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A Multiband Microstrip Patch Antenna with DGS for Various Wireless Applications

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Abstract-In this paper, a rectangular multi–band frequency patch antenna with a seven-band operation, design is proposed. The antenna resonates at 1.836, 2.815, 3.497, 4.751, 6.313, 6.8852 and 10.306 GHz, with a maximum bandwidth of 8.09% (3.433-3.716GHz), and a minimum return loss of-40.463dB (4.751GHz). In this proposed antenna, FR-4 material is used for substrate with a 4.3 dielectric constant and 1.6 mm thickness. The return loss can be improved by using square slots on the ground. This antenna is designed and simulated in the CST microwave studio. The design is simple and provides a good return loss with considerable bandwidth. The proposed antenna may be used for different applications in the L, S, C and X bands of wireless communications.

Key Words — *FR-4, DGS, CST, microstrip, multiband, square slot, gadget.*

I. INTRODUCTION

Wireless communication has advanced rapidly over the last three decades. In the present scenario, many wireless gadgets communicate simultaneously at a high data rate. The data for communication between different wireless gadgets may be text, image, audio & video, etc. These communications work at different frequencies. Small physical size limitations, material costs, and manufacturing costs are major factors for gadget manufacturing companies. To fulfil these requirements, manufacturing companies need a small, low material cost and low manufacturing cost antenna which can work at multiple frequency bands. Due to this, the developers tried to design a multiband antenna of the required operating bands of frequencies. The Microstrip antenna provides a small size, economical, and high performing antenna [1].A sorting pin can be used to improve the performance of a microstrip patch antenna in terms of size reduction and the creation of multiple resonance bands [2]. By using many techniques such as slots in-ground or patch, adding parasitic elements, a Multiband antenna can be designed that can work at multiple frequency bands [3].PIN diodes and switches are also used to design multiband patch antennas. H shape parasitic patch multiband antenna discussed in [4]. In [5], described, a simple square antenna produces a single frequency of resonance and if some slots are created on the patch, then that antenna converts into a multiband frequency antenna. In [6], they designed a stacked patch antenna with ground plane U slots and patch notch slots. And analyzed that, due to slots on both planes and adding parasitic patch generates new resonating frequencies. Effects on the resonance of rectangular patch antenna due to length of slot cut and position of the slot as well as the position of feed point have been discussed in [7].In [8,] an E-shape microstrip antenna design with cut slots and two feed lines was proposed. Due to the particular shape and twice the feed line, the antenna provides wideband resonance. In [9] a fractal microstrip antenna design was proposed as E-shape and used DGS (defected ground structure) to overcome the bandwidth and gain limitations. An antenna design was proposed with L- slots and rectangular slots that were created on a patch [10].In [11], a rectangular microstrip patch antenna with triangular slots on the ground was designed, and the same antenna with rectangular slots and the same feed point location was designed, and the return losses of both antennas were compared.

II. ANTENNA DESIGNED

In this paper, a microstrip antenna design using CST microwave studio. Here, L×W proposed a rectangular microstrip patch antenna (fig 1 (a)) design that is fed by a microstrip transmission line with impedance 50.The rectangular patch is isolated from the ground plane with an FR-4 substrate of εr =4.3, thickness h=1.6 mm. Here, another antenna with the same feed patch as the basic antenna was also designed, where square slots are created in the ground plane as DGS (defective ground structure) which is shown in figure 1 (c).

The width of the antenna has calculated by:

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$$W = \frac{C}{2f_c\sqrt{\frac{(\varepsilon_r + 1)}{2}}}$$

