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An Eight-Edged Star Shaped Dielectric Resonator Antenna for K-band Applications

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ABSTRACT

The operating properties of a Dielectric resonator antenna for K-band applications, i.e. 18GHz to 27GHz, are discussed in this paper. To obtain the desired effects, two DRAs are stacked oneon top of the other. The design is supplied via a partial ground line feed method. The substrateis made of FR4 Epoxy, and the DRA is made of AL_2O_3 with a height of 5.6mm including the substrate height. The gain of a planned aerial was discovered to be 3. 44dB. when compared to the previous design, it was discovered that the bandwidth had improved from 3GHz to 6GHz. The High Frequency Structure Simulator software was utilized to develop the proposed DRA (HFSS 17.2 version).

Keywords: K-band, HFSS, Dielectric Resonator Antenna.

1. INTRODUCTION

The ubiquitous nature of today's and tomorrow's wireless systems continues to drive demand for better antenna designs. During the last decade, the challenges of developing tiny and enhanced wireless antennas have been a key focus of antenna research. This research focuses on the usage of microstrip feed structures, which could be used at frequencies much below millimeter wavebands. In telecoms, a microstrip antenna (also known as a printed antenna) is an antenna that is manufactured on a printed circuit board using photolithographic processes (PCB). It functions as an internal antenna. They are mostly employed at microwave frequencies. A single microstrip antenna is made up of a patch of metal foil in different forms (a patch antenna) on the surface of a PCB (printed circuit board), with a metal foil ground plane on the other side of the board. The majority of microstrip patch antennas are made up of numerous patches arranged in a two-dimensional array. Typically, the antenna is linked to the transmitter or receiver using foil microstrip transmission lines. Between the antenna and the ground plane, a radio frequency current is delivered (or, in receiving antennas, the received signal is generated). The patch antenna is the most popular form of microstrip antenna. Patch antennas can also be used as constituent elements in an array. A patch antenna is a narrowband, wide-beam antenna that is made by etching the antenna element pattern in a metal trace bonded to an insulating dielectric substrate, such as a printed circuit board, and then bonding a continuous metal layer to the opposite side of the substrate to form a ground plane. Square, rectangular, circular, and elliptical microstrip antennas are the most common, but any continuous form is feasible. Several patch antennas are built of a metal patch placed atop a ground plane using dielectric spacers rather than a dielectric substrate; the resulting construction is less robust but has a broader bandwidth. Because they have a low profile, are physically robust, and can be bent to adapt to a vehicle's curving surface, such antennas are frequently installed on the outside of airplanes and spacecraft, or are incorporated into mobile radio communications equipment.

PRINCIPLE OF DRA

The key working technique of dielectric resonators is similar to that of cavity resonators. The cylindrical and rectangular radiating dielectric resonators are the most prevalent. The DRA'ssize is proportional to $\sqrt{\lambda_0/\varepsilon_r}$

,where λ_0 is the free-space wavelength at the resonant frequency and ε_r denotes the relative permittivity of the material creating the radiating structure. Robert Richmyer was the first to propose that dielectric materials can also resonate in 1939. It was firstused as a filter element in microwave circuits, where it was typically made of ceramic materialof various shapes and sizes. Because of its high permittivity and Q factor, it is very appealing for antenna applications in the current context (between 20- 2000). Aside from that, we now have sophisticated plastic materials such as polyvinyl chloride (PVC), which is being used as a substitute for ceramic materials and produces better results. DRA is a type of electronic component that exhibits ‘resonance' at a wide range of frequencies, usually in the microwave or radio frequency bands (RF). Because DRAs are volume devices, they provide designers withmore degrees of freedom than 2-D or 1-D antennas (e.g., micro strip antennas)(e.g.- monopole antennas). It is made of low-loss, high-relative dielectric constant material of various shapes, the resonant frequencies of which are determined by the size, shape, and permittivity of the material. The DRA has some remarkable properties, such as its compact size, ease of manufacture, high radiation efficiency, enhanced bandwidth, and low production cost, and it is frequently employed in wireless communications. Both the DRA and microstrip antennas are mimicked in full wave simulators such as HFSS, although the DRA has a higher efficiency than the micro strip. At higher frequencies, DRA are more efficient, having better fractional bandwidth. DRAs may be used in a broad wide range of temperatures.

