DESIGN OF MULTIBAND MICROSTRIP PATCH ANTENNA USING CIRCULAR (E-SHAPED) STRUCTURE FOR WIRELESS APPLICATIONS

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Abstract: The fundamental component in any communication system are antennas, they facilitate conversion of electrons to photons or vice-versa. The increasing traffic of mobile-devices have led to the need for multi-band antennas which can operate at multiple frequencies. Microstrip patch antennas are a great innovation as they facilitate for the antennas to be printed on a circuit board, they are light weight and offer ease of fabrication. Microstrip antennas can be rectangular, circular, elliptical or any other regular form but the most commonly used are circular and rectangular. In this research a circular (E-Shaped) antenna is proposed and it operates in multiple bands. Usually microstrip antennas like Kotch array, Sierpinski array are used but in many modern circuits space is limited, an antenna is designed in E-Shape in combination with closed ring resonators to achieve the multiband functionality. The four frequencies in which the proposed antenna works are 6.321 GHz, 7.729 GHz, 10.08 GHz and 12.63 GHz, it shows operation in C-band, X-band and Ku-band. Keysight Advanced Design System (ADS) software is used to create and simulate the proposed model. Circuit board FR4 (Flame Retardant 4) is used for designing this patch antenna as it depicts fabulous performance during fabrication process. Finally, by optimizing the best performance parameters like gain, directivity and radiation efficiency are achieved.

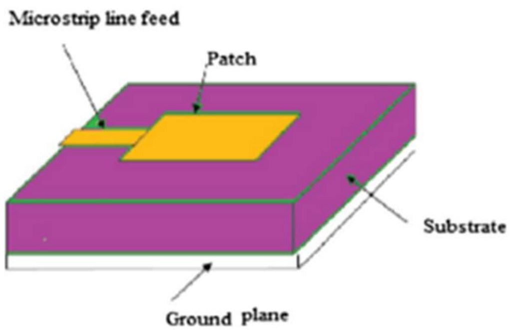
Keywords: Antenna, Circular E-shaped, Rectangular Shaped, Microstrip Patch Antenna, Radiation Pattern, Directivity

INTRODUCTION

Multiband antennas play an important role in the field of wireless communication because of its capabilities to operate in multiple frequency bands for different wireless devices such as Global System for Mobile (GSM), Wireless Local Area Network (WLAN), Worldwide interoperability for Microwave Access (Wi-Max) and Wireless Fidelity (Wi-Fi) [1]. A microstrip antenna is a patch of metal on top of grounded substrate that is normally rectangular or circular (other forms are also utilized) [2]. Microstrip patch antenna has a microstrip-line, electromagnetically coupled (EMC) and co-axial probe is used for the purpose of feeding technique [3]. Some of the advantages of patch antenna are Low weight, low profile planar configuration, low fabrication costs, microwave integrated circuits technology [4].

Wireless communication system, medical field applications, cellular phones, Global Positioning System (GSM), radar systems, military systems like rockets, aircraft missiles, etc., satellite communication are some of the major applications of E-Shaped microstrip patch antenna [5]. There had been numerous developments in the field of wireless communications, especially in the field of Tele-Health, monitoring and warning system [6], and due to its compact size, it is popular in mobile-phones.

Designing of microstrip patch antenna can be done using various feeding techniques. Main components of a microstrip-patch antenna are substrate, patch, ground plane and line-fed [7]. The substrate of microstrip antenna is responsible for its mechanical strength [8]. The Fractal antenna arrays like Kotch Array, Sierpinski Array are also used to achieve multi-band operations [9-10], but the fractal antenna has increased design complexity. Patch antenna are easy to design, light weight, field area spreading over substrate and substrate is cost economical [11]. Microstrip antenna topologies have been centre of focus for making millimeter wave monolithic integrated circuits for radar, communication and microwave applications [12]. Electromagnetic field used to track the storm systems by radar are in air-traffic control, air-craft navigation, marine navigations, topographical mapping of earth [13].