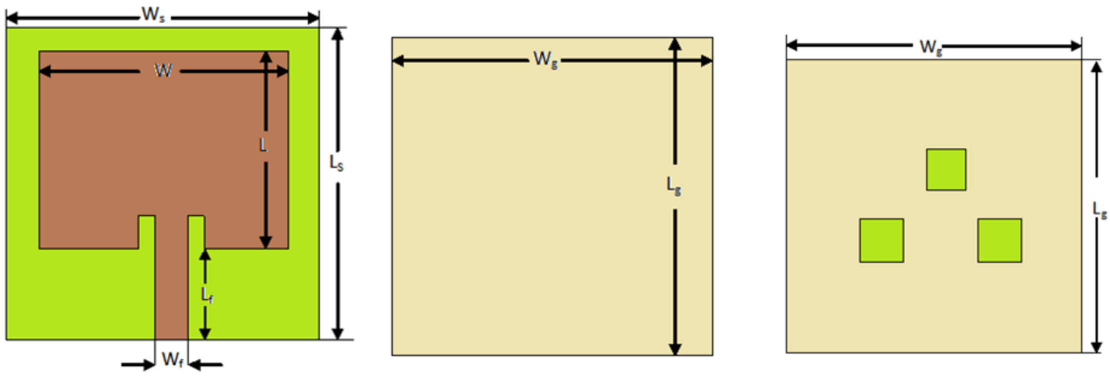
Where, C = speed of light in free space,
f_c = resonant frequency,
ε_r = dielectric constant.
The effective length of the antenna has calculated by:

$$L_{eff} = \frac{C}{2f_c \sqrt{\varepsilon_{reff}}}$$

Where, ε_{reff} = effective dielectric constant

Table 1 Parameters of Antenna

S.No.	Parameter	Dimensions	Material
1	Ground Plane	Wg =60 mm, Lg =60mm	Copper
2	Substrate	Ws =60 mm, Ls =60mm, hs =1.6mm	FR-4 (4.3)
3	Patch	W=50mm, L=38mm	Copper
4	Feed Line	Wf=3mm, Lf=17mm	Copper
5	Slots in Ground Plane	Width=6mm, Length=6mm	---



(a) (b) (c)

Fig 1 (a) Front View of Basic Antenna (b) Back View of Basic Antenna (c) Back View of DGS Antenna

III. SIMULATION RESULTS

The proposed antenna was simulated in a CST microwave studio to obtain results. The analysis put together VSWR, S-Parameter, and Radiation Pattern with a frequency range from 1GHz to 12 GHz. The proposed basic antenna exhibits resonance at seven different bands and that antenna with DGS exhibits resonance at eight different bands. The analysis is expressed below.

A. Return Loss

The resonance frequencies of the proposed basic antenna with return loss and percentage of bandwidth respectively, are the first band at 1.836GHz, -23.288dB and 4.74%, Second band at 2.815GHz, -16.49dB and 2.54%, Third band at 3.497GHz, -22.578dB, and 8.09%, Fourth band at 4.751GHz, -40.463dB and 2.29%, Fifth band at 6.313GHz, -26.851dB and 2.39%, The sixth band is at 6.885GHz,-20.677dB and 2.41%, the seventh band is at 10.306GHz,-18.289dB and 2.83%, which is shown in fig 2.

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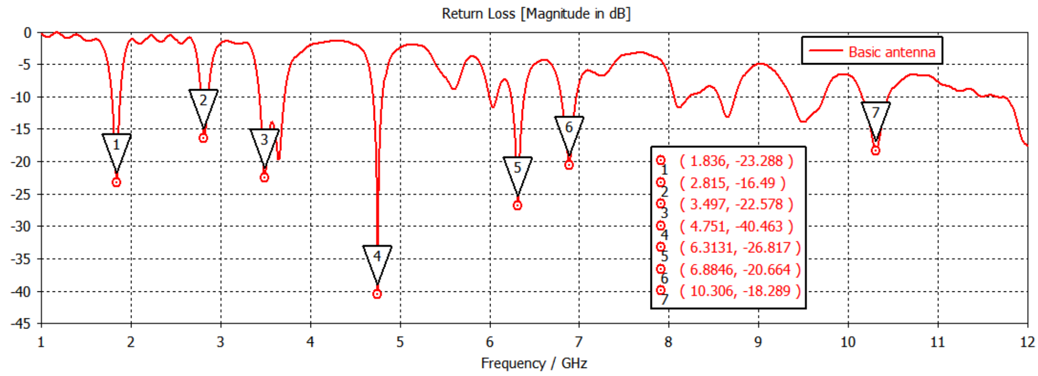

Fig 2 Return loss plot of the proposed basic antenna.

