Research of Dumbbell Shaped DGS to Enhance The Bandwidth and Multiple Band Applications

Karunaiah Bonigala, P.V. Sridevi

ABSTRACT—A monopole microstrip rectangular patch with dumbbell shape slotted on ground for multiple band, enhance the bandwidth. The proposed antenna is fabricated on FR4 epoxy material with electrical permittivity of 4.4 and magnetic permeability 1. The dimensions of proposed antenna are 70 x 50 x 1.6 mm² and the dumbbell shape is slotted on ground of substrate which resonates at four different frequencies 5.9 GHz, 7 GHz, 8.7 GHz, and 9.7 GHz. The proposed antenna has bandwidths of 200 MHz, 300 MHz, 300 MHz, 300 MHz at four resonant frequencies. The proposed antenna covers 4/8 GHz C band, 8/12 GHz X band and used in radar, satellite communications. The reflection coefficient ($S_{11}$), radiation characteristics, peak gain and VSWR of designed antenna are described.

Keywords- Rectangular patch, Multi band, Dumbbell DGS.

I. INTRODUCTION

The printed monopole antennas have wide growth in wireless technology and these have high gain, high efficiency, broad impedance bandwidth and planar. The defected ground structure has exponential growth with capacitive, inductive and the researchers are interested to develop DGS because of their compact size, easy to design two dimensional and three dimensional structure, easy to fabricate and broad bandwidth. Boutejdas proposed a H shaped DGS, coupled DGS for wide rejection of LPF, low insertion loss and mobile communication systems and equivalent circuit model is drawn for defected ground structure [2-3]. Amit A Deshmukh proposed rectangular patch antenna with U shaped and V shaped slots for dual-band, broadband applications. The slots are cut to the patch either quarter wavelength or half wavelength [4]. DivyaAshirwar develop a decagon shaped monopole patch applicable for multiple band like Wi-Fi, Wi MAX band and WLAN band, introduced the valley shape to increase the impedance band, radiation efficiency [5]. The microstrip patch has I shaped patch, partial ground plane for bandwidth enhancement, triple band applications [6], curved slot on rectangular patch with partial ground plane to enhance the bandwidth, useful for 2.4/5.2/5.8 GHz, 2.5/3.5/5.5 GHz and improve the gain of proposed antenna [7], partial slot on ground plane for dual band, minimize the antenna size, stable radiation pattern [8]. Rectangular parasitic to enhance broad and U shaped DGS creates the higher order resonances, improve the radiation efficiency of 87 % and higher gain 5.2 dB[9], dumbbell shaped microstrip with partial ground plane used in space and satellite communications, improve the surface efficiency [10]. 

Manish developed the circular patch with corrugated ladder shaped ground for ultra-wide band and lower order resonances are created because of circular slot on circular patch [11]. The circular patch with defected ground plane for multiple band has stable omnidirectional, bi directional radiation pattern over ultra-wide band applications [12], rectangular antenna with symmetrical placed circles in ground plane for dual band applications [13]. The researchers developed rectangular, circular shape patch with different kinds of slotted ground and useful for satellite over wireless communications and high gain, stable radiation patterns. Generally the circularly polarized microstrip antennas have very high input impedance on edges, to control the image impedance matching using DGS on ground plane. The design of rectangular antenna has slotted dumbbell shape on ground for multiple-band applications.

II. ANTENNA DESIGN GEOMETRY

The dumbbell DGS has two rectangular slots connected by one narrow slot which are etched from perfectly electric conductor coated on metallic ground plane. The surface waves are propagating through two patches. The dumbbell DGS is implemented for low pass filter, control the image impedance by placing DGS on ground. The overall dimensions of proposed antenna are 70 x 50 x 1.6 mm³ , FR4 epoxy material for substrate (electrical permittivity=4.4), copper, perfect electric conductor (PEC) for patch and ground plane. The length ($L_3$), width ($W_3$) considered as dimensions of dumbbell. The reflection coefficient ($S_{11}$=10dB) parameter results from 7.2 GHz-7.5 GHz for rectangular patch.