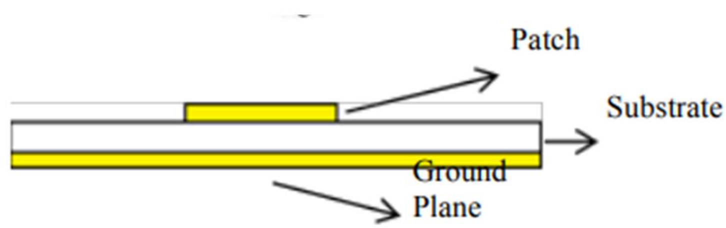


Fig. 1(b): Side View

Fig. 1(a): Basic Structure of Microstrip Patch Antenna

In this paper a circular E-shaped microstrip patch antenna is designed and simulated using the Keysight Advanced Design System (ADS) software is designed and simulated. For design the substrate used is FR4 having a thickness of 1.6 mm and dielectric constant 4.4. The paper includes the simulated results and various obtained parameters during simulation in ADS software.

ANTENNA DESIGN

Choice of Substrate: It is important to choose the right substrate as it is to select the design. The substrate plays determining role in radiative properties of the antenna. Several aspects such as dielectric constant, thickness, loss tangent are taken into consideration while selecting the substrate. To start the radiation, the dielectric should be low as feasible but to improve a impedance bandwidth a thicker substrate may be preferred. Though, thin substrates attract the loss of accuracy but they are used by most of the microstrip antenna models so, substrates which depict loss at higher frequency should avoided during fabrication.

Generally, for a substrate at highest point **height is typically $0.003\ \lambda_0 \leq h \leq 0.05\ \lambda_0$** [2]. The dielectric constant of substrate, denoted by letter Єr, typically of the range $2.2 \leq$ Єr ≤ 12 [2]. For the proposed model, the substrate selected is FR4 (Flame Retardant 4) with thickness (h) of 1.6 mm and dielectric constant (Єr) of 4.4.

For the proposed antenna the dimensions of ground plane are 41.99 mm × 26.70 mm, it is the same for the FR4 substrate.

The antenna is designed and stimulated using- Advanced designing system software. Slots are made in the patch to obtain multi band characteristics. Figure 2 shows the layout structure of proposed filter.

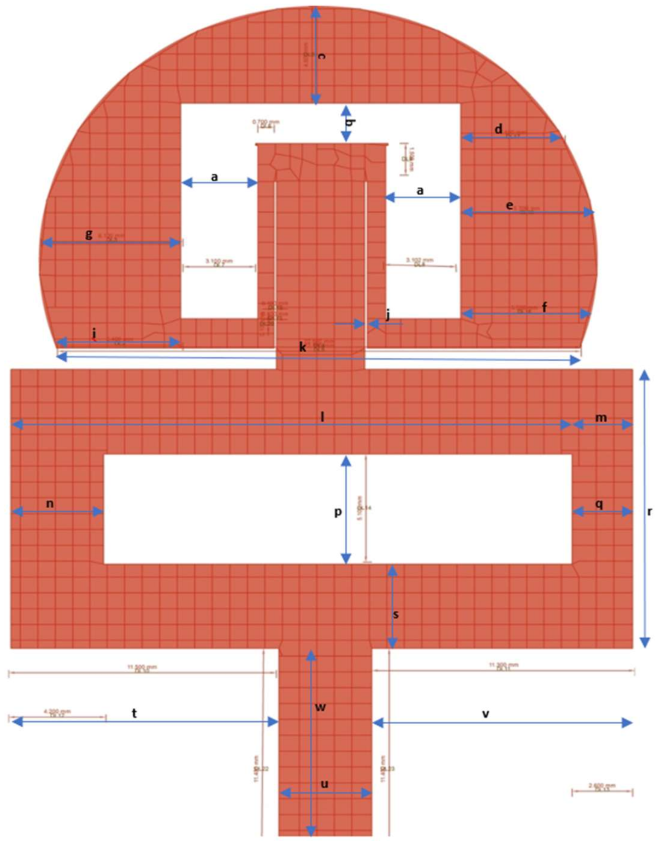


Fig. 2: Structure of proposed layout

Table 1: Value of different parameters.

Parameters	a	b	c	d	e	f
Value (mm)	3.100	1.508	4.600	4.500	5.700	5.400

Parameters	g	i	j	k	l	m
Value (mm)	6.100	5.400	0.100	22.500	24.100	2.600

Parameters	n	p	q	r	s	t
Value (mm)	4.000	5.100	2.600	13.200	4.00	11.500

Parameters	u	v	w
Value (mm)	3.900	11.300	11.400

The input port is connected at the bottom of the feed whose length and width are 11.4 mm and 3.9 mm respectively. In the E-structure, two cuts of width 0.100 mm are made.

