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Modified Circular Patch and Its Log Periodic Implementation for Ku Band Application

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Abstract: Patch on the basis of modification of Rodman Lens Structure has been designed in this paper .A biconvex lens structure is prepared on perturbation of circular pattern of Rotman Lens Structure .This proposed antenna operation is on Ku band.For preparation of substrate, FR4 epoxy material is chosen with dimension of 80 mm × 80 mm and the ground plane and patch material is chosen to be copper .By log periodic implementation frequency is made independent of the nature of the antenna , so that the bandwidth can be enhanced . Both HFSS and CST software has been used for the simulation to calculate different parameters like S_{11}, VSWR, antenna gain and directivity. To support the theoretical value, the fabrication is done accordingly and the testing results found out to be in an agreement of the simulated results.

Index Terms: Rotman Lens, FR4 Epoxy, Ku-Band, S-Parameter, VSWR, Antenna Gain

I. INTRODUCTION

Among all the antennas prepared, the top priority variety of them is the antennas with high gain and large bandwidth. Taking the cost into account a design on the basis of planar log periodic structure has been introduced. The patch of the proposed structure is somewhat modification of a circular pattern, resulting a biconvex type of shape. The original work of Rotman Lens, developed by Archer [1] is the motivation of this work. Later the Rotman lens was improvised by KIM [2] by placing the lens on the dielectric slab to reduce dielectric loss. With a modification of geometry, the lens pattern yields a better result. In this regard many ways of modification have been done, differing from designer to designer for high frequency like 50 GHz [3,4]. In recent years the mutual coupling between the patches are reduced by implementing different techniques. [5,6]. The log periodic implementation of bow-tie antenna has been proposed in the year 2015 [7].To enhance the bandwidth log periodic implementation is incorporated as it is also frequency independent. The difficulty arises for fabrication as the design parameters are very small so in this paper frequency is lowered to Ku band ranging from 12 GHz to 18Ghz as it is used in satellite communication. By the frequency scaling property,the dimensional parameters have been determined and the simulation has been done by both HFSS and CST software. HFSS software uses finite element method. To verify the resonant frequency and the S-Parameter again simulation has been done with the help of CST software.

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II. ROTMAN LENS STRUCTURE AND PROPOSED MODIFICATIONS

The efficient and effective patch geometry is given by Rotman-Turner is shown in the figure 1[8]. The left part of the lens is circular and the right part can be varied as circular, elliptical and parabolic etc. With the help of Gents' equation for optical patch length and on the principle of equality in the path transferred by different rays, co-ordinates of the position of array ports on the right inner 'array curve' are divided taking 3 reference points G, F_1, F_2, which are also known as focal points [8]. With the help of parameters like scanning angle (α), Focal length (F) and the distance between the origin and focal point on the axis all the necessary co-ordinate points are calculated from figure 1. The two symmetrical focal points F_1, F_2 have co-ordinates (-F cos α, F sin α) and (-F cos α, - F sin α) and on axis focal point has a constant (-G,0) with reference at origin O. The other parameters like $\eta=\frac{N}{F}$, $w=\frac{w-w_0}{F}$, $X=\frac{x}{F}$, $Y=\frac{y}{F}$, $g=\frac{G}{F}$, $a_0=\cos\alpha$, $b_0=\sin\alpha$, The design equation can be calculated as [3]

$$y = \eta(1-w) \quad (1)$$

$$x^2+y^2+2a_0x = w^2+b_0^2\,\eta 2 - 2w \quad (2)$$

$$x^2+y^2+2gx = w^2-2gw \quad (3)$$

The final value of 'w' can be found out by solving the quadratic equation which is given as [3]

$$Aw^2+Bw+C = 0 \quad (4)$$

Equation 3 is an equation of circle and in this case, both the sides of the lens are considered as circular. Specific values of the parameters like α, g and w ,are the function of η. To avoid the overall phase aberrations, as designed in the original lens design, the most appropriate value of 'g' ($\frac{G}{F}$) is calculated from the relation [3]

$$g = 1+\frac{\alpha^2}{2} \quad (5)$$

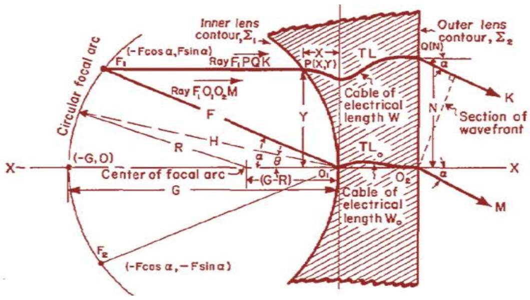

Fig.1 Rotman Lens Structural Geometry [5]

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Third equation can be rearranged by taking center of the circle at '-g' and radius 'g + w'. The perturbation of the conventional circular patch produces the biconvex shape. The largest distance between the two arc of the biconvex shape has been taken the value same as that of the free space wavelength of corresponding frequency 15GHz.The outline of the structure has been constructed using MATLAB.