If the ground plane is replaced with a slotted ground plane (DGS), the return loss of the antenna improves with only a minor compromise in the percentage of bandwidth. Now, the performance of the proposed DGS antenna at resonance frequencies, return loss, and percentage of bandwidth respectively, are the first band at 1.812GHz,-16.241dB and 4.02%, the second band at 2.784GHz, -17.432dB and 2.53%, Third band at 3.384GHz, -27.527dB and 3.09%, Fourth band at 3.588GHz, -30.182dB and 3.46%, Fifth band at 4.812GHz,-40.484dB and 2.27%, Sixth band at 6.288GHz,-29.651dB and 2.42%, The seventh band is at 6.972GHz,-26.55dB and 2.77%, the eighth band is at 9.408GHz,-24.084 and 3.35%,which are shown in fig 3.

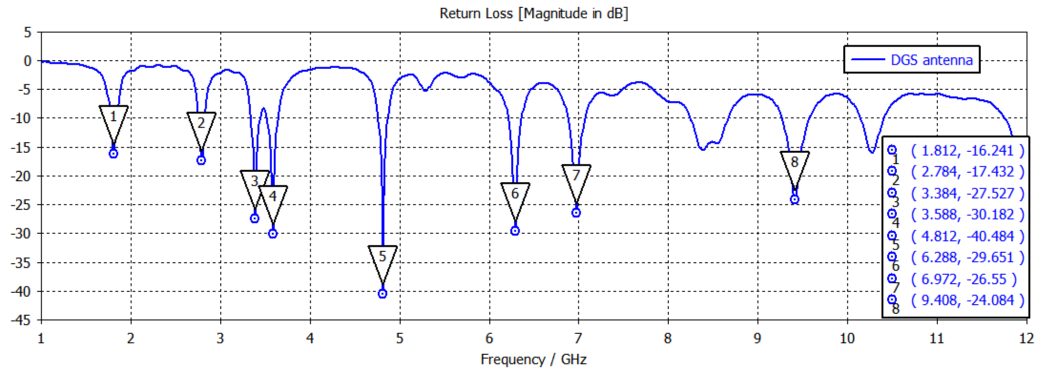

Fig 3 Return loss plot of the proposed DGS antenna.

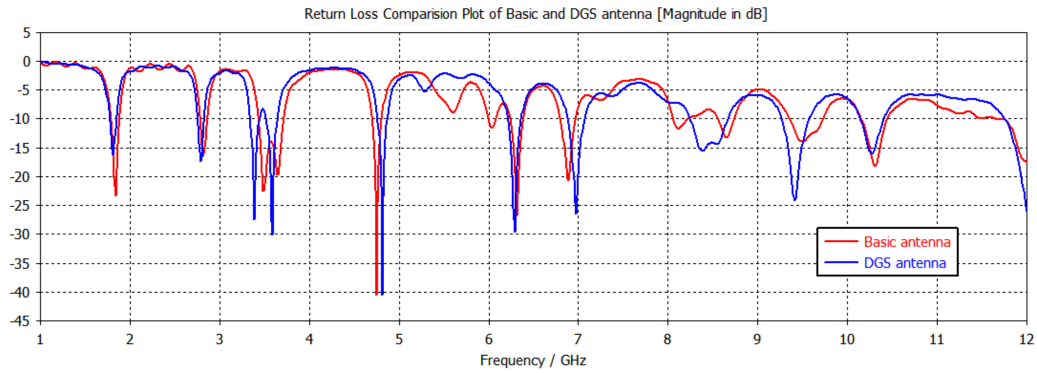

Fig. 4 Return loss comparison plot.

As the comparative graph, of the return loss of both antennas, it is seen, the proposed basic antenna provides only two operating bands below-25 dB level. And the proposed DGS antenna provides five operating bands below 25 dB level. That is the advantage of the proposed DGS antenna over the proposed basic antenna. Here it is clear that our proposed DGS antenna has reasonable return loss with considerable bandwidth. This makes the proposed DGS antenna usable in many applications for wireless communications.

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B. VSWR

VSWR is an important parameter of the transmission system. It is a measurement of how much power is returned to the transmission line by the antenna. Normally it should be < 2. Here, the proposed basic antenna and DGS antenna both have the value of VSWR < 1.4 at all resonance bands.

