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Design of Compact Parasitic Strip-Loaded CP Antenna With DGS for 5G-IoT Applications

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Abstract

Internet of Things (IoT) has is slowly revolutionizing ubiquitous computing with enormous applications built around various types of devices and sensors. 5th generation wireless systems and IoT require enormous amounts of bandwidth and highly computive systems. The higher frequencies of 5G require high permittivity substrate for antenna design leading to higher cost. It has been studied that a high frequency antenna can be designed by using a lower permittivity substrate parasitic strip with DGS technique. Due to this shorting loaded technique, miniaturization in the size of the antenna patch can also be obtained. In this paper, the use of DCSP method is to be analyzed for designing a compact circularly polarized antenna.

Keywords; *Circular polarization, 5G microstrip antennas, parasitic strip-loaded, DGS*

I. INTRODUCTION

Internet of Things is the by-product of 5G technology. The barrier that stands in the way of IoT in 5G is disconnected systems; since RFID and Bluetooth are efficient only for short range communication. Long range connectivity between device's sensors within a single system or between several other systems is yet to be developed. With a capacity of allowing 50,000 nodes (IoT device sensors) to be present in a single cell, the need of designing multi band antennas becomes a necessity. Polarized antennas help achieve security between IoT devices in case of secure communications. The 5G frequency ranges of 3300-3600 MHz and 5600-5800 MHz(designated bands in India) are chosen and antenna is designed. In this design, a thick Rogers substrate is used. A compact loop antenna incorporating out of- plane pin loading, which creates a longer electrical path in the antenna is used. The size of the antenna is $\lambda 0/8.8 \times \lambda 0/8.8 \times \lambda 0/19$. Above all, although many compact dual-band antenna have been proposed, the miniaturization of these antennas mainly relies on the high-permittivity substrate, which makes them very expensive. Some research is done on the compact antenna without the use of high-permittivity substrates, including the meta material inspired near-field resonant frequency. However, the size of this antenna is still large ($\lambda 0/6.7 \times \lambda 0/6.7$). Above all, due to the miniaturization techniques, these antennas employed are not sufficient to decrease the size of the antenna to a certain degree; the realization of compact dual-band antenna is highly dependent on high-permittivity substrate.

Parasitic Strip loaded technique, has a significant effect in decreasing the size of patch antenna. For the symmetrical and CP radiation, quadruple inverted-F arranged symmetrical to the center point is usually adopted as [6]. Air is used as the substrate. Many dual-band methods for patch antenna is found in literature. In this paper, a stacked patch antenna[3] is used. The operating band is dependent upon the structure of shorting load instead of the patch [10]. The shorting structure can be regarded as

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a series LC loading. In this paper, two parallel coupled shorting strips are designed with the patch antenna and shorted to the ground.. Measured results show good agreement with the simulation results, which means that the parasitic strip-loaded patch antenna is quite an effective solution for a compact low-cost dual-band antenna.

II. CONVENTIONAL STRIP LOADED PATCH ANTENNA

A prototype patch antenna model loaded with the conventional shorting probe (derived from the antenna in [2]) is built as shown in Fig. 1. Four strips are placed at the corner of the patch. Each strip is coupled to a shorting strip and is shorted to the ground using a shorting pin. The strip and the pin together form the first shorting probe. Besides that, L-probe feed is utilized, and microwave composites (relative dielectric constant ξr = 4.4 and loss tangent = 0.002) are used as the substrates.

The first resonate frequency represents the main resonance point and the antenna radiation performance is quite good here, where as the second parasitic resonance point represents a band where the radiation performance is quite undesirable. In the band higher than the required band , the antenna gain returns to normal. So, it is assumed that a band notch could be shifted, and a dual-band antenna can be realized. However, it is impracticable as the second resonance point moves with the same speed as the main resonance point by increasing the length of the shorting strip (L3 or L5), it means that the distance between the two bands could not be adjusted, respectively.