General Mathematical Formulae Used

For E-Plane (π = 90°)

$$E(\boldsymbol{\theta}) = \frac{1}{j\lambda} \times \left(\frac{I_o}{2}\right) \times Sin(\boldsymbol{\theta}) \times [\frac{Sin\left(KL \times \cos\left(\frac{\theta}{2}\right)\right)}{cos\left(\frac{\theta}{2}\right)}]$$

For H-Plane (π = 90°)

$$H(\emptyset) = \frac{1}{j\lambda} \times \left(\frac{I_o}{2}\right) \times Sin(\boldsymbol{\theta}) \times [\frac{Sin\left(RL \times \sin\left(\frac{\theta}{2}\right)\right)}{sin\left(\frac{\theta}{2}\right)}]$$

where, *E(θ) is the electric field in the E-plane,*
H(Ø) is the magnetic field in the H-plane
θ is the polar angle in the E-plane
Ø is the azimuthal angle in H-plane
k is the free-space wave number
λ is the wavelength
L is the effective length of microstrip patch
I_o is current on antenna

SIMULATION RESULT

By simulating the design, four different resonant frequencies are obtained as shown in fig. 3. The four resonant frequencies are 6.321 GHz, 7.729 GHz, 10.08 GHz and 12.63 GHz respectively.

