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# Design of Dielectric Resonator loaded Dual Band Microstrip Antenna for 5G mm-wave Applications

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***Abstract:-*** In the current day of wireless communication systems, the need for high data rates, good channel capacities, and dependability is always the main area of concern. The 5G mm-wave technology standards are brave enough to offer large device connectivity, low latency communications, and huge data throughput. A dual band mm-wave microstrip antenna based on a Dielectric Resonator (DR) was reported in this communication for 5G NR n-257, n-258, n-259, n-260, and n-261 band applications. The antenna was designed using an octal bowl-shaped dielectric resonator, a modified rectangular patch, and a partial ground plane. The dimensions of the antenna were 15 x 15 x 0.254 $mm^3$. This antenna was grounded by a 15 x 15 $mm^2$ partial ground plane with a 14 x 13 $mm^2$ dimensioned wide rectangular slot. The modified rectangular patch was etched on Rogers RT/duroid substrate (dielectric constant 2.2). The AI2_O3_ ceramic dielectric resonator with dielectric constant 9.8 was mounted on patch for high efficient radiation. Two millimeter-wave bands were resonated in this embedded antenna radiating structure: the first band was 23.21GHz–31.25GHz with a central frequency of 25.44GHz, and the second band was 37.33GHz–44.45GHz with a core frequency of 40.89GHz. The dielectric resonator assisted in increasing the antenna's gain. The greatest gains over the first and second bands are 9.24 dBi and 7.2 dBi, respectively. Over both bands, a radiation effectiveness of greater than 84% was noted. The suggested antenna's results showed that it could cover the 5G NR n-257, n-258, n-259, n-260, and n-261 bands with a considerable gain and efficiency. Therefore, the antenna is a viable option for 5G mm-wave wireless communication systems.

***Keywords****: 5G, Dielectric Resonator, Microstrip, mm-wave.*

## 1. Introduction

In the current day of wireless communication systems, the need for high data rates, good channel capacities, and dependability is always the main area of concern. These days, there is a greater scarcity of mobile communication spectrum in the sub-3GHz bands, making it impossible to provide users with faster data speeds and greater device connectivity. 5G wireless communication: The standards for 5th generation mobile technology are brave enough to offer large device connectivity, low latency communications, and huge data rates. Millimeter wave frequencies necessitate the creation of small yet effective antennas in order to provide increased bandwidth and enable the effective deployment of 5G systems. [1][2][11][12]

A dielectric resonator antenna (DRA) is a type of radio antenna that is primarily employed at microwave frequencies and beyond. It is composed of a metal ground plane and a block of ceramic material that can take on different shapes. Standing waves are created when radio waves from the transmitter circuit enter the interior of the resonator material and bounce off the walls of the resonator. The radio power can radiate into space because the resonator's walls are partially permeable to radio waves. [3][4]

It has been watched [5] that DRs can be alluring options to moo pick up recieving wires such as microstrip patches, monopole, and dipole. It has too been found that DRAs can be considered to be proficient radiators by energizing suitable mode [6-9].

More as of late, DRA have been the center of consideration for analysts in 5G radio wire plan. It offers appealing choice due to the immaterial metallic misfortune in higher recurrence band compared to other commercialized radio wire. The utilization of mmWave for 5th Era offers preferences such as omnipresent network, exceptionally small idleness and tall speed information exchange. With 5G, numerous gadgets will interface ubiquitously and get an continuous client encounter, which implies the omnipresent network can realize user-centric see. Also, the mmWave systems will bolster real-time applications and administrations with least delay resistance. When 5G association is formally roll out to clients in 2023, it is anticipated that the 5G will encounter amazingly moo inactivity of the arrange of 1 millisecond and the service-provider centric see will be realized by the zero inactivity. At long last, the transfer speed groups of mmWave are a few times broader than 3G and 4G recurrence groups. So, these wave groups can back higher speed information exchange which are required for a parcel of applications in the future [10].