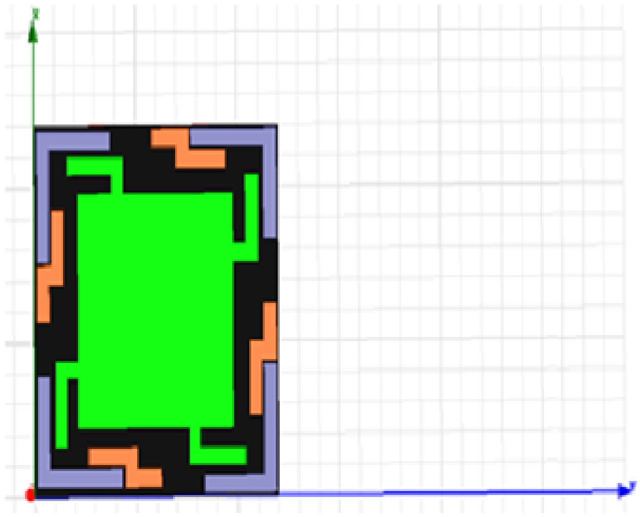

Fig. 2.1 Conventional strip loaded Patch antenna

Table I Antenna Parameters

Dimensions	**Calculated values**
Length x Width of substrate	60 x 60 mm
Height of the substrate	60 mm
Thickness of the patch	6 mm
Length of the patch	0.035 mm
Width of the patch	38 mm
Height of the antenna	38 mm
R pin(sorting pin radius)	6 mm
L1,L2 (Length of the strip)	1 mm
L3,L4 (Length of the strip)	(8,6) mm
L5 (Length of the strip)	(14,29.5) mm
W (Width of the strip)	(18) mm

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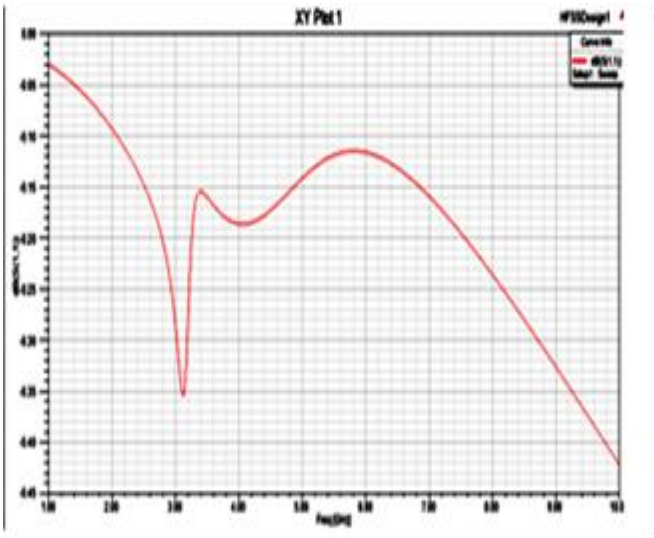

Fig. 2.2 Frequency response of conventional Antenna in band -I

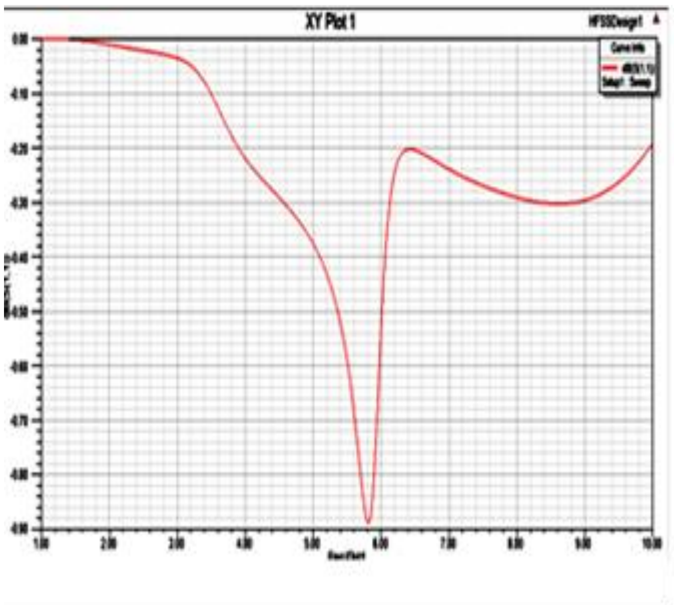

Fig. 2.3 Frequency response of conventional Antenna in band -II

The conventional strip loaded antenna gives a return loss of -4.9dBi. The radiation pattern is an omni directional pattern which is required in IoT communications. To improve the return loss and gain of this antenna, defective ground structure is studied.