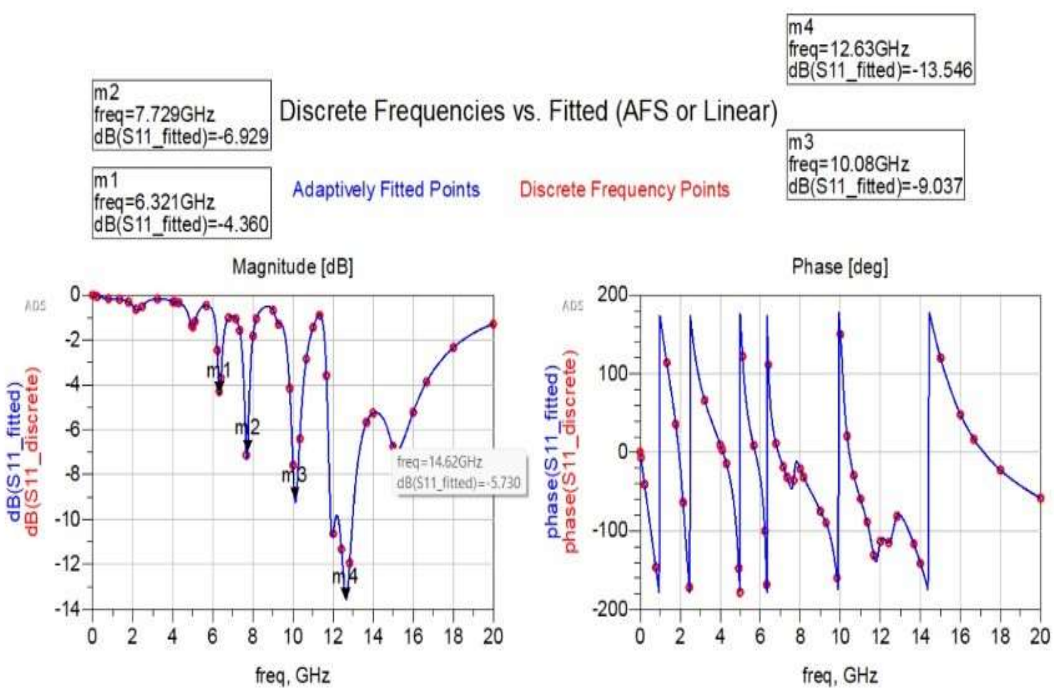


Fig. 2: S11 parameter of designed antenna

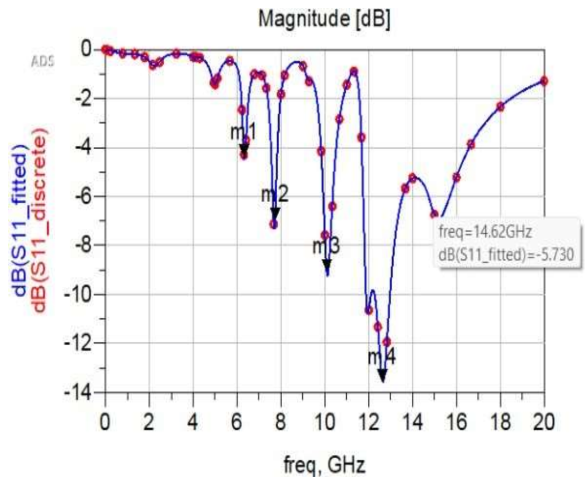


Fig. 3(a): Magnitude Plot

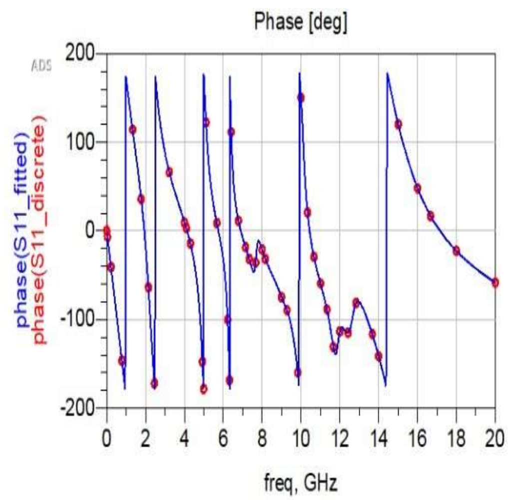


Fig. 3(b): Phase Plot

Return Loss: The ADS simulations assist in acquiring information regarding antenna's reflection coefficients. As just one probe is employed, other than S11 parameter, all coefficients will be zero, the S11 represents input reflection coefficients. The performance of proposed patch antenna is understood by looking at S11. As simulated, fig. 2 shows that antenna resonates at 6.371 GHz, 7.729 GHz, 10.08 GHz, 12.63 GHz with minimum magnitude of -4.36 dB, -6.929 dB, -9.037 dB, -13.546 dB respectively. The related phase fluctuation with frequency is shown in fig. 3(b).

Directivity: The amount to which an antenna focuses energy in a particular direction is known as its directivity and directivity (D) is directly proportional to gain (G), as all antennas emit in all directions, gain is defined as amount of power that may be gained in one direction at expense of power lost in all other directions. The graph for directivity is shown in fig. 4.

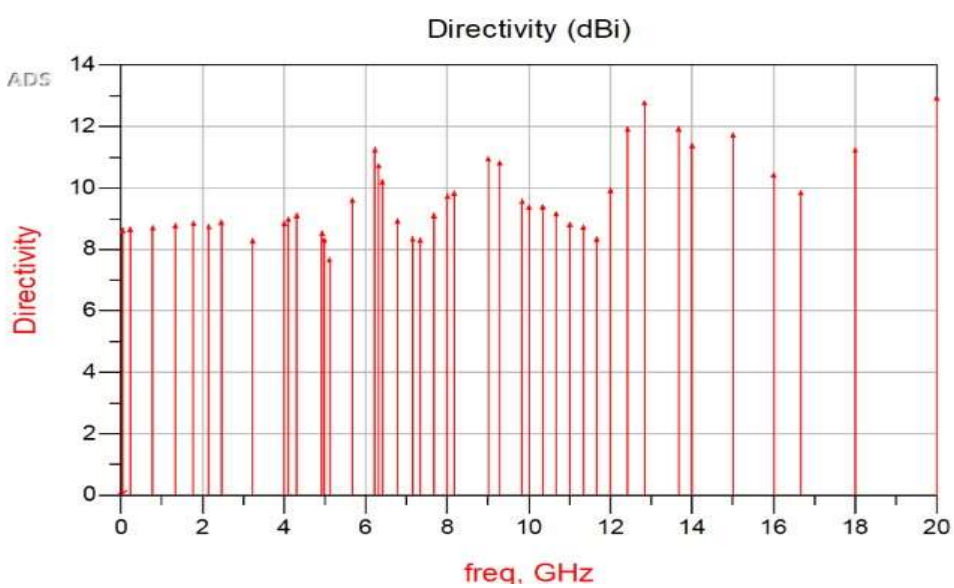


Fig. 4: Graph obtained for directivity

Current Distribution: Current distribution graph for the proposed structure can be obtained using the ADS software and fig. 5 shows the current distribution graph. If change occurs in the current distribution, it changes the performance characteristics of antenna.

