Wide Band Elliptical Ring Patch Antenna with Circular Polarization for K-Band

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***Abstract*— This paper presents design and simulation of wide band elliptical ring patch antenna with arc truncation in K-band for mobile communication application. Elliptical ring's intrinsic geometry leads to single feed circular polarization and high radiation efficiency so making it suitable for implementing on array and as well as for practical application were low losses are salient features. Antenna have large bandwidth and circular polarization at resonant frequency of 19.8 GHz and is suitable for satellite to mobile high speed communication were large free spectrum is required which is unavailable at lower frequencies. In K-band simulated results shows 20% impedance bandwidth and 110 MHz circular polarization band. Parametric study of antenna's figure of merit i.e. return loss and axial ratio with radius of truncating circle is also illustrated.**

Keywords—Wide band, Circular polarization, Elliptical Ring Patch, K-band, circular truncation. .

I. INTRODUCTION

Microstrip Patch Antenna is extensively used in communication due to the compactness, low cost and robustness. Conformity design of patch antennas is very handy for many practical applications like mobile antenna, wearable antenna, radar, telemetry and altimeter. For higher frequency bands like K & Ku horn antennas are used which have bulky size, but in era of compactness and slim tech gadgets, they seem obsolete.

Nowadays owing to absence of bandwidth at lower frequencies for high speed transmission of increasingly large data from satellite to ground, K-band systems are preferred. Requirement for ground based antenna to fit for satellite to ground transmission is large bandwidth, circular polarization, conformal and high radiation efficiency. Mobile antenna can have any orientation so circular polarization is much needed.

Purpose of this paper was to come up with a design to fit in above requirements.

Some designs in literature are modelled for K-band [1] but with lower bandwidth and linear polarization. K-band antenna has wide range of application in Radar. An array of (24x14) patch is modelled in K-band with vertical polarization and 100 MHz bandwidth [2].

Wideband with circular polarization is achieved by Prezymslaw *et al* [3] with 6 layer stacked configuration to enhance bandwidth, with orthogonal H-shaped slot, results are very promising, but stacking cause loss of conformity and feeding is also very complex. Most of designs uses dual feed to generate circular polarization, which results in increased complexity. We propose a slotted circularly polarized elliptical patch antenna with single probe-feed and very large bandwidth (20%,<-10 dB).

II. ANTENNA CONFIGURATION

The configuration of antenna illustrated in fig.1.

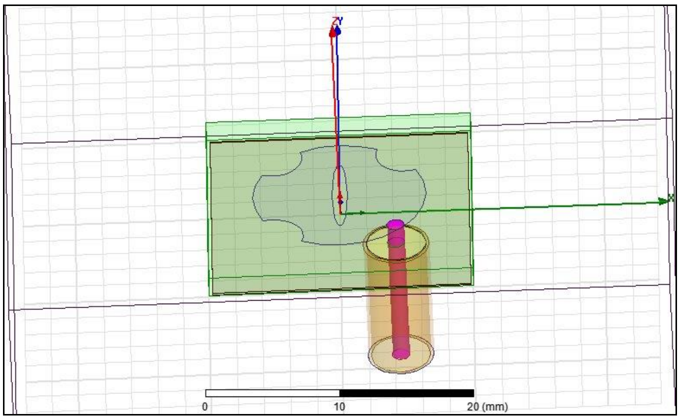

Fig. 1 Model

Dimension of patch is calculated from [4]

$$a = p/f_r\,(\mu_{eff}*\epsilon_{eff})^{1/2} \qquad (1)$$

μ_{eff} is effective permeability which is assumed unity in this case. ϵ_{eff} is effective permittivity calculated from 3. Length (L), Width (W) of ground and substrate of antenna is calculated from [5]

$$L=6h+2b \qquad (2a)$$

$$W=6h+2a \qquad (2b)$$

$$\epsilon_{eff} = (\epsilon_r+1)/2 + ((\epsilon_r-1)/2(1+12h/W)^{1/2} \qquad (3)$$

Were ϵ_r is dielectric constant of substrate. The patch is fabricated on FR4, substrate which has relative permittivity of 4.4 and thickness of 1.6mm and loss tangent of 0.002. (b/a) is 0.975 for purpose of circular polarization [4], ϵ_{eff} is calculated from [5].

