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Tetra-band Transparent Antenna for Future 5G Applications

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Abstract- The main objectives of the designed antenna are to achieve a 5G frequency band, Tetra band frequencies, transparency, and provide connectivity to multiple users in populated areas. This paper presents the design of a 5G transparent antenna made of plexiglass substrate having dimensions of 35 x 25 mm^2 with weather resistance, UV radiation protection, and comprehensive color activities. It is made up of a radiating patch of solid cylinders, a rectangular stub linked to a solid cylinder, and a whole ground plane with cuts on it. This antenna's lumped port is placed in the top right corner of the substrate, enabling feeding in the upward direction from ground to patch. By adjusting the port's position, different antenna characteristics can be noticed. This antenna covers the four frequency bands in which one band of the 5G spectrum in three distinct areas ranging from frequency ranging of (3100-3800) MHz. An antenna model is shown and explained, as well as numerous characteristics such as the S-parameter, gain plot, and radiation pattern plot. The simulated result of this antenna indicates that it is the best fit for future 5G applications due to its transparent characteristic, lightweight, simplicity of usage, and sizeable attainable frequency bandwidth.

Keywords- Tetra Band Antenna, Transparent Antenna, Optical Antenna, Antenna on Packet, Future 5G Applications

I. INTRODUCTION

As the globe moves forward, people hope for smart gadgets that operate faster than ever and have seamless connectivity. The ever increasing demand for higher data rates because of the extensive use of mobile handsets for video streaming necessitates constant advancements in device technology. Today for 4th generation systems, data rate speeds can reach up to 100 Mbits/s and can be increased to 1 Gbits/s. The goal for the 5th next-generation (5G) system is to achieve a speed of 20 Gbits/s. To meet the customer necessities, 5G technology is replacing with 4G. The fifth-generation mobile communication system is widely installed. It provides numerous benefits over the 4G system, including greater transmission rates, higher bit rates with lower battery consumption, and shorter latency. Such systems provide a connection at high speed for multimedia applications. [1-3].

Internet of Things (IoT) is a reality, with billions of gadgets expected to be connected in the future [4]. NASA initiated research on transparent antennas in 1997. [5]. Researchers used transparent conductive materials to create antennas. However, most designs were not completely transparent because the conductive traces were easily visible [6]. The research goal over the last two decades was to achieve transparency and efficiency using transparent conductive materials [7]. Transparent antennas are distinguished by their ability to be put on top of other items with almost transparent properties without altering their look [8-9].

The 5G-enabled devices are already becoming more prevalent in the telecoms sector today, and some companies are even creating entirely transparent and flexible devices [10]. Flexible and transparent antennas operating in the 5G frequency ranges are necessary for these circumstances.

Antenna designers face challenges in designing antennas to meet the demands of high-speed networks and the need to fulfill user capacity. Miniaturization of the installed antenna is also a challenge for designers, which gets more fascinating due to space constraints and interference effects among the device's components. A transparent antenna with high conductivity is one approach for avoiding space constraints [9]. Transparent antennas have sparked a lot of attention due to their applications in automobiles, building windows, and computer video monitors. Transparent antennas could be utilized in a variety of applications. Most of them entail vehicle-to-vehicle communication. These antennas would also be used for navigation, optimization, and security of vehicle performance. Blocking 5G frequencies adds security for hospitals and homeland security agencies while limiting internal communication to the outside world allows for secure communication within hospital wards and buildings [11-14].

Antenna design was the methodology we used for our research. On HFSS software, we created an "antenna on the packet" and observed the results after varying parameters such as operating frequency and sweep. Following that, we ran a simulation and then examined the results. Then we get a waveform covering various bands such as 2G, 3G, and 5G. By implementing this antenna, we can provide three types of network connectivity to our customers, and we will be able to accommodate more users. In our proposed antenna, we use traditional conductors like copper to offer wide operational bandwidth and good radiation patterns and gain [15-17].

Operators want the network to be "better, faster, and cheaper" without sacrificing these three characteristics [18]. The most significant distinction between 5G and previous generations is the wide range of applications that 5G networks must support. Objects ranging from cars and factory machines to appliances meet our needs by adapting to our behavior, environment, or business processes. New use cases, many of which have not yet been imagined, will emerge, resulting in novel business models [19].

The following areas will be impacted by 5G connectivity: The first one is mobility in the real world means the way we travel and interact with our surroundings. The second is mobility on the internet, which means we can control remote environments, and the third is high efficiency [20].