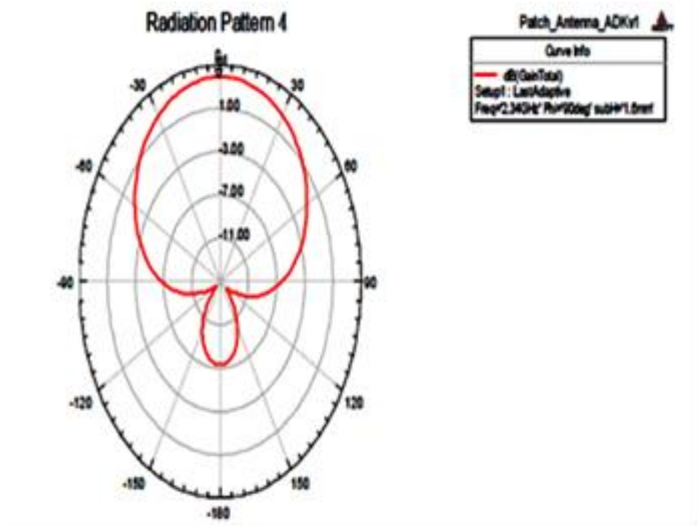

Fig. 2.4. Radiation Pattern of Conventional Antenna

III. STUDY OF DEFECTIVE GROUND STRUCTURE

Apart from improving the bandwidth and gain characteristics of microstrip antenna, DGS has been used to suppress higher mode harmonics, cross-polarization and mutual coupling between adjacent elements. Numerous methods are used in literature to improve the performance by modifying the ground plane into I-shaped slots for WLAN/WiMAX applications [3], asymmetric slits for CP operation [4,5], concentric circular-ring slots, and monopole antenna with strips for triple band operation [9, 10]. The microstrip patch antenna with a single substrate layer has found to have a drawback of having very narrow bandwidth of 1–5%. This disadvantage can be overcome by using multilayer stacked antenna structure for coaxial probe, slot and aperture coupled feeding [17]. In this design, a compact dual band antenna based on the DGS structure is designed as shown in Fig. 3.1. Compared to the prototype design, some improvements are made as follows.

FR4 with dielectric constant 2.2 and loss tangent of 0.002 is employed as the substrate to achieve cost reduction. Four layers of substrate are stacked together. Four of them in the bottom are 3-mm thick and the top substrate is 1-mm thick.

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Four slots are added to the patch, and the shorting strips(L5 in prototype antenna) are stretched into the slots and coupled to the patch instead of coupling to the strips (L3 in prototype antenna).

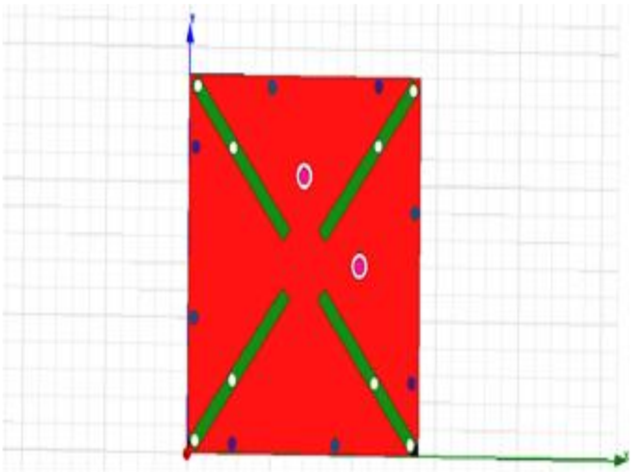

Fig.3.1 Bottom View of DGS structure

The patch and dual shorting structures are designed to be folded and divided into two layers due to the space limitation. They are printed on the bottom and top layer of the top substrate. The patch is assigned in the bottom layer. One branch is extended to the upper layer through a hole and shorted using a shorting pin which corresponds to the first shorting probe. The other branch is also extended to the upper layer through a hole in the corner of the antenna and coupled with the parasitic shorting probe in the upper layer, which is shorted to the ground by a shorting pin too and corresponds to the parasitic shorting probe. The overall size of this antenna is 28 mm × 28 mm × 13 mm. As it is known, dual-feed configuration is commonly used in dual-band CP antenna to achieve CP radiation due to the axial ratio

Performance is quite good over the whole operating band. In order to verify the CP radiation, a feed network in the form of wideband 90◦ phase shifter is designed on the other side of a large ground plane substrate with the dimension of 80mm × 80mm × 1 mm. In the engineering design, this feed network can be replaced by a compact hybrid coupler.