TABLE 1

Patch Size (a)	ϵ_{eff}	Thickness(h)	b/a
6.584mm	3.9	1.7mm	0.975

For larger frequencies loss are high because of small size of aperture, so we took a non-conventional step to increase the aperture size without much changing the actual size of an antenna (ground plane and substrate) which leads very high radiation efficiency >80% on an average for entire radiating band of 4 GHz.

TABLE 2

Outer Ellipse Dimensions

Sr. No.	Dimension Modification			
	Parameter	Calculated	Modified	Ratio
1	Aperture (patch dimensions)	a=2.2mm b=2.145mm	a=6.584mm b=6.384mm	3
		Area=14.85mm^2	Area=110.29mm^2	7.45
2	Antenna Dimensions	L=14mm W=14.0mm	L=20mm W=20mm	1.42
		Area=196 mm^2	Area=400mm^2	2.04

A. Elliptical Slot

b=3.9mm, a=0.6mm.Slotting leads to formation elliptical ring which has better performance as analyzed by General Transmission Line Model [6],good circular polarization over wide range and gain also higher than elliptical and circular patches [7]. Slotted for meandering the flow of current on patch. Meandering will generate higher modes leading to higher frequencies using larger patch size.

B. Circular Truncation

r=2.2mm, 1/3rd of circle is truncated from edge of patch where patch was not radiating, thus reducing the size. Truncation is done to enhance the performance of antenna as sighted in literature [8]. Electric field on patch can be seen from Fig.7.

C. Feed Point

F(x y) = (4.17,-4.17). "Generally, the radiation associated with the elliptical antenna element is elliptically polarized, but is circularly polarized when the antenna element is coupled through a feed point on a radial line of the elliptical lamina which is oriented at 45 degree azimuthal angle relative to semi major axis" [9] Probe feed gives unconstrained feeding anywhere in the plane but results in reduced bandwidth. Thus bandwidth can be further enhanced using aperture coupling or proximity feeding [9].

III. SIMULATION RESULTS

Table 3 and Table 4 shows different parameters of antenna for the resonant frequency 19.8 GHz. Model is simulated on Ansoft HFSS 13.0 and results are shown in Fig.1-7 to aid the results in table.

TABLE 3

Resonant Frequency (f_r) (GHz)	Bandwidth (GHz)	Bandwidth (%)	Axial Ratio (GHz)
19.80	3.99	20.15	0.11

TABLE 4

Resonant Frequency (f_r) (GHz)	Return Loss (< -10dB)	VSWR	Radiation Efficiency (%)
19.80	-32dB	1.05	80.58

Fig.2 shows variation of return loss with frequency, graph dip at 19.80 GHz, the optimized resonant frequency. VSWR in Fig.3 shows minima at same point, infers matching of feed point and efficient radiation. Axial ratio in Fig.4 shows dip at 19.90 GHz which is in limit of radiating band of antenna.