The following is how this paper is organized. The abstract is explained at the beginning of the paper, in which we presented a brief overview of our research. Section 2 describes a 5G transparent antenna on the packet with materials and geometry with measurements. It also highlights the parametric analysis of the antenna. The results and performance analysis are highlighted regarding the fundamental antenna properties and diversity factors in section 3. Conclusions are covered in Section 4.

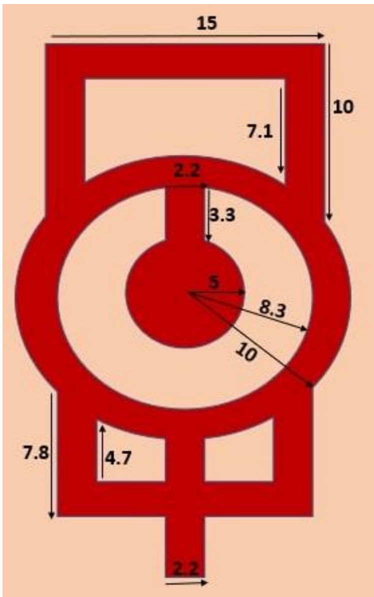
II. MATERIALS AND GEOMETRY

A. Material with Dimensions

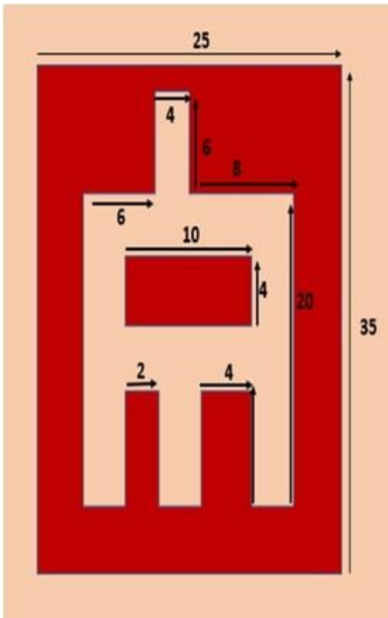
This paragraph depicts the proposed antenna's step-by-step geometry. We used HFSS software for Tetra-band Transparent Antenna for Future 5G Applications. Proceeding from the rectangular substrate made up of Plexiglas with dimensions of 25mm X size, 35mm Y size, and 1.85mm Z size. We used Plexiglas material which protects this proposed antenna from worse weather and ultraviolet radiation. The design of the patch with a beginning circular ring of a 10 *mm* radius that is connected to a 5 *mm* center circular solid by a rectangle. Draw a stub from the bottom up with X size equal to 2.2 *mm* and Y size equal to 7.56 *mm*. Draw two U-shaped domes on the main circle's top and lower sides.

Connect this ground to the patch through a lumped port with a 50-ohm impedance—airbox, which encloses our proposed antenna from all sides and assigns boundaries and excitation to this air box. Create a solution setup with the frequency of 5.8 GHz with a maximum number of passes of 6 and a maximum delta S is 0.02. Now check parametric analysis. Then simulate this suggested antenna and check the results.

The front and top view of the antenna is given below.



(a) front view



(b) back view

Fig. 1. Transparent antenna geometry. (Dimensions are in mm).

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B. Parametric Analysis:

S11 parameter can be altered by adjusting parameters. The first technique of changing S11 characteristics is when the location of the lumped port changes. When we relocated the lumped port from top to bottom or top center, we didn't get the intended results. We suggest a solution to this problem by installing a lumped port in the upper right corner, which accomplishes the expected effects and enables us to utilize the 5G spectrum. The second way to change the S11 parameter is to change the parameters of the rectangular stub.

III. Simulation And Results

It presents a brief and accurate description of the experimental data, their interpretation, and the experimental inferences that may be reached in this part. The suggested antenna's results have been examined, covering the needed bandwidth of 5 GHz. The proposed transparent antenna covers the four bands with resonance frequencies of 3.1 GHz, 5.4 GHz, 6.9 GHz, and 9.8 GHz, respectively. These bands are utilized in public safety, security, and transportation; networks that employ this technology include Airwave (UK) and Astrid (Belgium). Panorama offers a comprehensive selection of tetra bands of resonant frequencies for all UHF (ultra-high frequency) and 800MHz band allocations to meet mobile (land and marine), portable and fixed site applications.

Our suggested antenna covers the C-band frequency range, which refers to the section of the electromagnetic spectrum authorized for satellite communications between 4GHz and 8GHz. C-band satellite antennas are commonly employed in areas where signals might be reduced owing to heavy rain or other extreme weather conditions. So, this antenna will be capable of providing services in these areas.