When introduction of dumbbell shaped DGS on ground plane, the reflection coefficient parameter from 5 GHz to 10 GHz and impedance bandwidth is improved from 30 % to 150 %. 

![Dumbbell DGS Antenna Design](image-url)
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![Fig. 1 Geometry of rectangular patch has slotted dumbbell on ground (a) top view (b) bottom view](image)

**TABLE 1**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Dimension (mm)</th>
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<th>Dimension (mm)</th>
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<td>L₄</td>
<td>20</td>
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<tr>
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<tr>
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<tr>
<td>W₆</td>
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<td>18</td>
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**III. SIMULATION RESULTS**

There is wide improvement of impedance bandwidth while introducing the dumbbell shaped DGS on ground plane. Fig. 3 shows the variation of return loss ($S_{11}$) of simulated antenna with slotted on ground plane and without slotted on ground. The without slotted on ground is operating from 7.2 - 7.5 GHz and dumbbell DGS slotted on ground plane is operating at four different resonant frequencies. The bandwidths of designed antenna have 200 MHz, 300 MHz, 300 MHz, 300 MHz at center frequencies 5.9 GHz, 7 GHz, 8.7 GHz and 9.7 GHz with reflection coefficient ($S_{11}$) of design antenna -23 dB, -14 dB, -33 dB, -19 dB. The without dumbbell DGS operating in single frequency (7.3 GHz), very low bandwidth. The VSWR values of simulated antenna and fabricated measured at operating frequencies 1.25 dB, 3.5 dB, 0.4 dB, 2 dB shown in Fig. 4. The theoretical analysis of simulated and fabricated measured antenna of reflection coefficient values have good agreement shown in Fig. 2.

![Fig. 2 Fabricated measured and theoretically simulated results of dumbbell DGS](image)

![Fig. 3 Operating return loss of rectangular patch antenna](image)

![Fig. 4 Theoretically simulated and fabricated measured VSWR of designed antenna](image)
The radiation pattern of far field electromagnetic simulation with E (XZ) plane, H (YZ) plane at four center frequencies. The radiation pattern is measured at two orthogonal planes such as E plane (XZ), H plane (YZ). The good radiation patterns at 5.9 GHz, 7 GHz which are radiated by all directions but the frequencies increase, the radiation efficiency decreases because of unstable radiation pattern. The co polarization of E plane at 5.9 GHz radiates all directions, cross polarization of E plane is very low (-30 dB). The Fig. 6 shows designed proposed antenna has peak gain of 9.65 dB, 4.69 dB, 6 dB, 9.8 dB.

The fabrication of rectangular patch with dumbbell DGS is shown in Fig. 8, by using vector network analyzer with anechoic chamber measure the real time reflection coefficient values and VSWR values shown Fig. 9.
The maximum electric field distribution on ground plane because of slotted dumbbell DGS and electric field lines 1.25 V/m and maximum magnetic field distribution are shown in Fig. 7

![Fig. 7 The maximum field distribution of rectangular patch antenna at (a) E field, (b) H field.](image)

IV. CONCLUSION

The rectangular patch with dumbbell shape slotted on ground for multiple band applications and enhances bandwidth. The design antenna is fabricated on FR 4 epoxy material with electrical permittivity of 4.4 and dimensions of proposed antenna are 70 x 50 x 1.6 mm³. It resonates at four different center frequencies 5.9 GHz, 7 GHz, 8.7 GHz and 9.7 GHz. The proposed antenna has bandwidths of 200 MHz, 300 MHz, 300 MHz, 300 MHz at four resonant frequencies. The proposed antenna covers 4/8 GHz C band, 8/12 GHz X band used in radar, satellite communications.

REFERENCES


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