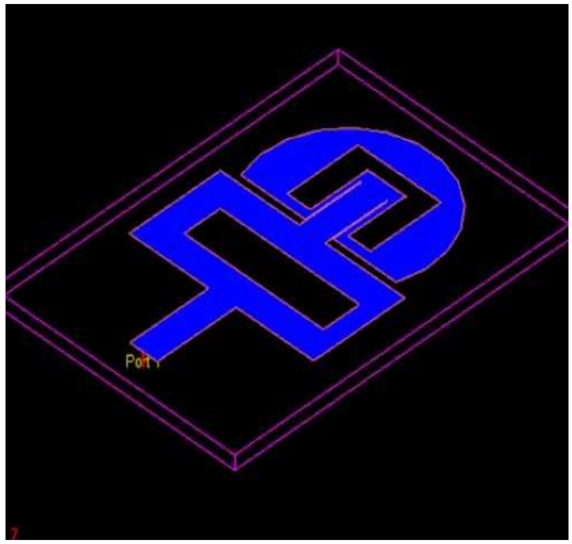


Fig. 5: Current Distribution Graph

Efficiency: It is defined as the ratio of antenna to the radiated power accepted by it. For the proposed antenna structure, Fig. 6 shows the graph of efficiency with varying frequency.

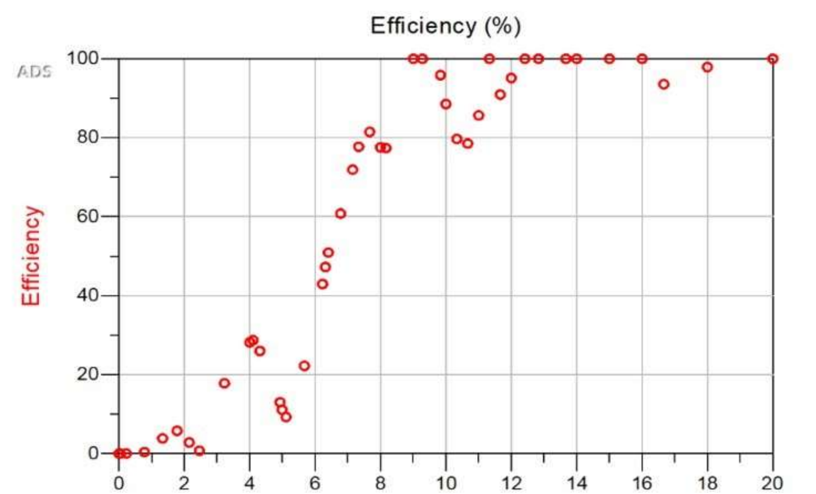


Fig. 4: Efficiency pattern

Radiation Pattern: For an antenna, it is the 3D Graph that shows that how the antenna radiates energy into space. A normalized radiation pattern is represented, as obtained from simulation.