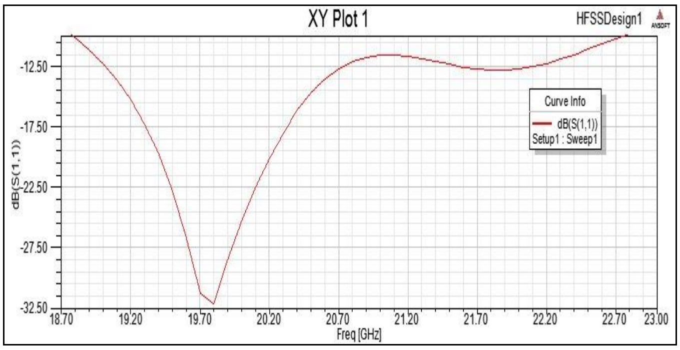

Fig. 2 Return Loss vs Frequency

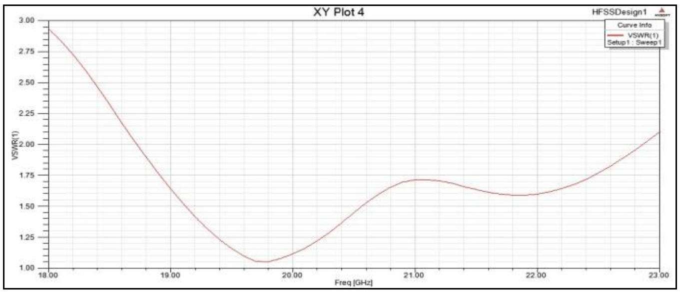

Fig. 3 VSWR vs Frequency

Efficiency of Antenna is quite high, 80% for resonant frequency in Fig.5 which outcome of modification done to the shape of patch. Aperture size is always an important parameter for deciding the radiation efficiency and gain of antenna.Fig.6 shows radiation pattern of antenna with larger main lobes and very small side lobes. Demonstrating high directivity of antenna. Magnitude of electric field pattern of patch is illustrated in Fig.7 which shows mostly blue color area which are radiating non radiating sector along edge are truncated enhancing the radiation pattern and reducing size. For different size of truncation return loss and axial ration varies. Truncation leads to reduction in size but also deteriorate performance of antenna both axial ratio and return loss visible in Fig.7 & 8, so for specific purpose trade off must occur between size reduction and performance.

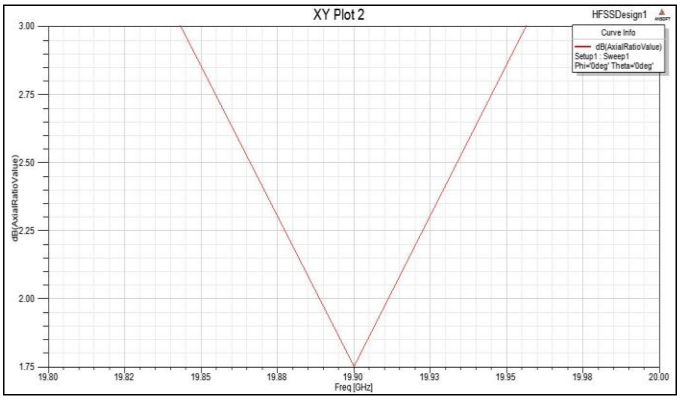

Fig. 4 Axial Ratio vs Frequency

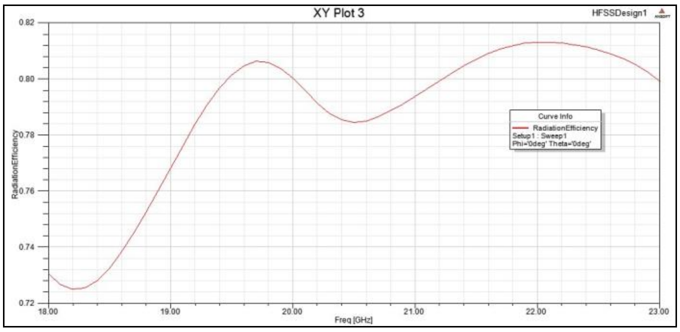

Fig. 5 Radiation Efficiency vs Frequency

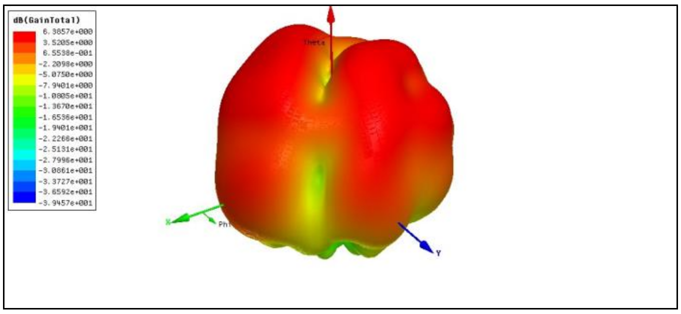

Fig. 6 Radiation Pattern

Radiation pattern is almost omnidirectional with central void because of slot in the center of patch. Axial ratio peaked at 19.9 GHz which in radiating region of antenna.

