High Gain Dense Dielectric Patch Antenna for 5G Communication Using EBG Ground Structure and Dielectric Superstrate

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Abstract: In this paper, another thick dielectric (DD) fix cluster radio wire model working at 28 GHz for future fifth generation (5G) cell systems is exhibited. This cluster radio wire is proposed and planned with a standard printed circuit board procedure to be reasonable for combination with radio recurrence/microwave hardware. The proposed structure utilizes four round molded DD fix radiator radio wire components encouraged by a 1-to-4Wilkinson power divider. To enhance the cluster radiation qualities, a ground structure in light of a conservative uniplanar electromagnetic bandgap unit cell has been utilized. The DD patch demonstrates better radiation and add up to efficiencies contrasted and the metallic fix radiator. For further pick up change, a dielectric layer of a superstrate is connected over the exhibit reception apparatus. The deliberate impedance data transmission of the proposed exhibit reception apparatus ranges from 27 to past 32 GHz for a reception coefficient (S11) of under 10 dB. The proposed configuration displays stable radiation designs over the entire recurrence band of enthusiasm, with a add up to acknowledged acquire than 16 dBi. Because of the wonderful execution of the proposed exhibit, it can be considered as a decent possibility for 5G correspondence applications.

Keywords: Wireless Communication Networks, Dense Dielectric, 5th Generation, Electromagnetic Band Gap (EBG).

I. INTRODUCTION

A sensor network is defined as composition of a large number of low cost, low power multi functional sensor nodes which are highly distributed either inside the system or very close to it. These nodes which are very small in size consist of sensing, data processing and communicating components. The position of these tiny nodes need not be absolute; this not only gives random placement but also means that protocols of sensor networks and its algorithms must possess self organizing abilities in inaccessible areas. However nodes are constrained in energy supply and bandwidth, one of the most important constraints on sensor nodes are the low power consumption requirements. These constraints combined with a specific deployment of large number of nodes have posed various challenges to the design and management of networks. These challenges necessitates energy awareness at all layers of networking protocol stack. The issues related to physical and link layers are generally common for all kind of sensor applications, therefore the research on these areas has been focused on system level power awareness such as dynamic voltages calling, radio communication hardware, low duty cycle issues, system portioning, and energy aware MAC protocols. At the network layer, the main aim is to find ways for energy-efficient route setup and reliable routing of data from the sensor nodes to the sink so that the lifetime of the network is maximized. Sensor nodes not only carry limited but usually carry irreplaceable power sources and thus the main focus of sensor network protocol is primarily on power conservation. At the cost of lower throughput or higher transmission delay they must possess inbuilt trade-off mechanism that gives the end user the option of prolonging network lifetime. Realization of these and other sensor network applications require wire less ad hoc networking techniques. Although many protocols and algorithms have been proposed for traditional wire less ad hoc networks, they are not well suited for the unique features and application requirements of sensor networks. To illustrate this point, the differences between sensor networks and ad-hoc networks are as follows

- Sensor nodes mainly use broadcast communication whereas ad-hoc network uses point to point communication.
- The topology of a sensor network changes very frequently.
- Sensor nodes may not have global identification because of the large amount of overhead and large number of sensors.
- The number of sensor nodes in a sensor network can be several orders of magnitude higher than the nodes in Ad-hoc networks.

II. RELATED WORK

In the late 1960s, dielectric resonators have been proposed as high-Q elements in microwave circuits, such as filters and oscillators, [1]. In the early 1980s, dielectric resonators have been used as antennas (DRAs) [2]. Many researchers have shown great interest in using DRAs in many different applications because of their unique feature of low-loss and high-efficiency compared to metallic patches [3]. Dielectric resonator antenna (DRA) consists of a dielectric resonator (DR) placed either directly above the metallic ground plane or above a relatively low dielectric substrate existing between
the DR and the metallic ground plane. In such case, the DR antenna mode HEM11 will be excited. Other than exciting the high dielectric material in the HEM11 DR mode, it has been reported that a TM11 cavity mode can also be excited in the region between the circular di- electric resonator and the metallic ground plane. The antenna excited with this cavity mode is designated the dense dielectric (DD) patch antenna. It is considered as a member of the patch antenna family rather than the DRA. It is expected that the efficiency of this antenna is higher than that of the conventional metallic patch antenna, especially at higher frequencies where the radiation efficiency of the microstrip patch antenna becomes low [4], besides maintaining the low-profile feature. To overcome signal attenuation due to oxygen molecules absorption at millimeter-wave frequencies high gain antenna system is required. One of the main gain enhancing techniques is using an antenna array with a proper feeding network. In addition, for extra gain enhancement superstrate technology can be adopted [5], [6]. In which, dielectric slab with an approximate thickness of \( \lambda/4 \) is mounted over a radiating patch antenna at a distance of approximately \( \lambda/2 \). Gain enhancement is obtained as a result of multiple reflections that occur between the radiating element and the dielectric slab providing multiple images of the radiator. In other words, the superstrate layer is used as a lens for focusing the main beam radiation of the antenna resulting in a noticeable enhancement for the antenna gain.