An advantage of dielectric resonator radio wires is they need metal parts, which gotten to be lossy at tall frequencies, scattering vitality. So these radio wires can have lower misfortunes and be more effective than metal recieving wires at tall microwave and millimeter wave frequencies. Dielectric waveguide recieving wires are utilized in a few compact versatile remote gadgets, and military millimeter-wave radar hardware. The recieving wire was to begin with proposed by Robert Richtmyer in 1939. In 1982, Long et al. did the to begin with plan and test of dielectric resonator radio wires considering a defective waveguide demonstrate accepting attractive conductor show of the dielectric surface. In that exceptionally to begin with examination, Long et al. investigated HEM11d mode in a round and hollow formed ceramic square to emanate broadside. After three decades, however another mode (HEM12d) bearing indistinguishable broadside design has been presented by Guha in 2012.

An recieving wire like impact is accomplished by intermittent swing of electrons from its capacitive component to the ground plane which carries on like an inductor. The creators assist contended that the operation of a dielectric radio wire takes after the radio wire conceived by Marconi, the as it were contrast is that inductive component is supplanted by the dielectric material.

Dielectric resonator radio wires offer the taking after alluring highlights: There is no inalienable conductor misfortune in dielectric resonators. This leads to tall radiation proficiency of the recieving wire. This include is particularly alluring for millimeter (mm)-wave recieving wires, where the misfortune in metal manufactured radio wires can be high.

DRAs offer basic coupling plans to about all transmission lines utilized at microwave and mm-wave frequencies. This makes them reasonable for integration into distinctive planar advances. The coupling between a DRA and the planar transmission line can be effectively controlled by changing the position of the DRA with regard to the line. The execution of DRA can subsequently be effectively optimized experimentally.

The working transmission capacity of a DRA can be changed over a wide extend by appropriately choosing resonator parameters. For illustration, the transfer speed of the lower arrange modes of a DRA can be effectively shifted from a division of a percent to around 20% or more by the reasonable choice of the dielectric consistent of the fabric and/or by key forming of the DRA element.

Use of numerous modes transmitting indistinguishably has moreover been effectively tended to. One such illustration is cross breed combination of dielectric ring-resonator and electric monopole which was at first investigated by Lapierre. Different indistinguishable monopole-type modes in an annular molded dielectric ring-resonator were hypothetically analyzed by Guha to appear their one of a kind combinations with that due to a conventional electric monopole coming about in UWB recieving wires.

Each mode of a DRA has a interesting inner and related outside field dissemination. Hence, diverse radiation characteristics can be gotten by energizing distinctive modes of a DRA. In an unexpected way transmitting modes have too been utilized to produce indistinguishable radiation designs utilizing composite geometries, with a extraordinary highlight of more extensive transfer speed.

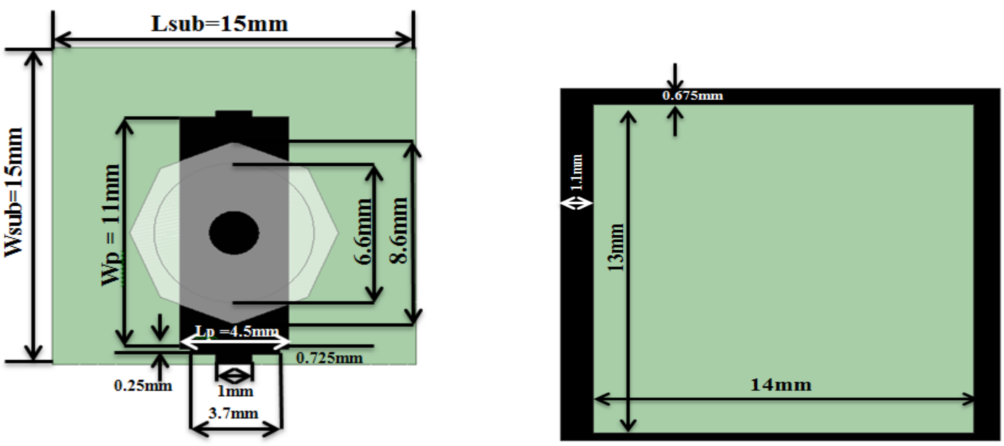
In this communication, a Dielectric Resonator (DR) based dual band mm-wave microstrip antenna was presented for 5G NR n-257, n-258, n-259, n-260, and n-261 band applications. The antenna was modeled using modified rectangular patch, partial ground plane and octal bowl shaped dielectric resonator with in dimensions of 15 x 15 x 0.254 $mm^3$ with respect to length, width and height. The modified rectangular patch was etched on Rogers RT/duroid substrate (dielectric constant 2.2), the AI2_O3_ ceramic dielectric resonator with dielectric constant 9.8 was mounted on patch for high efficient radiation and this antenna was grounded by 15 x 15 $mm^2$ partial ground plane with 14 x 13 $mm^2$ dimensioned wide rectangular slot. This embedded antenna radiating structure was resonated in two mm-wave bands, the first band was 23.21GHz-31.25GHz band with central frequency 25.44GHz and second one was 37.33GHz-44.45GHz with central frequency 40.89GHz.