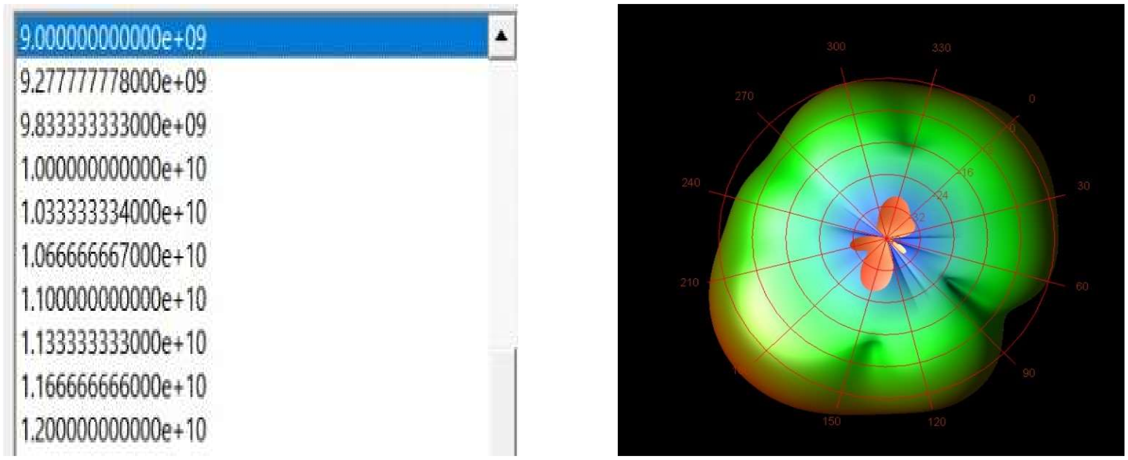


Fig. 5(a): Radiation Pattern – 1

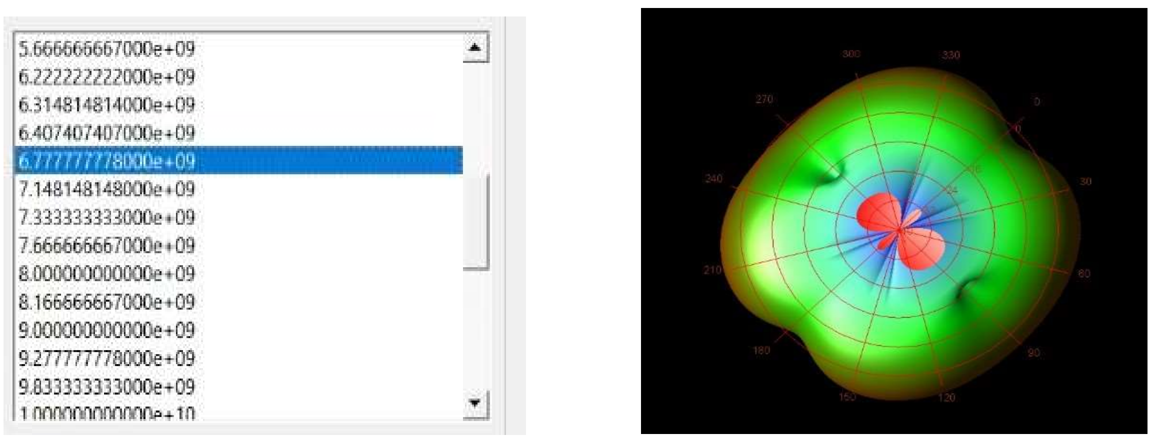


Fig. 5(b): Radiation Pattern – 2

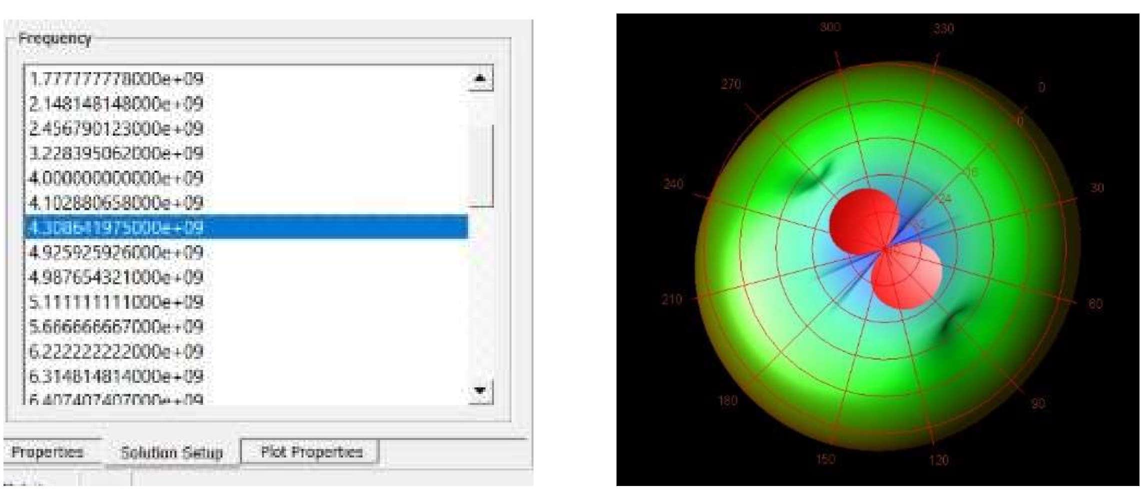


Fig. 5(c): Radiation Pattern – 3

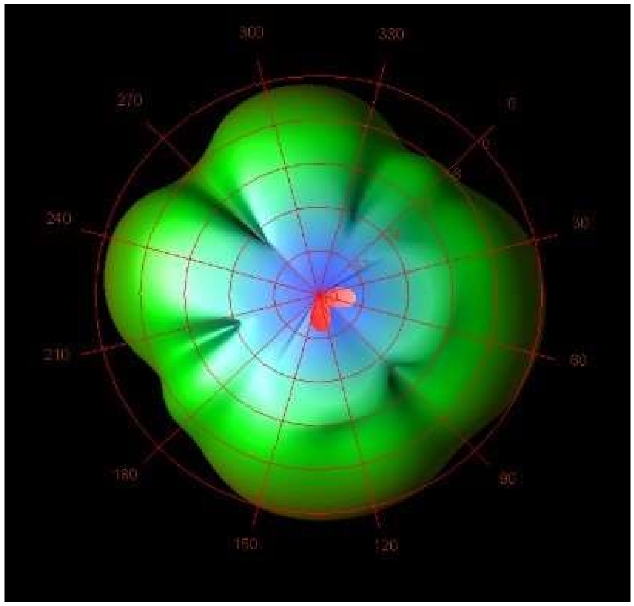


Fig. 5(d): Radiation Pattern – 4

Various Parameters of Antenna

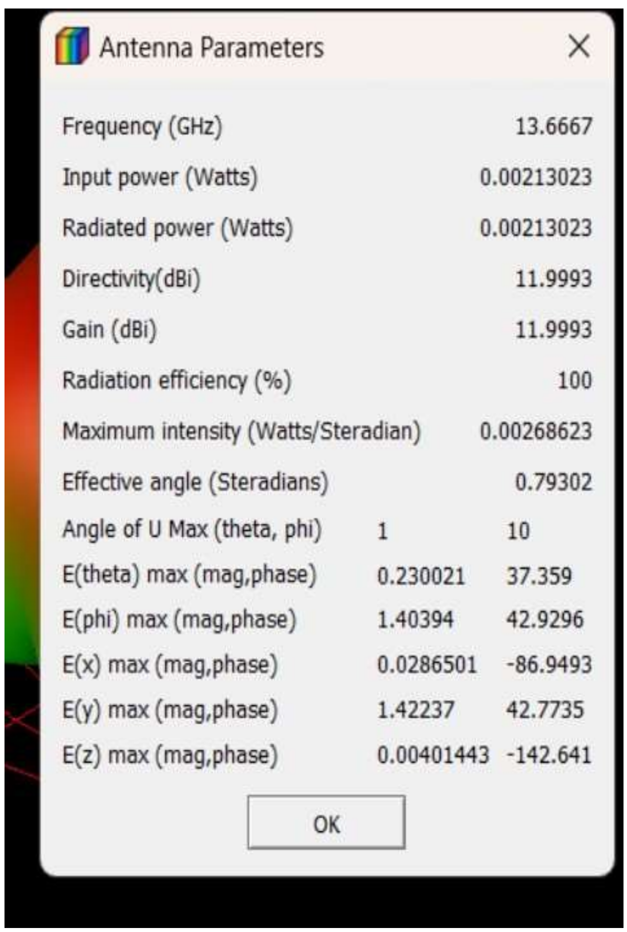


Fig. 6: Window showing parameters of antenna

CONCLUSION AND DISCUSSION

Microstrip patch antenna is simple to design due to its high sensitivity at high gain. In this paper a multiband circular (e-shape) antenna was designed which resonates at 6.371 GHz, 7.729 GHz, 10.08 GHz, 12.63 GHz frequency. Low return loss was achieved which infers that the design is very efficient and it has a negligible power loss. The antenna is thin, compact with a material of very low dielectric constant substrate material. In this research, the return loss of all four frequencies lies between the range of -4.3 dB to -13.5 dB which is less than the previous work [1]. The proposed antenna is capable of operating in C-band (6.371 GHz, 7.729 GHz), X-band (10.08 GHz) and Ku-band (12.63 GHz). These obtained bands are useful in many applications including satellite communication, radar systems, wireless broadband, microwave links, remote sensing applications, television broadcasting, data transmission in space and military communication and the multiband use is very promising for future applications.

- The C-band is primarily useful in for satellite communication and can be highly useful in areas with tropical rainfall.
- The X-band is primarily used by military in radar applications including air-traffic control, maritime vessel control, defence tracking, weather monitoring and vehicle speed detection by law enforcement agencies.
- The Ku-band is primarily used in Europe for satellite communication for direct broadcast services.

For future, other shapes of slots can be implemented to attain better effect of various parameters and make the size of antenna more compact.

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