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STUDY OF A NOVEL C-BAND CIRCULAR SLOT ANTENNA HAVING FRQUENCY BAND-NOTCHED FUNCTION

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Abstract- The Circular slot antenna is designed for C-Band(4Ghz-8Ghz) is suitable for mobile applications centre frequency at 5 GHz. It contains 12 semicircular iteration section, each section is 1mm wide produce fringing effect. The proposed antenna has a compact size, good radiation characteristics, wide band-width of 4.6 GHz to satisfy the requirement of the current wireless communication systems. Antenna parameters like return loss(S11), gain, VSWR and radiation pattern are calculated and simulated and compared. The design and simulation is done using HFSS v13 simulation tool and it is fabricated on a FR4 Epoxy and RT duroid 5880 dielectric substrate.

Keywords- FR4 Epoxy; RT Duroid 5880; Circular Slot Microstrip Antenna; Gain; Directivity; HFSS

I. INTRODUCTION

Modern Wireless communication Systems require low profile, lightweight, high gain and simple structure antennas to assure reliability, mobility, and high efficiency .A patch antenna is very simple in construction using a conventional microstrip fabrication technique. It consists of a patch of metallization on a grounded dielectric substrate. They are low profile, lightweight antennas, most suitable for aerospace and mobile applications. Patch antennas have matured considerably during last years, and many of their limitations have been overcome. In our study we are interested in circular slot by introducing stubs in circular patch because of their small size compared with other shapes which is desired in wireless communication. In this study, several designs of circular slot antennas are presented in Fr4 Epoxy and RT Duroid. We will compare simulation result of both dielectrics. Moreover, these designs are simulated using HFSS. Based on the simulation results, comparison between both dielectrics is achieved in C-Band. This band contains frequency ranges that are used for many satellite communications transmissions, some Wi-Fi devices, some cordless telephones, and some weather radar systems. This paper is divided into five sections: the first section is devoted to give an overview of the patch antennas in and a preface of the important parameters in single element designs, for both and circular Fr4 Epoxy and RT Duroid 5880 substrates. Second section discusses the Design,Procedure and presents simulation results for Paper Submission. Third section presents a comparison between both substrates simulation results. Finally, a brief conclusion is presented in the fourth.

II. ELEMENT STUDY

2.1. Theory

Circular slot antenna design in C-band and with optimal characteristic is the overall objective of this section. To achieve this overall objective, the primary task is to choose a suitable geometry of the patch for the antenna. The proposed shape is circular slot frequency band notch function patch for review. The study of return loss and gain show that the antenna has a band-notched characteristic at 5-GHz C band. An important and notable feature of this antenna set up is the 50 ohm microstrip line with elliptical shaped stubs on the opposite side of the substrate.
The microstrip feed line width is 4.9 mm in RT duroid and 3.0mm width in FR4 Epoxy with 12 C shaped Stubs iterations of 1mm wide.

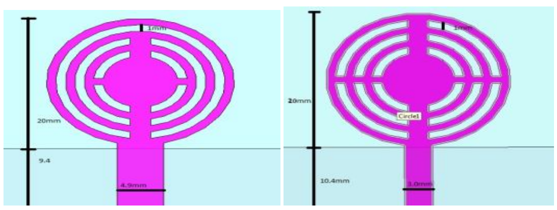

Figure 1. Shows Structure of Circular slot antenna with 12 semicircular iteration 1mm wide and Partial Ground plane of RT Duroid and FR4 Epoxy with feed line width 4.9mm and 3mm respectively.

For circular slot antenna, suppose patch length is L, patch width is W, dielectric thickness is h, dielectric constant is εr, light speed is c, resonant frequency is fr, wavelength is radius of circular patch a, we found in equation (1) .

$$a_{o} = a\sqrt{1 + \frac{2h}{\pi a \varepsilon r}\left[\ln\left(\frac{\pi a}{2h}\right) + 1.7726\right.} \quad (1)$$

Δf is bandwidth, f_{o} is center frequency and VSWR is Standing wave ratio in equation (2).

$$\frac{\Delta f}{f_{o}} = \frac{\mathrm{VSWR} - 1}{\mathrm{Q}\sqrt{\mathrm{VSWR}}} \quad (2)$$

$$z_{o} = \frac{120\pi}{\left[\frac{W}{H} + 1.393 + \frac{2}{3}\ln\frac{W}{H} + 1.444\right]\sqrt{\varepsilon r}} \quad (3)$$

Z_{o} is Normalized Impedance is obtained by putting the value of patch width is W, dielectric thickness is h, dielectric constant is εr in last equation.

