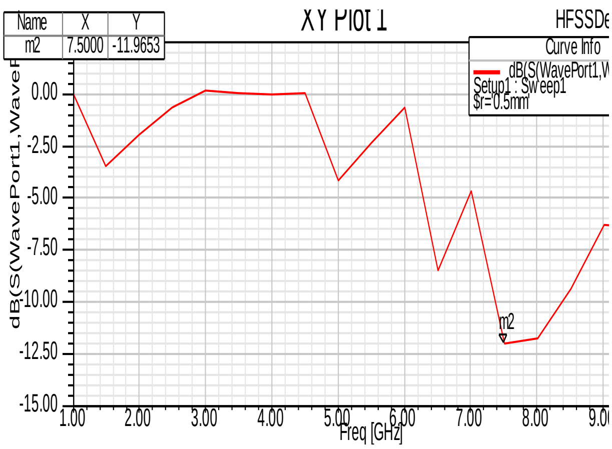

Fig. 2 Simulated S-parameter result of single band antenna

Designing Parameters of dual band antenna and results

The dual band operation is achieved by employing an extra annular-ring, in addition to the first one which surrounds the small circular patch as shown in below figure 3. The circularly-polarized frequency ratio of the two resonant modes is tunable to a small value, suitable for wireless communications systems. The resonant frequency of the lower mode is mainly determined by the larger outer ring radius while the resonant frequency of the higher mode is dependent on both the inner ring radius and the separation between the inner annular-ring and the inner circular patch [9].

By adjusting the lengths of the cross-slot arms, the upper and lower resonances can be split into two orthogonal modes with nearly equal amplitude and 90^0 phase difference. Hence, a dual-frequency circularly-polarized antenna is achieved either lateral slot length $L_x>L_y$, then right-hand circular polarization or lateral slot length $L_x<L_y$, then left-hand circularly polarization [3-9]. The result of two ring structure is achieved at four resonating frequency band i.e. 6.5, 7.5, 8.0 and 9.9 GHz respectively. The common band is 7.5 GHz which have improved return loss value as compare to single ring geometry as shown in figure 4.

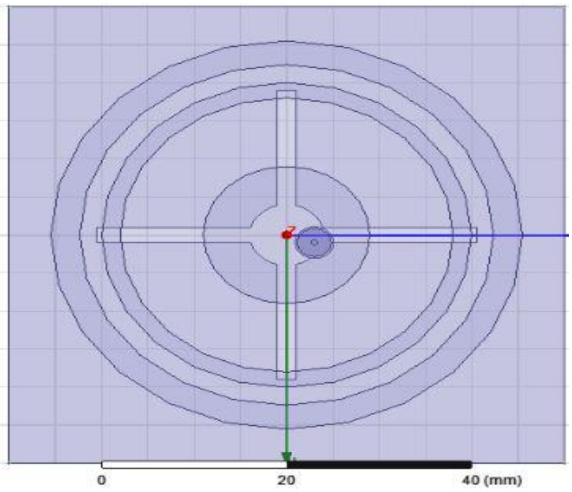

Fig.3 Geometry of dual band antenna.

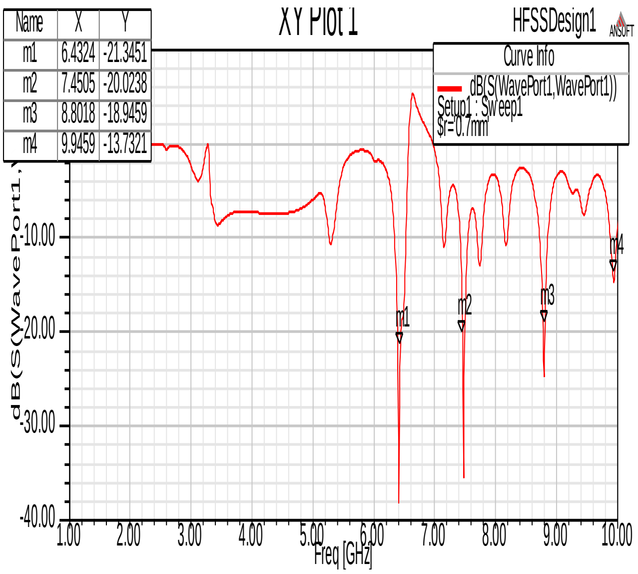

Fig. 4 Simulated S-parameter result of dual band antenna

III. CONCLUSIONS

The performance of annular ring antenna was designed, optimized and has been studied for single and dual band. The effect of varying the diameter of annular ring and feed point was calculated and simulated using HFSS. Comprehensive simulations, analysis and optimization demonstrate the complexity of the structures in terms of design fabrication process. The planar antenna return loss, radiation pattern and polarization was calculated and concluded that these antennas show excellent performance as compare with numerical formulae.

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