## 2. Design and Analysis

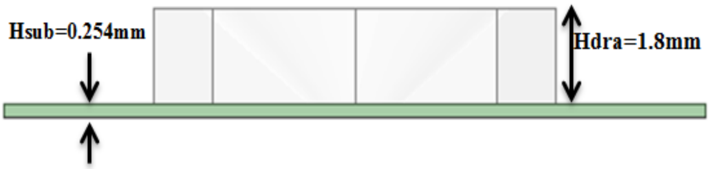
The demand for high data rate, good channel capacity, and reliability is always the primary area of concern in the modern era of wireless communication systems. Present days mobile communication spectrum, below 3GHz bands is faces more shortage and not able to serve people with more device connectivity and data speed. 5G wireless communication: The 5th generation mobile technology standards have the guts to deliver high data rates, low latency communications, and massive device connectivity. For the efficient deployment of the 5G systems and in order to support higher bandwidth requires the design of compact yet efficient antennas at mm wave frequencies.

In this communication, a Dielectric Resonator (DR) based dual band mm-wave microstrip antenna was presented for 5G NR n-257, n-258, n-259, n-260, and n-261 band applications. The antenna was modeled using modified rectangular patch, partial ground plane and octal bowl shaped dielectric resonator with in dimensions of 15 x 15 x 0.254 $mm^3$ with respect to length, width and height.

The modified rectangular patch was etched on Rogers RT/duroid substrate (dielectric constant 2.2), the AI2_O3_ ceramic dielectric resonator with dielectric constant 9.8 was mounted on patch as shown in Fig.1 (a) for high efficient radiation and this antenna was grounded by 15 x 15 $mm^2$ partial ground plane with 14 x 13 $mm^2$ dimensioned wide rectangular slot Fig. 1 (b). This embedded antenna radiating structure was resonated in two mm-wave bands, the first band was 23.21GHz-31.25GHz band with central frequency 25.44GHz and second one was 37.33GHz-44.45GHz with central frequency 40.89GHz.




(a) Top view (b) Bottom view




(c) Side view

**Fig. 1 Prototype of proposed design with dimensions**

Here used a microstrip feeding technique for antenna excitation .The proposed antenna fed with this strip feeding technique got more bandwidth in the mm-wave frequency range. Using HFSS software the antenna was designed according to the proposed dimensions. The proposed antenna was operated in dual wide millimeter wave bands. It offers some advantages; low cost, high flexibility, harmless to human body and resistive towards environmental effects. The dimensions of proposed antenna were as shown in Fig. 1 and Table I.