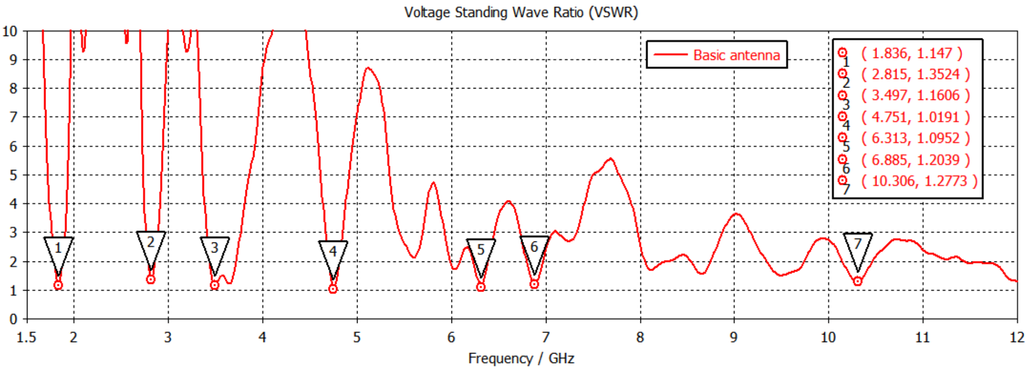

Fig.5 VSWR plot of basic antenna.

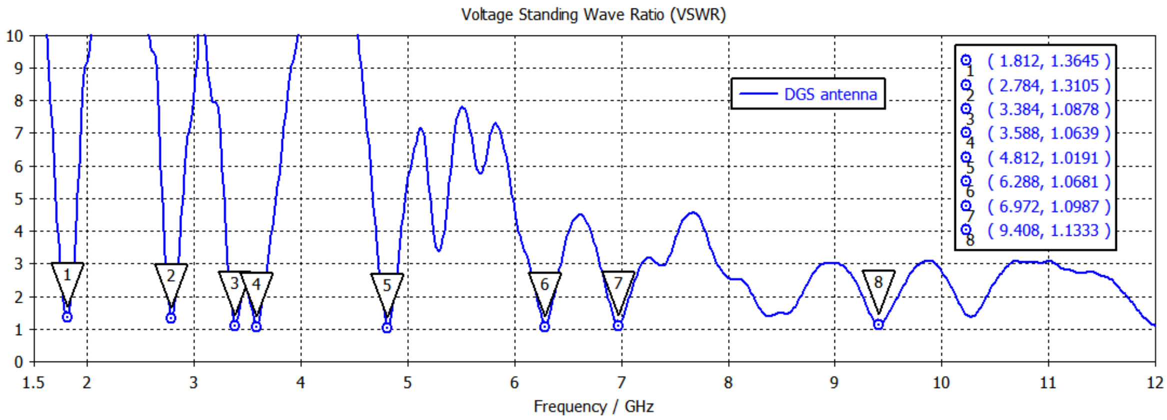

Fig.6 VSWR plot of DGS antenna.

C. Radiation Characteristics

The radiation pattern of the proposed basic antenna and proposed DGS antenna have been analyzed in terms of 2-D (Polar Plot) and 3-D simulated radiation pattern at the 1.836 GHz operating frequency. These are shown in Fig. 7. This antenna radiated to the perpendicular of the antenna plane, as seen here.