VARIOUS TYPES OF DRAs

The gain and impedance bandwidth are bolstered for the different shape of DRA and feed mechanisms, namely, cylindrical DRA sundered with T-shaped micro strip, ring DRA sliced with L-shaped feed micro strip, cubic shaped DRA cleaved with question mark-shaped micro strip, dumbbell shaped DRA sheared with coaxial probe, tetraskelion DRA splintered with coaxial probe feed mechanism, H-shaped DRA cleaved with trapezoid-patch, ring DRAsevered with annular-shape micro strip feed, hemispherical shaped DRA cleft with coaxial probe micro strip feed, arrow, hemispherical, triangle shaped DRA ligated with conformal patch existing micro strip feed. DRAs provide easy coupling methods to almost all microwave and mm-wave transmission lines. As a result, they are well-suited for incorporation into various planar technologies. By changing the location of the DRA with regard to the line, the couplingbetween a DRA and a planar transmission line may be efficiently altered. DRA's performance may thus be readily improved experimentally. Each DRA mode has a distinct internal and exterior field distribution. As a result, by stimulating different modes of a DRA, varied radiation properties may be produced. Different radiating modes have also been used to produce equivalent radiation patterns utilizing composite geometries, with the added benefit of a larger bandwidth. Some of the shapes of Dielectric Resonator Antenna is as shown in the Figure 1.