TABLE I. OPTIMIZED DIMENSIONS OF PROPOSED ANTENNA

| **Parameter** | **Alias Used** | **Size in mm** |
|---|---|---|
| Length of substrate | Lsub | 15 |
| Width of substrate | Wsub | 15 |
| Hight of substrate | Hsub | 0.254 |
| Length of Patch | Lp | 4.5 |
| Width of Patch | Wp | 11 |
| Length of Ground | Lg | 15 |
| Width of Ground | Wg | 15 |
| Length of Ground slot | Lgslot | 14 |
| Width of Ground slot | Wgslot | 13 |
| Radius of outer octal cylindrical DRA | Rdra_out | 4.3 |
| Height DRA | Hdra | 1.8 |
| Bottom Radius of inner conical DRA | Rdra_in1 | 0.5 |
| Top Radius of inner conical DRA | Rdra_in2 | 3.3 |
| Width of feed line | Wfeed | 1 |

## 3. Results and Discussion

The proposed Dielectric Resonator loaded micostrip antenna in this project capable to cover mm-wave 5G NR n-257, n-258, n-259, n-260, and n-261 frequency bands. The proposed antenna radiating structure was resonated in two mm-wave bands, the first band was 23.21GHz-31.25GHz band with central frequency 25.44GHz and second one was 37.33GHz-44.45GHz with central frequency 40.89GHz. It can observe in return losses plot of proposed antenna design, which was shown in Fig. 2.

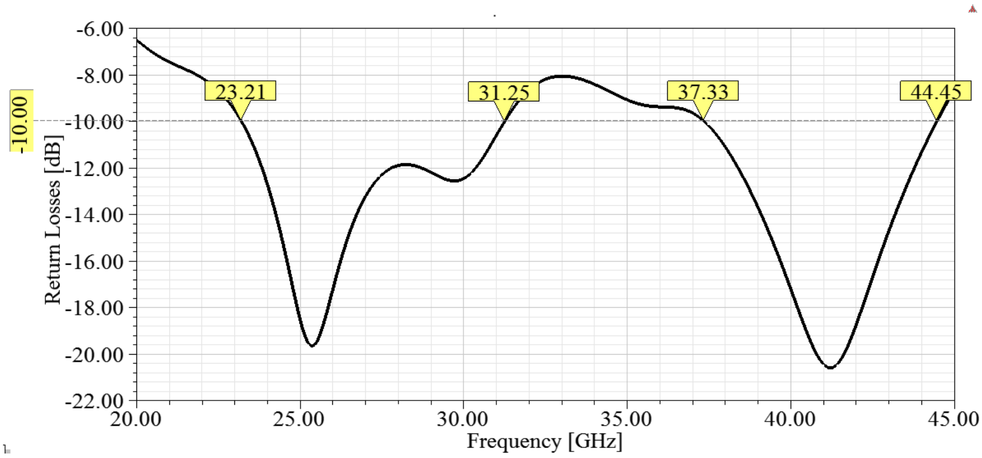



**Fig. 2 Return Loss plot of Proposed Antenna**

At both resonated bands, the voltage to standing wave ratio was less than 2. The VSWR of proposed antenna were given in Fig. 3.

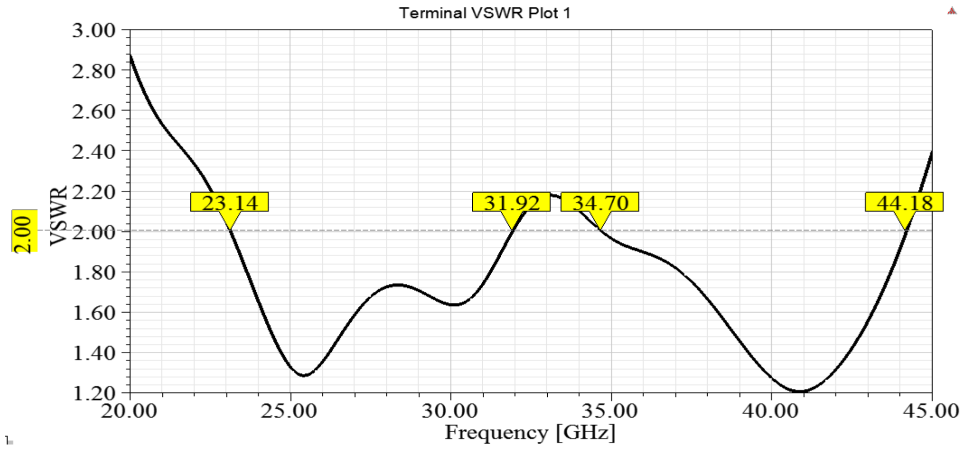



**Fig. 3 VSWR plot of Proposed Antenna**

The dielectric resonator was helped to enhance the gain of antenna. The 9.24dBi, 7.2 dBi are the maximum gains obtained over the first band and second band respectively. It can observe in Gain plot of proposed antenna design, which was shown in Fig. 4. Greater than 84% radiation efficiency was observed over both bands. It can observe in return efficiency plot of proposed antenna design, which was shown in Fig. 5.