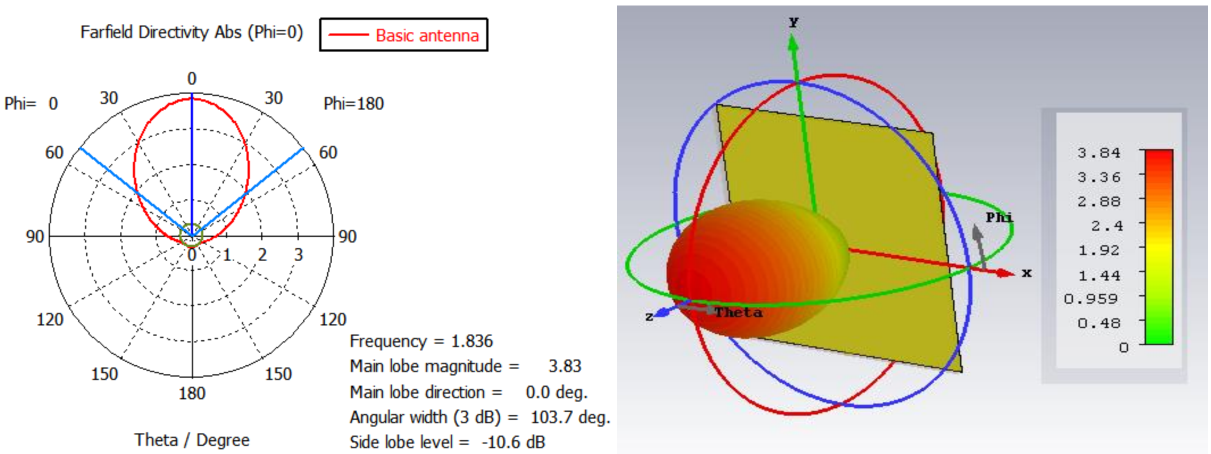

Fig. 7 2-D and 3-D Radiation pattern of Basic Antenna.

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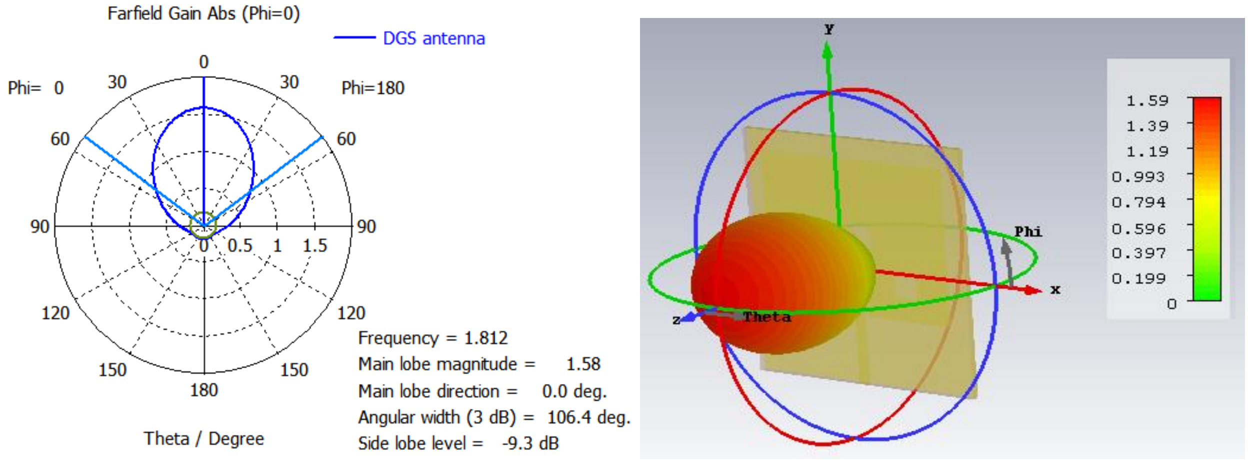

Fig 8 2-D and 3-D Radiation pattern of DGS Antenna.

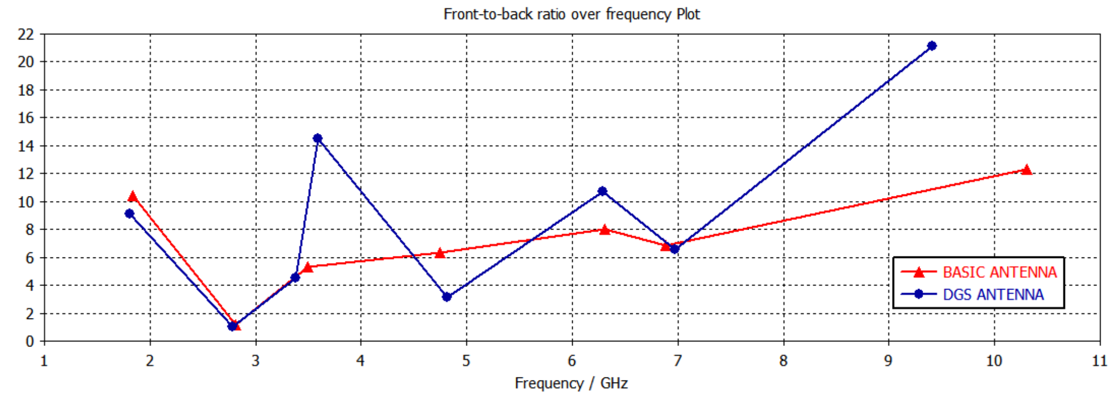

Fig 9 Front and back ratio plot of Proposed Antennas

It is clear that here the front-to-back ratio is poor at mid frequencies and better for corner frequencies of the proposed Basic antenna and for proposed DGS and it is better for mid and higher frequencies.