2.2. Design

2.2.1. Substrate Selection

One of major steps in designing a patch antenna is to choose a suitable substrate of appropriate thickness, permittivity and loss tangent. First a circular patch microstrip antenna with radius a has been considered. The Patch having substrate thickness (h≪λ) substrate dielectric constant εr and relative preamibility μ = 1 having considered lying in XY plane over a large ground plane.The magnetic field has X and Y components.

The substrate Dimension is 30 mm wide and 32 mm long with dielectric permittivity of between 2.2 in RT Duroid and 4.4 in FR4 Epoxy substrates. Most of the microstrip antenna work in the past has employed electrically thin, low permittivity substrates. The Loss tangent is 0.0009 for RT duroid and 0.001 in FR4 Epoxy substrates.

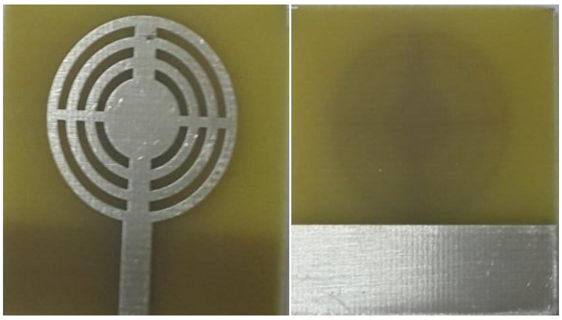

Fig 2 Shows Fabricated Circular slot antenna on Substrate FR4 Epoxy with 12 semicircular iteration 1mm wide and Partial Ground plane 9.4 mm with feed line width 4.9mm .

Recent interest in C-Band systems and miniaturized structure has created a need for substrates that are electrically thicker or have high permittivity. The proposed antennas are designed using the substrate RT Duroid (permittivity ε = 2.2, Dissipation factor tanδ = 0.004,Thermal coefficient = -125ppm/c) and FR4 Epoxy (permittivity ε = 4.4, tanδ = 0.018) and which is widely used for patch antennas..Design and analysis of the proposed antenna in C-Band is done with two different substrate FR4Epoxy and RT Duroid 5880 with BW =4.6GHz , VSWR= -75, H = 1.6mmz.

Parameters	FR4	RT
W(Transmission line width)	3.9 mm	4.9 mm
W/H	1.88	3.06
ε_o(Effective Permittivity)	3.32	1.87
εr(Relative Permittivity)	4.4	2.2
Fr (Centre Frequency)	5 GHz	5 GHz
a (Radius)	8.7 mm	10 mm
Z (Impedance)	50.83	50.49

Table 1. shows parameters used for antenna design in both FR4 Epoxy and RTduroid

2.3.Results and Analysis

2.3.1.Circular microstrip patch antenna

shows the return loss simulated for both Fr4 Epoxy and RT Duroid of circular slot antennas. Circular sector antenna resonates only for one frequencies in out of C-Band :9.5 GHz with return loss between –12 dB and –20.2 dB. But in FR4 Epoxy, it resonates for 6 GHz and the return loss is –17.2 dB. The Bandwidth, gain and efficiencies of corresponding substrates antennas are very poor. This outcomes suggest that circular patch antenna in its present form is not applicable for wireless communication systems .The simulated reflection co-efficient (S11) variation of same antenna in both substrate is given in Fig 3(a) and 3(b).

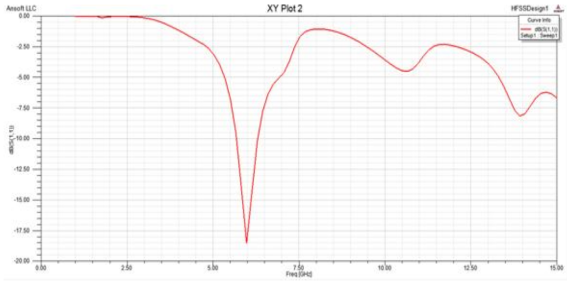

Fig 3(a) Shows Return loss (db(s(1,1))) at Centre Frequency 5 GHz wide BW of 4.4 GHz on FR4 Epoxy.