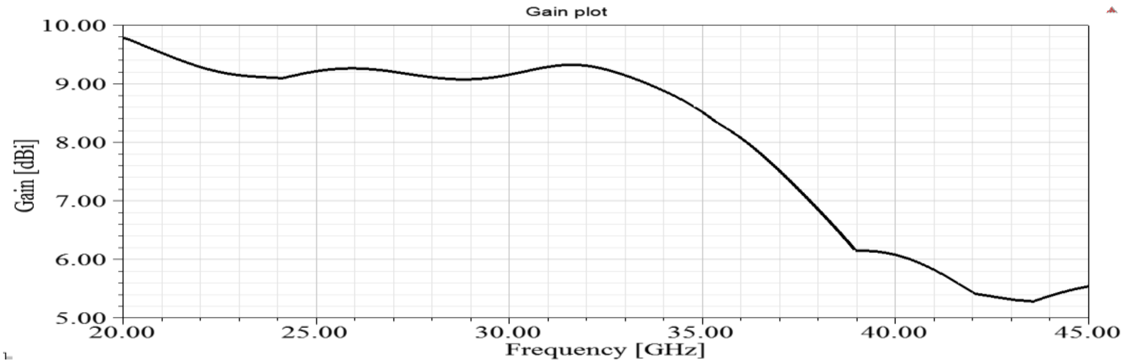



**Fig. 4 Gain plot of Proposed Antenna**

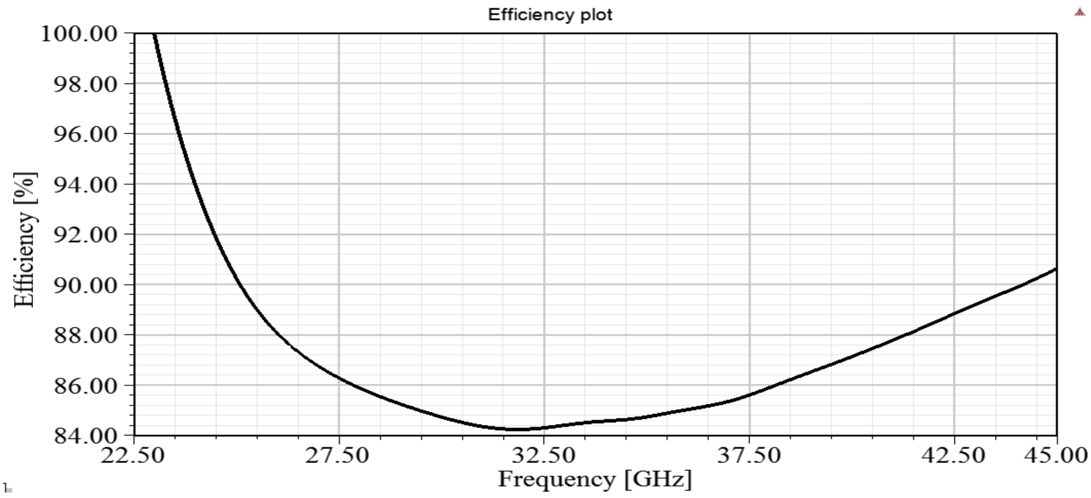



**Fig. 5 Efficiency plot of Proposed Antenna**

It was already stated that the proposed antenna was resonated in two mm-wave bands, the first band was 23.21GHz-31.25GHz band with central frequency 25.44GHz and second one was 37.33GHz-44.45GHz with central frequency 40.89GHz. The gain 9.24dBi was observed at first band central frequency 25.44GHz and the gain 5.86 dBi was observed at second band central frequency 40.89GHz. The 2D E-plane and H-plane radiation patterns at both resonant frequencies were shown in Fig. 6.