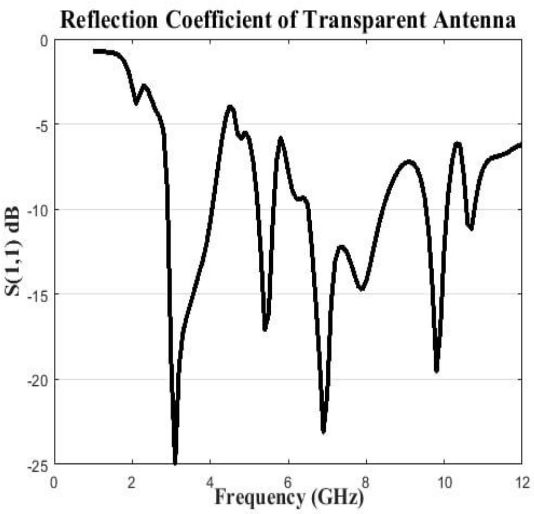
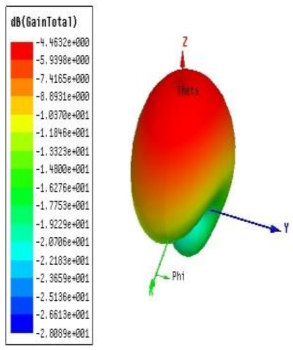


Fig. 2. Antenna Evaluation

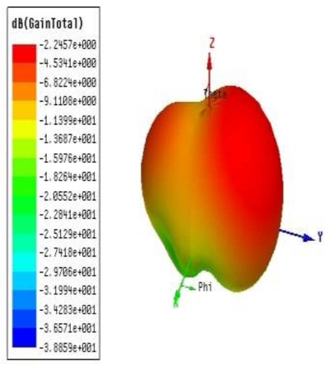
5G has different frequency band requirements in different regions. However, the essential requirements of the 5G spectrum are (3400-3800 MHz) for Europe, (3300-3600 MHz) for China, (3400-3700 MHz) for Korea, and (3100-3550 MHz) for the United States has been covered in the first band of our proposed antenna.

Antennas for 5G are used to manage the high speed, capacity, and bandwidth of 5G networks, and this antenna has all the attributes that make it an excellent choice for the 5g band. This suggested antenna covers three distinct types of 5G bands in three different places China, Korea, and the United States of America. This antenna demonstrates its features for quicker transmission rates, lower latency, and therefore improved remote execution capabilities. It also covers the C-Band, which ranges from (4-8) GHz and is used in those areas where signals of the internet are weak due to the worst weather conditions.

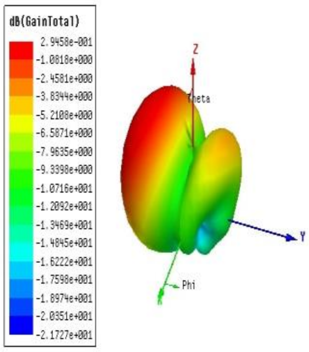
Our proposed antenna covers tetra frequency bands of 3.1 GHz, 5.4 GHz, 6.9 GHz, and 9.8 GHz. We examine the gains at these resonant frequencies to see how well our suggested antenna performs and analyze the drawbacks of this antenna. The suggested antenna's gain at these frequencies is shown below.



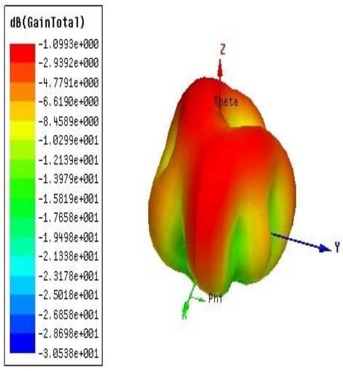
(a) At Frequency 3.1 GHz



(b) At Frequency 5.4 GHz



(c) At Frequency 6.9 GHz



(d) At Frequency 9.8 GHz

Fig. 3. 3D radiation pattern of proposed antenna at different frequencies.

The table below shows the gain values at the tetra band with resonant frequencies.

TABLE: 1 GAINS AT DIFFERENT FREQUENCIES

Sr. No.	Central Frequency	Gain (dB)
I.	3.1 GHz	-4.4632
II.	5.4 GHz	-2.2457
III.	6.9 GHz	2.9458
IV.	9.8 GHz	-1.0993

The Radiation pattern of this proposed antenna is given below.