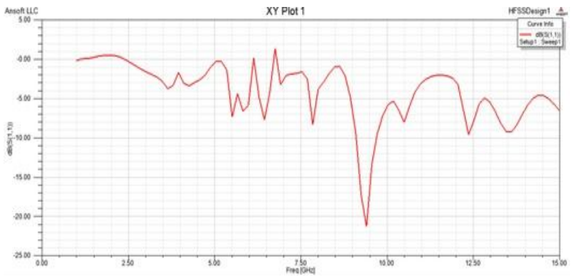

Fig 3(b) Shows Return loss (db(s(1,1))) at Centre Frequency 5 GHz wide BW of 4.4 GHz on RT Duroid.

2.3.2. Effect of C- Shaped slot on Patch

The single layered circular patch geometry discussed above has been modified by inserting a concentric C-shaped stubs in circular patch. It may realize that on increasing the number of stubs in the patch, which in turn increases the resonance frequency of antenna under consideration. Now the antenna resonates for more than one frequencies in C-Band : 5 GHz and 7.6 GHz with return loss between –30 dB and –20.2 dB in FR4 Epoxy and in RT Duroid resonates for two frequencies in C-Band :3.8 GHz and 7.6 GHz with return loss between –25 dB and –27 dB. With insertion of C-shaped slots in the patch geometry, which in turn improves impedance bandwidth of antenna Structure is fed through inset Feed arrangement using a SMA connector associated with 50 ohm. The simulation results suggest that in the range of

5 GHz and 7.6 GHz. The dB (VSWR) simulation results of RT Duroid is given in Fig 5(a) and VSWR simulation results of FR4Epoxyis given in Fig 5(b).

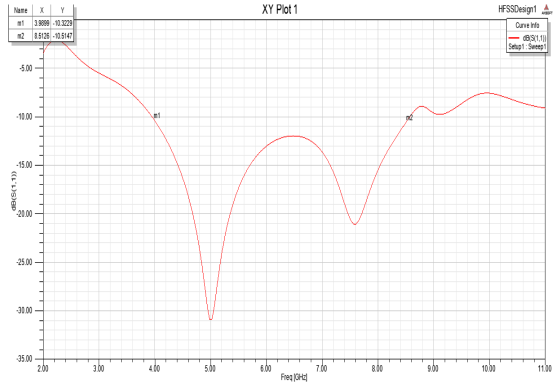

Fig 4(a)Shows Return loss (db(s(1,1))) at Centre Frequency 5 GHz wide BW of 4.6 GHz in FR4 Epoxy Substrate

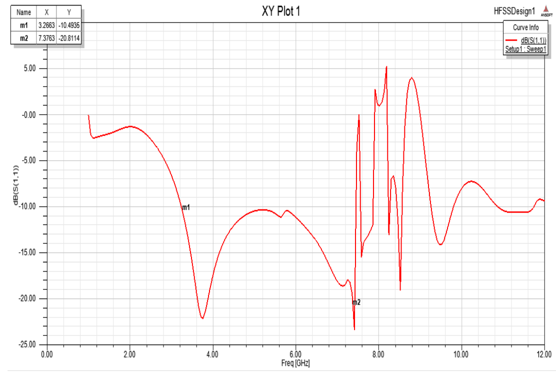

Fig 4(b) Shows Return loss (db(s(1,1))) at Centre Frequency 5 GHz wide BW of 4.4 GHz in in FR4 Epoxy and RT Duroid.