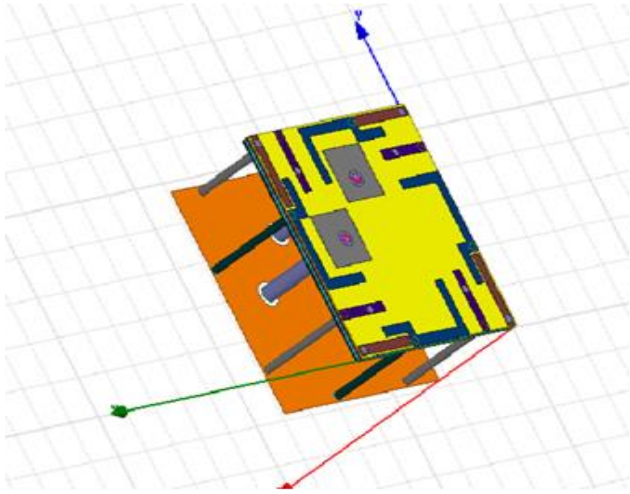

Fig.3.2 3D structure of the designed antenna

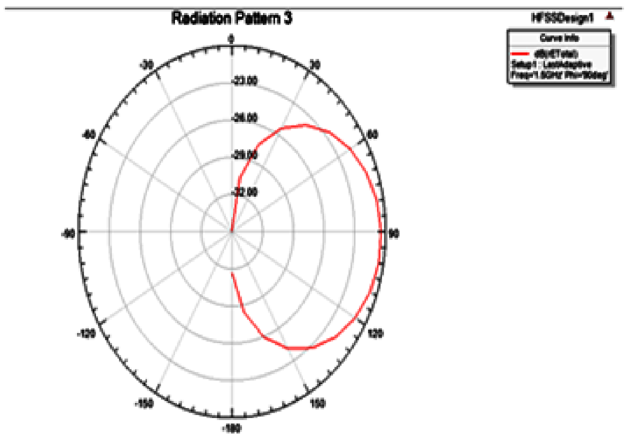

Fig.3.4 .Radiation pattern of DGS structure antenna.

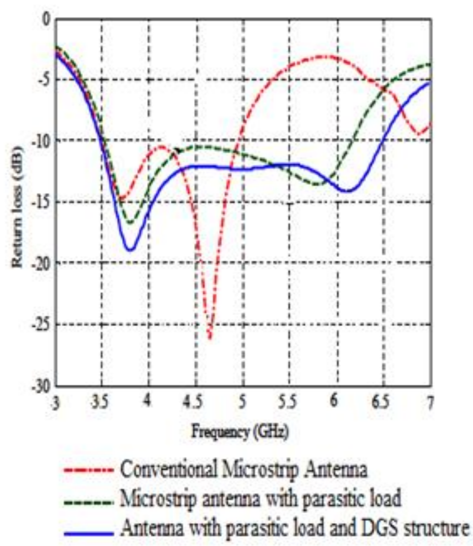

Fig.3.5 Frequency Response of the antennas

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IV. CONCLUSION

A compact CP antenna for 5G application is designed and the simulation for conventional shorting loaded patch antenna, DGS Structure and design of a compact circular polarized antenna loaded by proposed DGS structure is done . The technique proposed enables the antenna to resonate at two bands. Simulated and measured voltage standing-wave ratio (VSWR) is below 1.5 over both the bands. The results show that this proposed DGS technique is realizable and practical. Compared to the other techniques , the parasitic shorting probe technique reduces the cost of the antenna and easily removes the parasitic resonance frequency. Therefore, the shorting loaded technique eliminates the dependency on high-permittivity substrate for compact patch antennas.

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