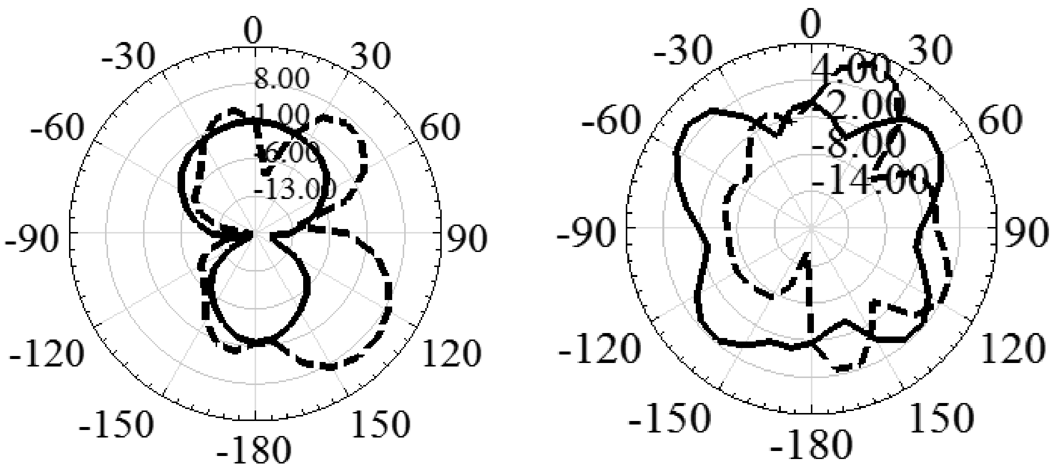



**Fig. 6 2D principle plane patterns of Proposed Antenna at 25.44 GHz and 40.89 GHz**

From the results extracted from proposed antenna, it was found that, the antenna capable to cover 5G NR n-257, n-258, n-259, n-260, and n-261 bands with significant gain and efficiency. Thus the antenna can be considered as a potential candidate for 5G mm-wave wireless communication systems.

TABLE II. RESULTS OF PROPOSED ANTENNA

| **Radiation Parameter** | **Obtained result** |
|---|---|
| Resonant Frequency Bands | 23.21GHz-31.25GHz |
| | 37.33GHz-44.45GHz |
| Central Resonant Frequencies | 25.44GHz |
| | 40.89GHz |

| | |
|---|---|
| Return Losses at 25.44GHz | 19.8 dB |
| Return Losses at 40.89GHz | 20.4 dB |
| Band width over first band | 8.04 GHz |
| Bandwidth over second band | 7.12 GHz |
| Gain at 25.44GHz | 9.24 dBi |
| Gain at 40.89GHz | 5.86 dBi |
| Maximum gain over first band | 9.24 dBi |
| Maximum gain over second band | 7.2 dBi |
| Efficiency over first band | >84 % |
| Efficiency over second band | >84% |

## 4. Conclusion

In this communication, a Dielectric Resonator (DR) based dual band mm-wave microstrip antenna was presented for 5G NR n-257, n-258, n-259, n-260, and n-261 band applications. For the purpose of high efficient radiation, the antenna was modeled using modified rectangular patch, partial ground plane and octal bowl shaped dielectric resonator with in dimensions of 15X15X0.254mm3 with respect to length, width and height. With this embedded radiating structure, the antenna was resonated in two mm-wave bands, the first band was 23.21GHz-31.25GHz band with central frequency 25.44GHz and second one was 37.33GHz-44.45GHz with central frequency 40.89GHz. The dielectric resonator was helped to enhance the gain of antenna. The 9.24dBi, 7.2 dBi are the maximum gains obtained over the first band and second band respectively. Greater than 84% radiation efficiency was observed over both bands. From the results extracted from proposed antenna, it was found that, the antenna capable to cover 5G NR n-257, n-258, n-259, n-260, and n-261 bands with significant gain and efficiency. Thus the antenna can be considered as a potential candidate for 5G mm-wave wireless communication systems.

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