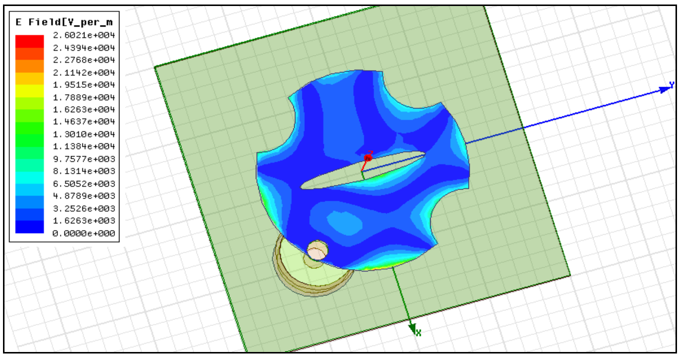

Fig. 7 Electric- Field Pattern on patch

IV. PARAMETRIC STUDY

Variation of return loss and axial ratio with size of truncation is studied and a comparative data is plotted in graph shown in Fig.8 & 9.Bandwith remain unaffected by the truncation dimension but return loss performance of antenna show large variation. Axial ratio also show some nominal degradation with increasing truncation size.

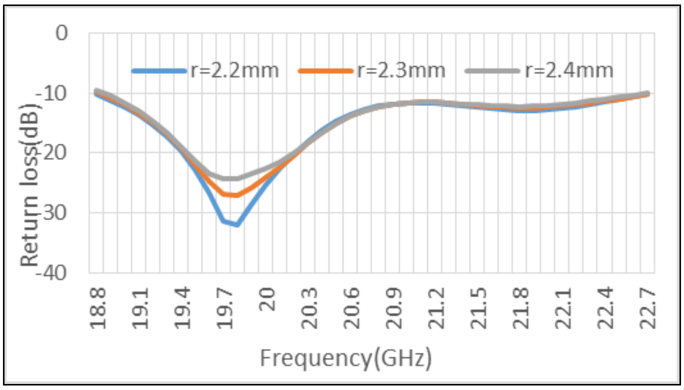

Fig. 8 Return loss for different radius of truncation circles

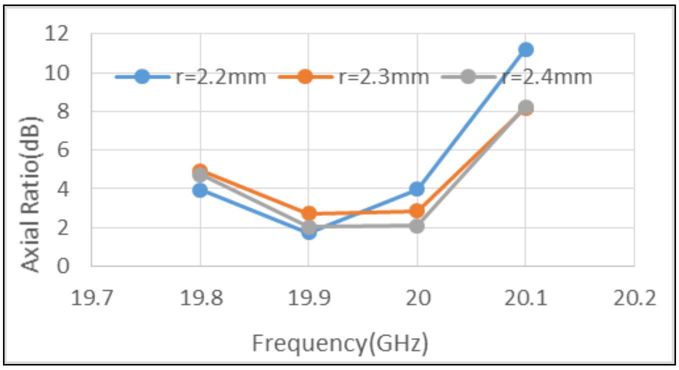

Fig.9 Axial ratio for different radius of truncation circles

V. CONCLUSION

A single probe feed elliptical patch antenna is designed. Antenna has very large bandwidth with average radiation efficiency (> 80%).It shows circular polarization for resonant frequency and elliptical otherwise. It can be seen that changing size of truncation shifted the value of resonant frequency and axial ratio from fig.7 & 8.This design has great potential to be used for Satellite to ground communication in K-band. Other feeding techniques can be used to enhance the bandwidth even further for ultra wide band application.

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