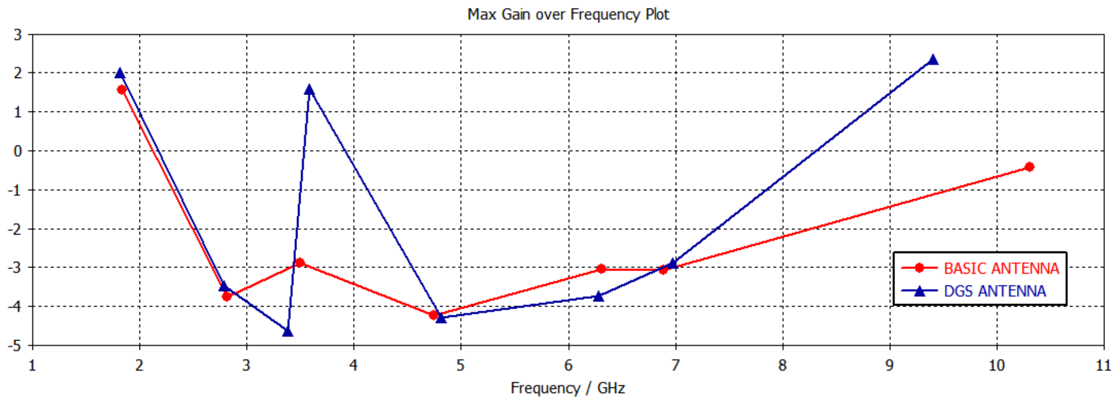

Fig 10 Gain V/S frequency plot.

From the gain versus frequency plot, we have seen, the proposed Basic antenna has a poor gain at mid frequencies and better at corner frequencies, and the proposed DGS antenna has a better gain for mid as well as corner frequencies. The performance of both antennas in terms of radiation efficiency is better at lower frequencies and poor at mid and higher frequencies.

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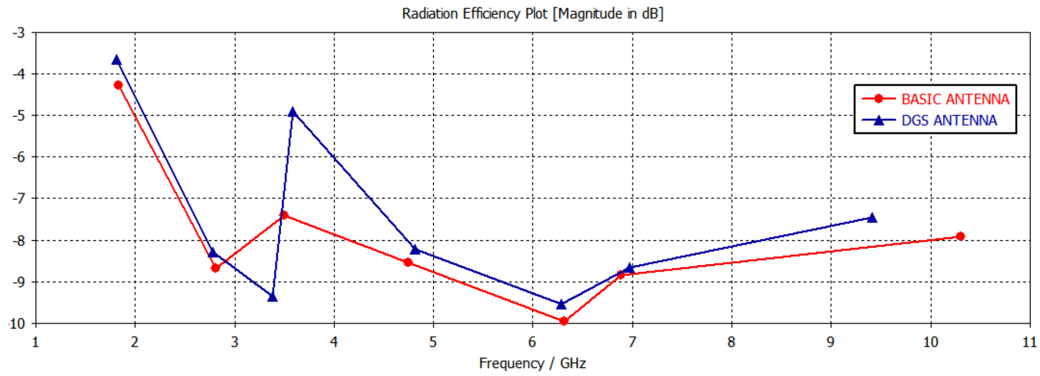

.Fig 10 Frequency V/S radiation efficiency plot.

IV. CONCLUSION

A rectangular multiband frequency basic antenna and DGS patch antenna have been designed and analyzed in the CST studio. If we compare the simulation results of both antennas, then it is clear the DGS antenna performs well in terms of return loss, VSWR, radiation direction front and back ratio, and antenna efficiency. The efficiency of the DGS antenna is better as compared to the basic antenna, but it is moderate (~45%) in the future to improve the efficiency of the antenna by more work on the top layer. The proposed multiband DGS antenna is small, simple to make, and inexpensive, and it can resonate at eight frequencies ranging from 1 GHz to 12 GHz.It can be used for WLAN and wireless communication. This antenna provides good VSWR, return loss, and considerable bandwidth.

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