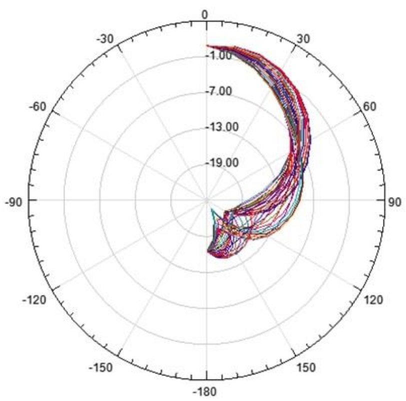


Fig. 4. Antenna Radiation Pattern

The above graph gives the graphical depiction of the antenna's radiation characteristics as a function of space. In other words, the antenna's design illustrates how our suggested antenna emits energy into space or receives energy. In brief, it provides the overall transmitting and receiving pattern of energy.

Voltage standing wave ratio (VSWR) provides information on how efficiently power is delivered from the antenna's ground to the patch through the lumped port. In an ideal antenna, 100% of the energy is transmitted to the path through the lumped port. It helps us in differentiating ideal and non-ideal antennas. In a non-ideal case, when the value of VSWR (voltage standing wave ratio) is lower, the antenna impedance matches the transmission line, and in this way, more power is delivered to the antenna. Our proposed antenna may damage the lumped port and, as a result, decrease its efficiency.

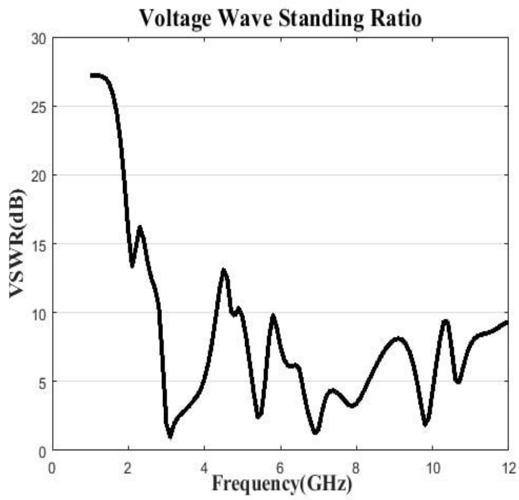


Fig. 5. Voltage Standing Wave Ratio

The current distribution of the antenna is depicted below. It exhibits the identical surface current distribution on a solid cylinder's outer circular part. The green region has the potential to change the results of the proposed antenna. However, if we change parameters to the blue side, the findings stay the same.

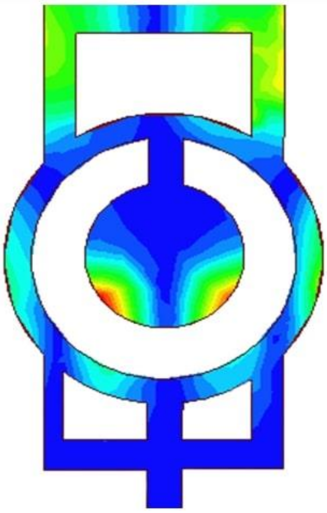


Fig. 6. Current Distribution and Flow

The realized gain of the transparent antenna is given below. It provides details on both internal antenna structural losses and losses resulting from reflections at the input terminals.

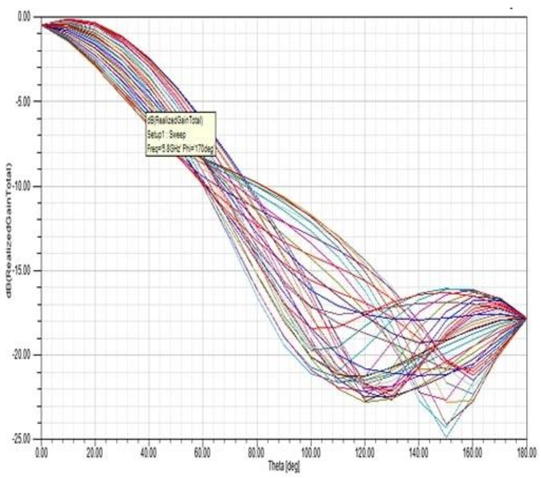


Fig. 6. Realized Gain

IV. Conclusion

A conductive patch and plexiglass substrate are used to create a 5G transparent antenna, for which reflection coefficient and gain characteristics are studied. Due to having C-band coverage in our proposed antenna, it can be used in villages and areas where weak signals are transmitted due to poor trunks or the worst weather. The feeding of the antennas comes from the top right corner of the antenna, and if we move the port, the results will change automatically. The frequency spectrum of (3100-3800) is achieved, covering 5G band requirements of 3 different regions. The antenna's gain is 1.18 from (0-360^0), and the suggested transparent antenna constructed connected to the whole ground is suited for smart devices employing 5G in IoT applications since it has no co-site position concerns and complete transparency.

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