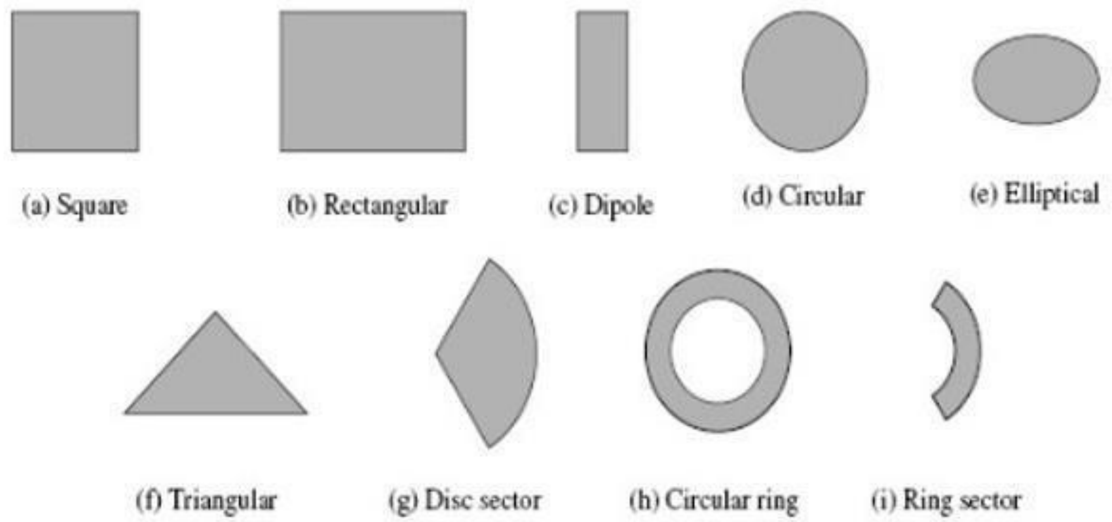


Fig 1: Different shapes of dielectric resonator antennas

MOTIVATION OF DRA

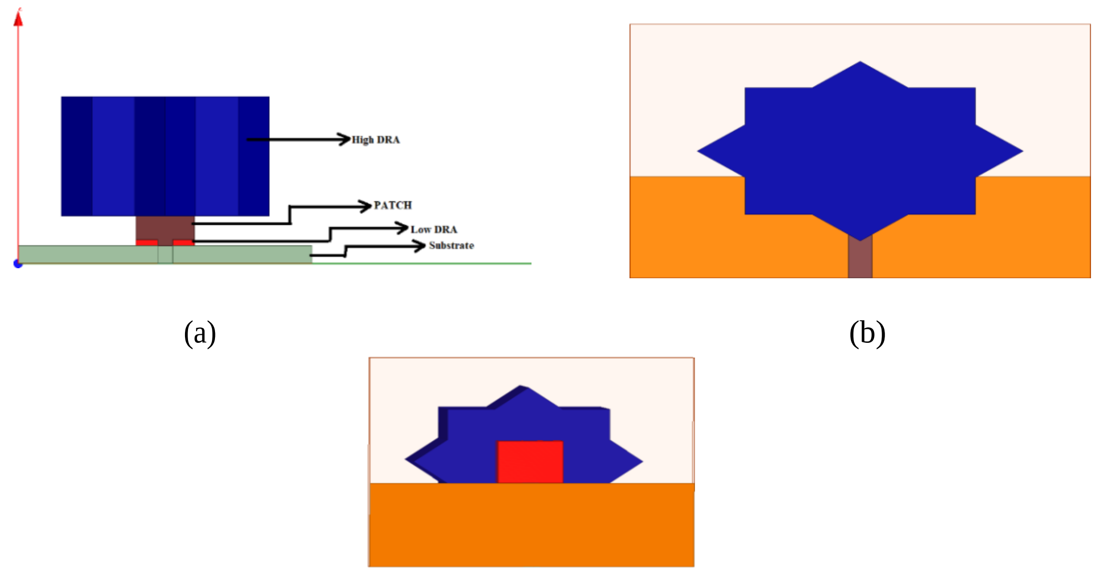
Some drawbacks of a simple microstrip patch antenna include spurious radiation, which exists in many microstrip-based antennas such as microstrip patch antennas, microstrip slot antennas, and printed dipole antennas. Due to dielectric and conductor losses, it has a poor efficiency. It has a lesser gain. It emits more cross-polarization radiation. It can only handle a certain amount of electricity. It has a reduced impedance bandwidth by definition. The feeds and other connection points of the microstrip antenna construction emit. One approach for overcoming some of the micro patch antenna's limitations is to use a dielectric resonator antenna. Due to the lack of conducting material, DRAs have a high radiation efficiency when a low-loss dielectric material is used. This property makes them ideal for applications requiring extremely high frequencies, such as those ranging from 30 GHz to 300 GHz. Traditional metallic antennas, in fact, suffer from greater conductor losses at these frequencies. DRAs can have a wide impedance bandwidth if the resonator size and material dielectric constant are correctly selected. DRAs may be stimulated using a variety of methods, which is useful in a variety of applications and for array integration.

2.0 LITERATURE REVIEW

MSM Aras had designed a disc-shaped DRA and achieved less bandwidth of 140MHZ in both simulation and measurement with a return loss of -19dB[1]. In [2], they had achieved the 65% of bandwidth when compared to the single hexagonal shaped DRA, but they had achieved circular polarization with 8.65 dB of gain using trapezoidal patch antenna [3]. Abhijeet C et al, had designed an H- shaped DRA by achieving the 24% of impedance bandwidth and attain 90% of radiation efficiency [4]. In this paper the author had designed an conical DRA using the probe feed technique and attain good gain i.e., 6.41dB with low bandwidth of 667MHZ [5]. Alina Khan et al, discussed the comparison of the MPA with the DRA and achieve the low peak gain 4.73dB [6]. In [7], they designed the MIMO cylindrical DRA and they was observed the multiple bands and left hand circular polarization throughout the four bands and achieve the 85% radiation efficiency.

GEOMETRY OF THE PROPOSED ANTENNA

The DRA's design specifications are intended for diameters of 10mm x 10mm. The substrate material in this DRA is FR4 Epoxy, the dielectric constant (εr) is "4.4", and the thickness is 0.6mm. The ground plane has dimensions of 10mm x 4mm and is a partial ground beneath the substrate. In this arrangement, a 50Ω resistance micro strip transmission line is supplied through the DRA's rectangular feed. To increase the performance of the DRA, the shape of the transmission line bent over the dielectric resonator can be adjusted. The low DRA is positioned in the center of the substrate and disseminates the rectangular feed. The dielectric permittivity of the low DRA is “9.8”, the length is 2mm x 2mm, and the height is 1mm. As illustrated in figure 2, the upper DRA in the shape of an 8-edged star is put on top of the lower DRA with a height of 4mm. The upper and lower DRAs are utilized for the material Al_2O_3, which has a dielectric constant (r) of 9.8 and a height of 5.6mm. The Al_2O_3 series ensures that no material is harmed during the manufacturing and assembly processes. Though many DRA designs were evaluated, octagonal DRAs have a high radiation efficiency and a low return loss. Because the height of the low DRA is 1mm and the material utilized is Al_2O_3, the size of the antenna is kept to a minimum due to its high dielectric constant. Furthermore, LTCC (Low Temperature Co-fired Ceramic) is utilized to minimize the size of the antenna. In the design, two cubes are joined to produce an 8-edged star shape DRA. The size of the DRA is inversely related to the dielectric constant; however this dielectric constant might cause limited bandwidth, thus multilayer DRA is employed to overcome this restriction. However, size, impedance bandwidth, and gain may be adjusted by adjusting the height of each DRA layer and the dielectric constant.



(a) (b)

(c)

Fig 2:(a) Side view of the proposed antenna and (b)&(c) represents the front and back view of the proposed antenna.

RESULTS & DISCUSSION

The reflection coefficient must be low, and the bandwidth must be as large as feasible, in order to justify any antenna. This section will cover return loss, VSWR, gain, and radiationpattern.