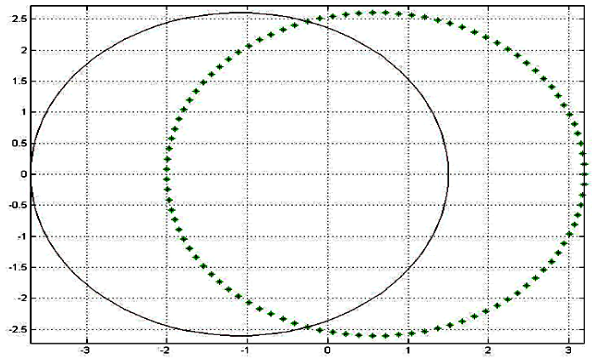

Fig 2. Structure of the two arcs of the proposed antenna using MATLAB

III. DESIGN OF PROPOSED STRUCTURE

Fr4 epoxy material which is resistive to fire and having a dielectric constant 4.4 is used for the substrate.[9].As frequency of operation is related to dielectric constant [10, 11, 12] , the cut off frequency f_1 in GHz related to dialectic constant and height of the substrate is given by

$$f_1 = \frac{150}{h\pi}\left[\sqrt{\{2/(\varepsilon_r - 1)\}}\{\sqrt{tan^{-1}\,\varepsilon_r}\}\right] \quad (6)$$

In the equation (6) the height of the substrate is denoted by 'h' in mm. Here h=1.6mm, which can support up to 20GHz.

$$\tau = \frac{L_{n+1}}{L_n} = \frac{W_{n+1}}{W_n} \quad (7)$$

'L' and 'W' represent length and width of the patch respectively. To implement the proposed perturbed patch as log-periodic array the formula for scaling factor has been taken in account [13,14,15] So

$$\tau = \frac{f_{n+1}}{f_n} = \frac{\lambda_{n+1}}{\lambda_n} \quad (8)$$

Where 'f' is the frequency at which the design has been done and the wavelength has been found out to be 16.94 mm. Frequency of the proposed antenna will be in continuous variation whenever the value of the scaling factor will have the value nearly equal to unity. Scaling factor τ has a value 1.1 in this paper to implement the biconvex shape in logarithmic array. The largest distance with in the two sides of first patch is λ =16.94 mm. Considering the value of scaling factor τ, λ_2 and λ_3 has been calculated for 2nd and 3rd patches respectively. From the calculated values it has been found out that λ_2=15.4 mm and λ_3= 14 mm . HFSS software and CST software are used for design and simulation

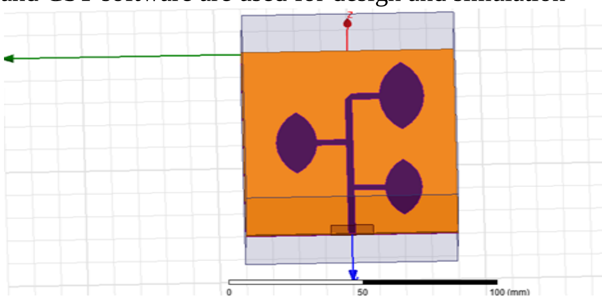

Fig 3 :Proposed Antenna design using HFSS

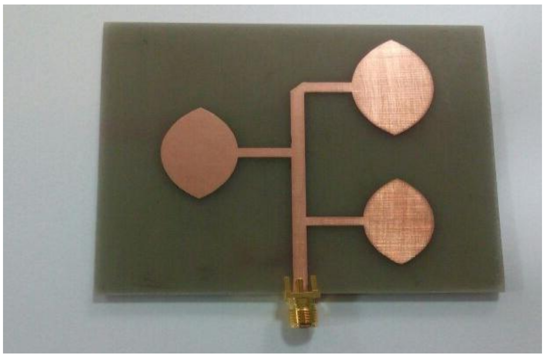

Fig 4 : Fabricated log periodic modified circular Antenna

IV. SIMULATION AND MEASUREMENT

At first the HFSS software has been used for the simulation and the return loss , gain , directivity parameters have been found out .Then the fabrication and testing has been done.