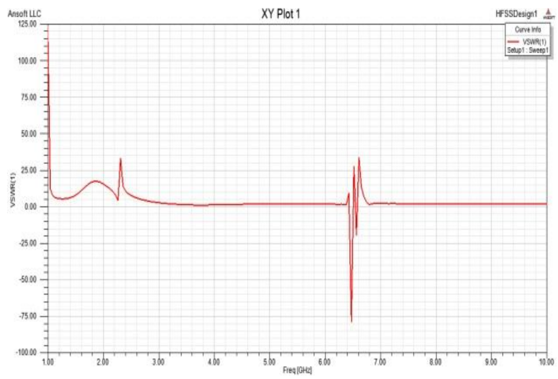

Fig 5(a) Shows VSWR(-80dB) of Circular slot antenna of FR4 Epoxy

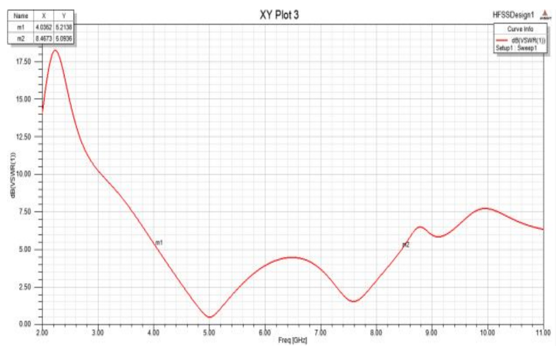

Fig 5(b) Shows VSWR of Circular slot antenna of RTduroid

2.3.3. Radiation pattern and gain

It has omnidirectional radiation pattern for both the substrates and gain for FR4 Epoxy is 3.5 db and for RT Duroid is 3.7 db is given below.

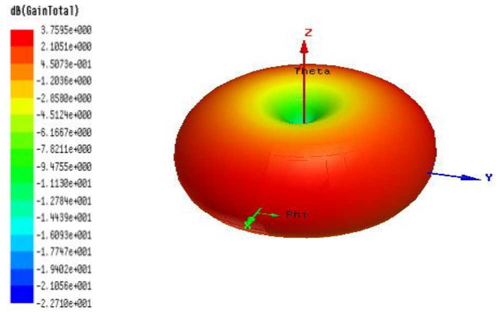

Fig 6(a) Ominidirectional pattern and 3.5 db of gain of FR4 Epoxy

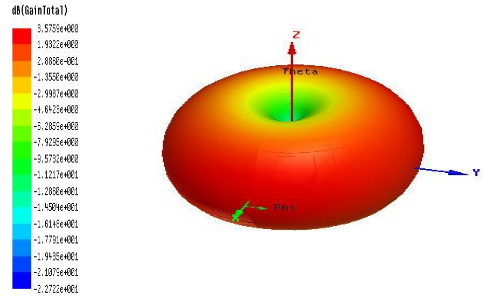

Fig 6(b) Ominidirectional pattern and 3.75 db of gain of RTDuroid

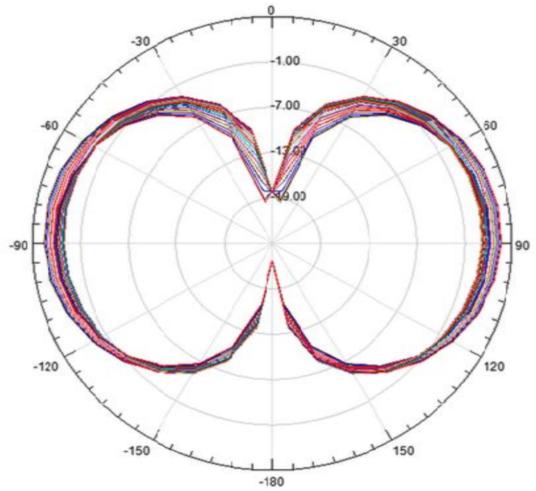

Fig 6(a) Simulated E and H plane elevation patterns of antenna at different frequencies of FR4 Epoxy.

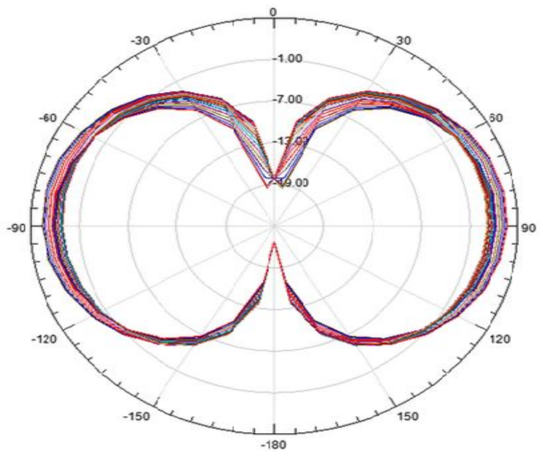

Fig 6(b) Simulated E and H plane elevation patterns of antenna at different frequencies RT Duroid.