RETURN LOSS:

Return loss is the amount of sent signal that can be reflected back to the feeder. In general, the maximum reflected power for a given aerial type should be 3dB. The suggestedaerial's reflection coefficient is shown in Figure 3.

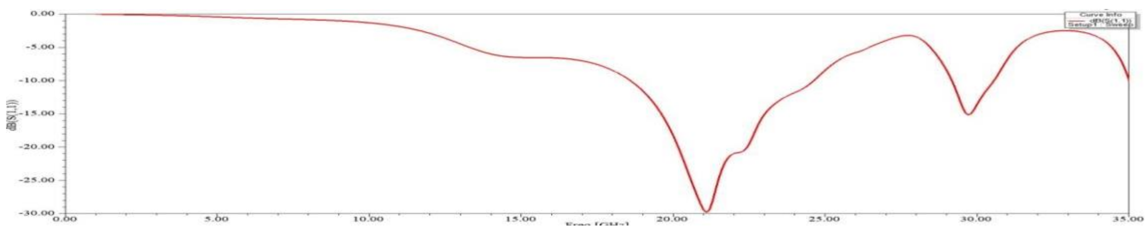


Fig 3: Return loss of the designed antenna

The reflection coefficient for the suggested antenna was found to be -30dB, and the designed antenna was tested in dual band mode with maximum bandwidths of 6GHz and 1.38GHz at K- Band and millimeter wave frequencies.

VSWR:

In general, VSWR stands for voltage standing wave ratio. The VSWR of any type of antenna is between 1 and 2, and the higher the number, the greater the reflected power. Figure 4 depicts the VSWR of the proposed antenna.

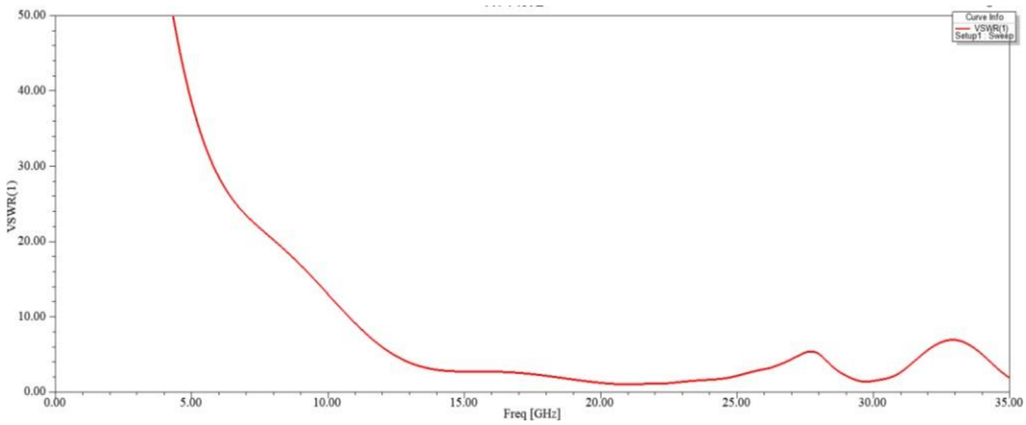


Fig 4: VSWR of the designed antenna

GAIN:

Figure 5 depicts the gain of the proposed antenna. In Figure 4, the red color represents the highest gain and the blue color represents the minimum gain of the proposed antenna.

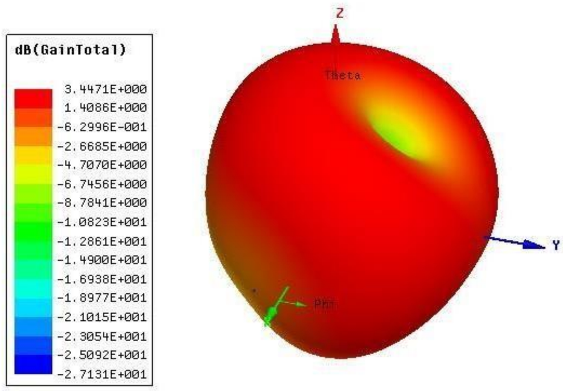


Fig 5: Gain of the proposed aerial

RADIATION EFFICIENCY:

Radiation efficiency is defined as the ratio of radiated power to accepted power of the antenna. It was discovered that the design antenna obtained a radiation efficiency of 94.81 percent. The acceptable power for the design antenna was determined to be 985mw out of 1w from the system, and it emitted about 934mw of power.

CURRENT DISTRIBUTIONS:

The maximum electric field and magnetic field distribution of the proposed antenna are depicted in figures 6 and 7.