### III. PROBLEM FORMULATION

The main application of Microstrip antenna at 3GHz frequency is in WIMAX technology. But in the referred work the combination of the rectangular microstrip patch antenna was fabricated on the top of the substrate Rogers RO3003 with Electromagnetic Band Gap structures at the ground plane and then investigated the metamaterial characteristics in antenna design for satellite application. The patch antenna along with the EBG structure was designed to resonate at 7.3 GHz. Simulations and measurements were carried out to verify the performance of EBG structures in patch antenna. Metamaterial characteristics exhibits negative permittivity and permeability of the proposed EBG structures which was verified using Nicolson-RossWeir (NRW) method. And hence results in combining the rectangular patch with EBG structure, the bandwidth of the antenna got increased by 39.63\% and the size of the antenna reduced by 22.38\% compared to the antenna without EBG. The return loss also met the specification of -10 dB cut off. But the limitation of this antenna was that it was having some strong spurious bands at lower frequencies which can be useful for the purposes of WIMAX applications and hence the work has to be done for designing the antenna for this band and also the decreasing the size of antenna with improved parameters such as return loss and efficiency of the antenna. The antenna is designed using software HFSS 10.0 version. Lot of optimization is done on the antenna by varying its parameters such as length, width, height, material used, feeding techniques and applying different geometries to the patch antenna. Also DGS was applied to the existing structure by applying various slots at different locations and of different shapes.

In the reference design the slots are cut on the ground plane of butterfly shape which is not easy to designed and fabricate. Hence the structure is made simpler by applying rectangular shape slots at the ground plane. The optimization was done by applying circular and triangular shape slots and finally rectangular was proposed.

![Geometry of the proposed DD patch antenna design](image)

**Fig 1. Geometry of the proposed DD patch antenna design**

(a) isometric view (b) detailed view.

Fig1 shows the geometry and configuration of the proposed DD patch antenna. The circular DD patch has a radius \( R_d \) and a height \( H_d \) with relative permittivity of 82. It is designed and realized on RT5880 substrate (substrate 2) with relative permittivity \( \varepsilon_r \) D 2.2, loss tangent \( \tan \gamma = 0.0009 \) and thickness \( H2 \). The two substrates have the same length \( L \), width \( W \) and thickness \( H2 \). The antenna is fed through a slot of length \( L_S \) and width \( W_S \) in the ground plane in the middle layer between the two substrates. On the other side of substrate 1, a 50\( \square \)microstrip line of width WF and length LF is located. For further gain improvement, a superstrate dielectric layer of a thickness \( HS \) and located at a distance \( d_S \) from the top of substrate 2, is applied above the antenna.

### IV. PROPOSED DD PATCH ANTENNA ARRAY WITH EBG GROUND AND A DIELECTRIC SUPERSTRATE

The geometrical configuration and photograph of the proposed DD array antenna prototype are illustrated in Fig.1. The array consists of four identical DD patch antennas fed by a 1-to-4 Wilkinson power divider [8]. Electromagnetic bandgap (EBG) structure has been used to reduce the losses...
High Gain Dense Dielectric Patch Antenna for 5G Communication using EBG Ground Structure and Dielectric Superstrate due to surface wave. Fig 2. Presents the dispersion diagram of the proposed UC-EBG unit cell with a band-gap occur in the 28 GHz frequency band. The inter-element spacing among antenna elements is set to d D 12 mm.

Fig 2. Geometry of the proposed DD patch array antenna design (a) array layers (b) top view (c) bottom view (d) EBG unit cell (e) photograph of fabricated prototype.

Fig 3. Reflection coefficient S11 of the proposed DD patch antenna design compared to the conventional metallic patch antenna.

Fig 4. Dispersion diagram of the proposed UC-EBG unit cell.

Fig 5. Simulated maximum realized gain for the proposed DD patch array compared to the metallic patch array.

V. RESULTS

The calculated reflection coefficient S11 against the frequency for the designed DD patch antenna is plotted in Fig 3.
Fig. 5 introduces the simulated maximum realized gain for the proposed 4-element DD patch array and 4-element conventional metallic patch array. The gain for DD patch element and conventional metallic patch element are also shown in the same figure for comparison purposes. It can be noticed that the proposed 4-element DD patch array antenna exhibits a maximum realized gain better than that of the 4-element conventional patch array.

VI. CONCLUSION

In this paper, a new four-element dense dielectric (DD) patch array antenna design at 28 GHz for future 5G short-range wireless communications has been introduced. Its radiation characteristics can be improved by using EBG structure in the ground plane and a dielectric superstrate above it. A detailed comparison of performance between the proposed DD patch array and conventional metallic one has been presented. The proposed array antenna is a good candidate for future 5G applications.

VII. REFERENCES