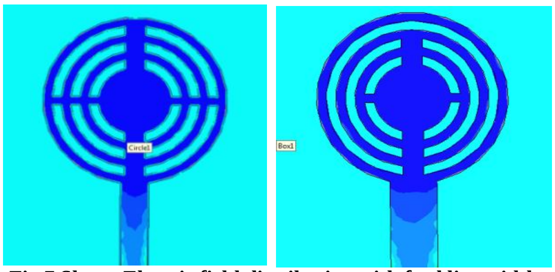

Fig 7 Shows Electric field distribution with feed line width 4.9mm & 3mm of FR4 Epoxy and RTduroid.

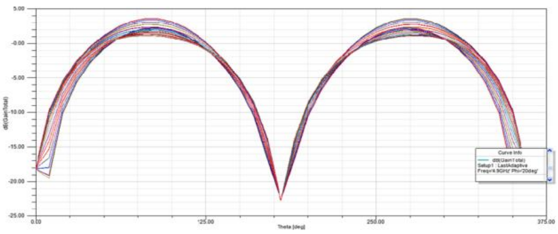

Fig 8(a)shows Theta Vs Gain graph of FR4 Epoxy.

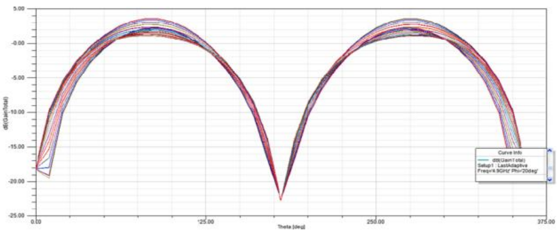

Fig 8(b) shows Theta Vs Gain graph of RT Duroid.

The simulated two dimensional E and H plane elevation patterns of modified circular microstrip of modified circular slot antenna at two frequencies covering 5 - 7.8 GHz in Fr4 Epoxy and 4 – 7.75 GHz in RT Duroid performance is realized in Fig 6.The simulated and measured co and cross polar patterns of this antenna in E and H plane at frequency 5 GHz. The following table differentiate the simulation results of both the substrates.

III. COMPARISON OF FR4 EPOXY AND RT DUROID CIRCULAR SLOT ANTENNA

If we compare realize gain S11(db) and Bandwidth for RT Duroid and FR4 Epoxy antennas. We can deduce that gain of FR4 Epoxy substrate antenna array is superior to gain,S11(db)and Bandwidth of RT Duroid patch antenna. From obtained results in Table 2, we can make a comparison for both studied shapes:

Parameters	FR4	RT
S11(db)	-30	-23
Bandwidth	4.6 GHz	4.4 GHz
Fr(centre frequency)	5.0 GHz	5.0 GHz
Gain(db)	3.5 db	3.7 db
Radiation pattern	Omni-directional	Omni-directional

Table 2 shows comparison of Results of antenna simulated in both FR4 Epoxy and RT Duroid substrates.

Circular slot have interesting geometric dimension, surface of C-shaped consecutive stubs of 1mm in FR4 Epoxy and RT Duroid. So for same frequency band, FR4 epoxy showing reduce dimension of patch, therefore dimension of substrate can be reduced.
In C-band, Circular slot antenna resonates for two frequencies: 5 GHz and 7.6 GHz with return loss between –30 dB and –20.2 dB. But for RT Duroid substrates antenna, it resonates for 3.8 GHz and 7.6 GHz and the return loss doesn't exceed –30 dB. So when could say that FR4 Epoxy circular slot antenna exploit the C-band better than RT Duroid patch antenna.

CONCLUSIONS

In this paper, a detailed study of circular slot antenna was presented. It has been demonstrated that changing shape has a major effect on resonance frequency and radiation pattern. It switched from a circular patch antenna with good reflection coefficient (–80 dB) to a multiband frequency antenna that can be used to cover C-Band with reflection coefficient S11 < –30 dB. Omnidirectional radiation patterns is observed for the antenna.Then after changing the shape of patch, the circular slot antenna was compared to without iteration circular patch antenna and also compared in different substrates. This comparison demonstrates the effect of changing shape of patch result fringing on both substrates. From comparison with literature proved the ability of using FR4 Epoxy circular slot antenna with good performance of patch with interesting dimension with good characteristics.

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