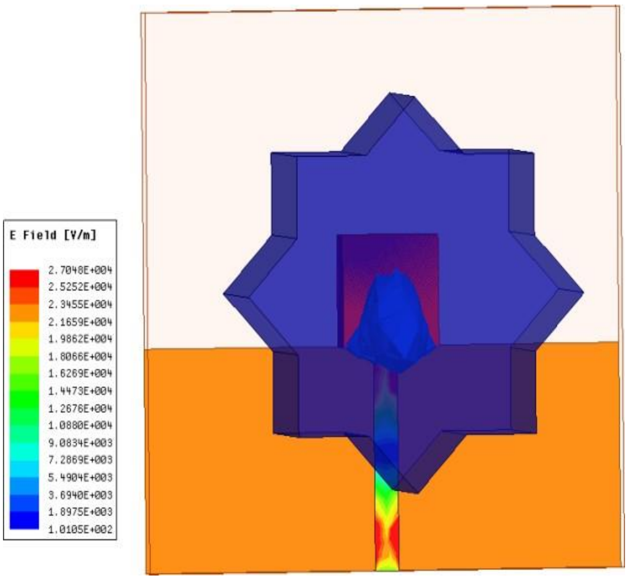


Fig 6: E-field distribution of the designed antenna

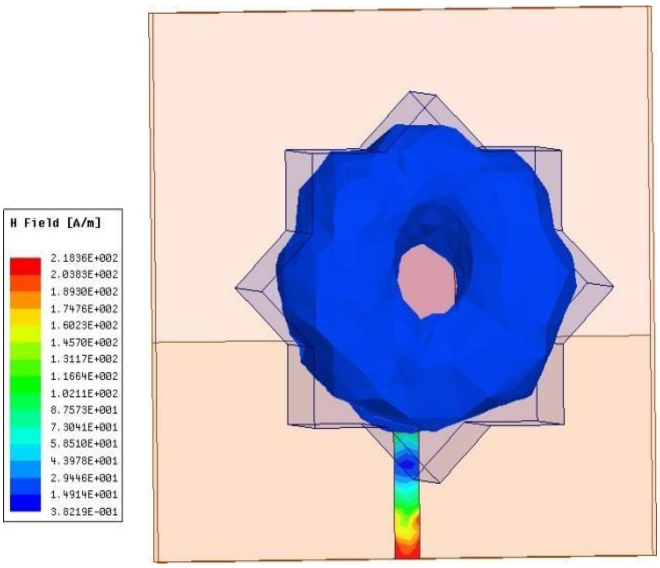


Fig 7: H-field distributions of the designed antenna

5.0 COMPARISON TABLE

Ref No	Shape of DRA	Type of feed	S(1,1)	Resonant Frequency	Bandwidth	E-Field (V/m)	H-Field (A/m)	Type Of Polarization
[1]	DISK	Line	-19db	2.4GHz	140 MHz	-		-
[2]	Hexagonal	Co-axial	-25db	4.5GHz	3.5GHz	-		-
[3]	Swastik	Line	-	5.5GHz	88%	-	-	Circular
[4]	H-Shape	Co-axial	-20db	4.18GHz	2GHz	1.08E+004	8.30E+000	-
[5]	Cone	Aperture	-38db	11GHz	0.699GHz	-	-	-
[6]	Cylindrical	Cross	-26db	5.7GHz	1.6GHz	-	-	-
[7]	Cylindrical	MIMO	-28db	2.8GHz	1.75GHz	-	-	LHCP
Proposed Design	**8-Edge Star**	**Line**	**-30db**	**21.1GHz**	**6GHz**	**6.15E+004**	**2.18E+002**	**Linear**

Table 1: Comparison of proposed antenna with various research work

The Table 1 shows the comparison of the proposed antenna with the earlier designs. It was found that the proposed antenna had enhanced bandwidth when compared to the earlier designs i.e., 6GHz and 1.38GHz. It was observed that the proposed antenna had got improved gain and electric field distribution is 6.15E+004 V/m and magnetic field is 2.18E+002 A/m.

6.0 CONCLUSION

The goal of this article is to create an eight-edged star-shaped dielectric resonator antenna for K-band applications. According to the literature, their antenna has a maximum bandwidth of 65 percent and a radiation efficiency of 90 percent. The AL_2O_3 and FR4 epoxy resin may be used to make an eight-edged star-shaped dielectric resonator for the propped antenna. It was discovered that the proposed antenna has increased bandwidth, namely 6GHz and 1.38GHz with dual-band. The suggested antenna has a higher radiation efficiency of 95%. The suggested antenna was examined using the HFSS 17.2 software.

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