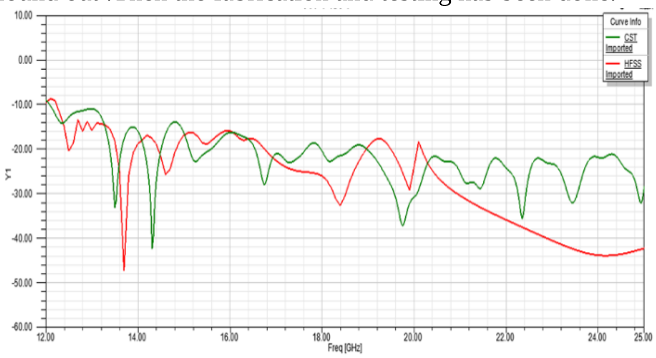

Fig 5 : Comparison of S_{11} of the Proposed Antenna Using HFSS and CST

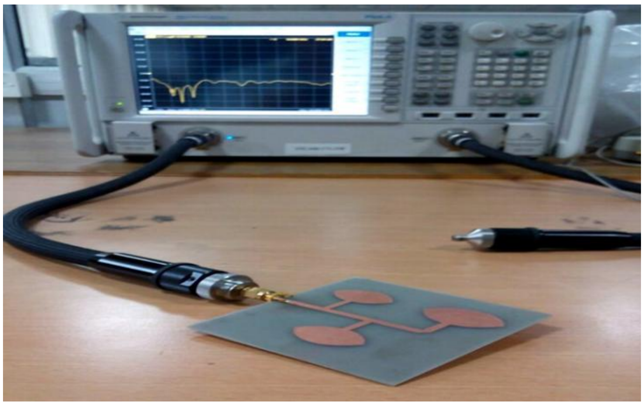

Fig 6 : Measurement of the S-Parameter

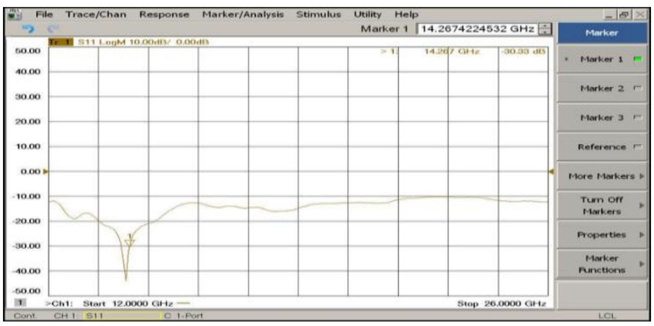

Fig 7 : S_{11}graph of the fabricated Antenna

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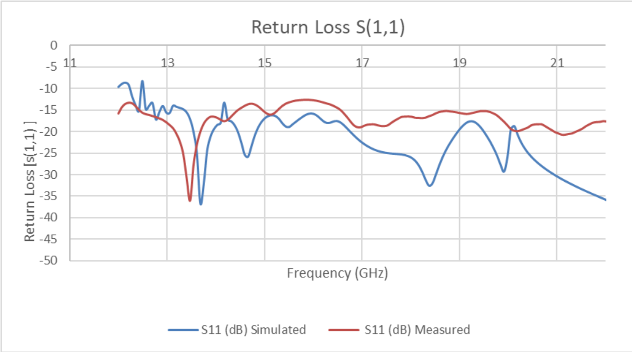

Fig 8 : Simulated Vs Measured return loss (S_{11})

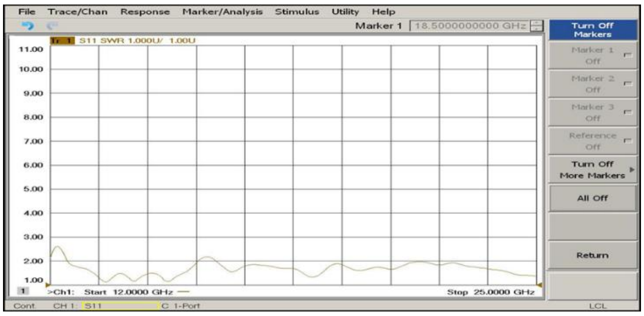

Fig 9 : Measured VSWR of the proposed antenna

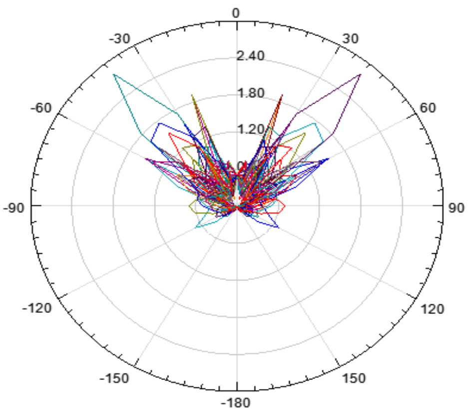

Fig 10 : Gain Pattern

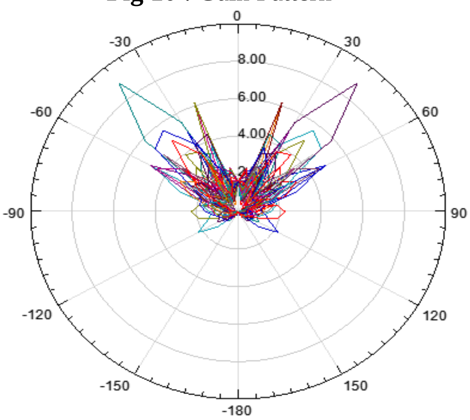

Fig 11 : Directivity Pattern

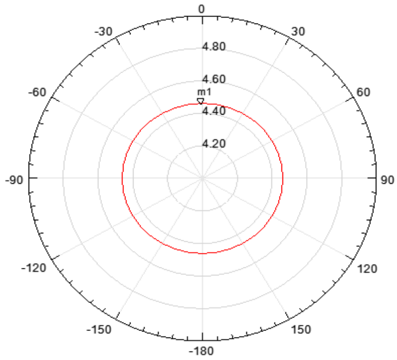

Fig 12 :Maximum Gain in dB

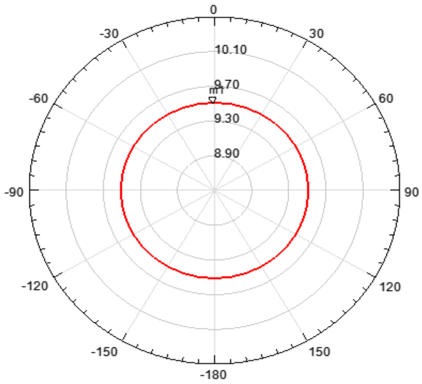

Fig 13 : Peak Directivity in dB

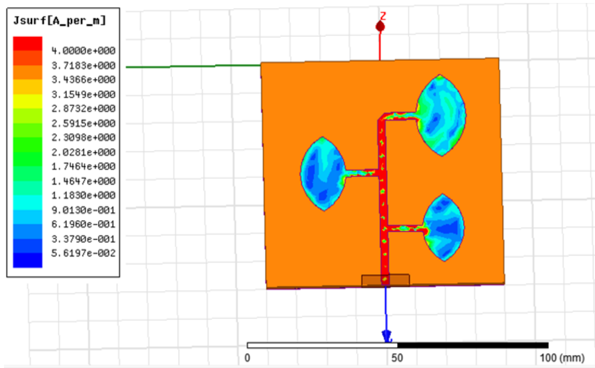

Fig 14: Distribution of Surface Current

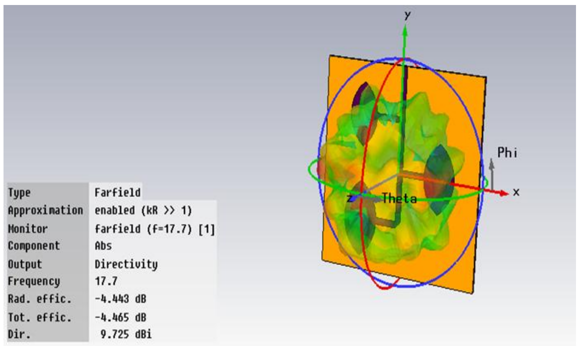

Fig 15: Far Field Radiation Pattern of the proposed Antenna using CST

V. RESULTS

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As this model can be implemented as transmission line model, the voltage standing wave ratio (VSWR) can also be calculated. The peak to peak voltage ration of standing wave which is formed by terminating the transmission line with a load. By analyzing the simulation results it has been found that S-Parameter plots of the proposed antenna covers Ku-Be nd ranging from 12 GHz to 18 GHz and resonating at 13.6 GHz having return loss of -36.698 dB. From measurement it is found that the antenna is resonating at 13.47 GHz having a return loss (S11) -35.98dB. The simulated and measured results are in good agreement. Similarly, the VSWR has been found out 1.1167 from the simulation and 1.148 from the measurement. The simulation and measurement result of VSWR have very good agreement to the desired value. The directivity has been found out to be 9.81 dB with gain 4.6 dB. The radiation pattern corresponds to the end fire radiation pattern which is the desired radiation of log periodic antenna.

Table 1: Simulated and Measurement results

Antenna Parameter →	Resonant frequency (GHz)	Return Loss (dB)	VSWR	Antenna Gain (dB)	Directivity(dB)
Simulated	13.6	-36.698	1.1167	4.48	9.47
Measured	13.47	-35.98	1.148	4.32	8.88

VI. CONCLUSION

From the simulated as well as the measured results it is observed that the proposed antenna can be used efficiently in the frequency range from 12 GHz to 18 GHz .This antenna can be used for space communication , radio astronomy as well as satellite communication .

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AUTHORS PROFILE

Mr.Ribhu Abhusan Panda is currently doing PhD at VSSUT Burla with research areas like Log Periodic antenna , Microstrip Patch antenna. Being very enthusiastic student, he has participated in many seminars and research work .He has an expertise in softwares like HFSS, CST ,MATLAB

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