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Frequency Reconfigurable Aperture coupled Microstrip Antenna with DGS for Bandwidth Improvement

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***Abstract*— This paper presents a novel design of frequency reconfigurable aperture coupled microstrip antenna with bandwidth improvement. The proposed design was based on the structure of a 2 by 2 planar array antenna with separated feeding technique, aperture coupler. The antenna is designed on Rogers Duroid substrate having dielectric, ε, of 2.2. Four dumbbell shaped DGS were etched on the ground plane for back radiation reduction. An antenna without DGS is first designed acting as reference. Both of the designs were simulated Electromagnetic simulation software based on operating frequency of 5.8GHz and 6.48GHz. The results show that, by incorporating DGS onto the antenna, the bandwidth and gain of the antenna increased significantly. Gain improved from 9.51dBi to 9.99 dBi at 5.8GHz. The bandwidth of the antenna improved by 28%. This design concept can be useful in reducing the back radiation of aperture coupled microstrip antenna.**

***Index Terms*— antenna, patch, aperture coupler, DGS, planar array,**

I.INTRODUCTION

Aim of antenna design is to transmit large amount of information to the longer distance, so the research in wireless communication is growing toward the reduction of antenna size and get the higher transmission bandwidth of antenna. Microstrip antenna is widely used in various field. Due to its low profile configuration, light weight and low cost, it can be easily integrated with planar and non planar surfaces. The microstrip antenna discussed in this paper uses aperture coupler feeding technique. This type of feeding technique can reduce the unwanted signal generated by the feedline from interfering the signal radiated by the patch. However, the drawback of antenna having this kind of feeding is its bad back radiation pattern which represents power loss. This backward radiation may cause interferences to neighboured cell and is unfavourable in mobile applications. If antenna with a significant back radiation used in handset, the users may be exposed to the electromagnetic energy [1].

A few studies had been done on reduction of back radiation of multi layered antenna. The common methods used to improve reducing the size of radiation characteristics are to place a shielding plane behind the antenna or to enclose the aperture in a cavity. On the down side, both techniques can degrade the performance of the antenna. In [2,3], reflector is placed behind the aperture to improve the front-to-back ratio. However this approach adds the bulkiness to the antenna. DGS has been studied to help in improving the bandwidth of the antenna of conventional antenna, but no studies on DGS on aperture coupled antenna been done yet.

Therefore, this paper presents the application of DGS in frequency reconfigurable microstrip aperture coupled antenna. The objective of this paper is to improve the bandwidth and gain of 2 by 2 aperture coupled antenna. Dumbbell shaped DGS are etched on the ground plane. The proposed antenna is expected to have an improved radiation characteristic.

II ANTENNA STRUCTURE

DGS has now widely used to enhance the performance of microstrip antenna.DGS often used for size reduction [4-5], cross polarization reduction, mutual coupling reduction etc.The proposed antenna is designed by locating 4 dumbbellshaped slots etched on each of the edge of the ground symmetrically. The basic structure of the antenna is based on 2 by 2 plannar array antenna with non contacting feed; aperture coupler. The antenna is printed on Rogers Duroid 5880 dielectric substrate of thickness, h of 0.787mm and relative electric permittivity of ε r of 2.2. The dimensions of both substrates layer are 70mm x 64.2mm. The 4 patches of the antenna are of the same size and calculated by using this formula [7]:

$$\Delta L = 0.412\, h \frac{(\varepsilon reff + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon reff - 0.3)\left(\frac{W}{h} + 0.8\right)} \quad (1)$$

The effective length of the patch Leff now becomes:

$$Leff = L + 2\Delta L \quad (2)$$

For a given resonance frequency fo, the effective length is given by [7] as:

$$Leff = \frac{c}{2fo\sqrt{\varepsilon reff}} \quad (3)$$

for a rectangular Microstrip patch antenna, the resonant frequency is given by

$$f_0 = \frac{c}{2\sqrt{\varepsilon_{reff}}}\left[\left(\frac{m}{L}\right)^2+\left(\frac{n}{W}\right)^2\right]^{\frac{1}{2}} \quad (4)$$

where m and n are modes along L and W.

$$W = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r+1}{2}}} \quad (5)$$

In realizing non contacting feed antenna, patches are printed on top of the first substrate, while the feedline is printed at the bottom of the second substrate. As for the ground, it is sandwiched in between of both of the substrate. Width of the feedline of the antenna is set to be 3.22mm in order to maintain characteristic impedance of 50Ω . A P-I-N diode is placed at feed branch to obtain the reconfigurability. Fig1 shows the side view of proposed antenna.

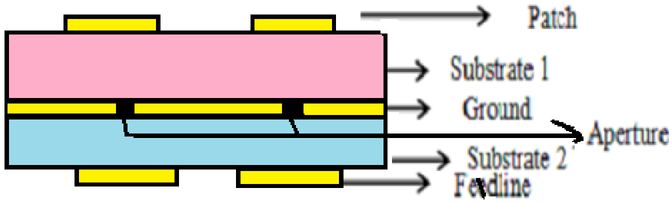

Fig.1. Side view of the proposed antenna.

The antenna parameters are:

Thickness of the substrate (h)	.787 mm.
Patch size	20 mm by 13 mm.(each)
Ground size	70mm by 64mm.
Substrate dielectric (εr)	2.2
Antenna resonating frequency	5.8GHz,6.48GHz.
Input Impedance	50 Ω.

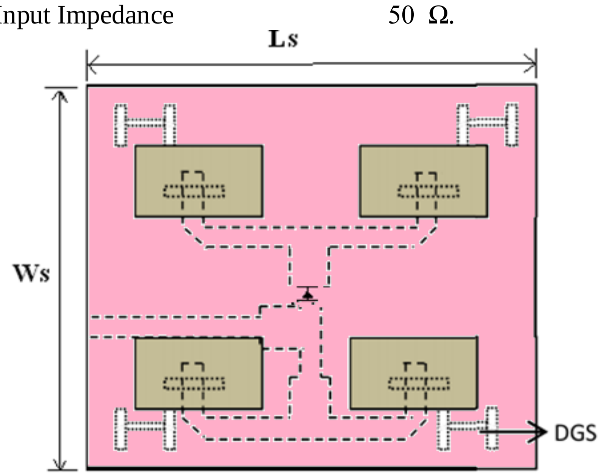

Fig2 Structure of frequency reconfigurable reference antenna.

In designing the antenna integrated with DGS, almost all the parameters are kept constant. Four dumbbell shaped DGS were etched off the ground plane as shown in figure 6.2). The length of the DGS(L) is 8.2mm ,width(W) is 3mm and the height of the arm(H) is 6.4mm as shown in figure 6.3 The aperture size is 8.3*2 mm2 ,there are four aperture of same size for patches as shown in fig2.

III. IPLIMENTATION AND RESULTS

The results has been discussed of the proposed antenna in different cases. Starting with the reference antenna with diode in on condition i.e. all four patches are radiating.

CASE 1. REFERENCE ANTENNA WITH DIODE ON

Fig3. shows the S11 for reference antenna i.e. there is no DGS and diode is in on condition. As we can see resonant frequency is 5.85GHz, at this frequency S11 is -21.88 dB. Fig 4 shows the farfield for this case.

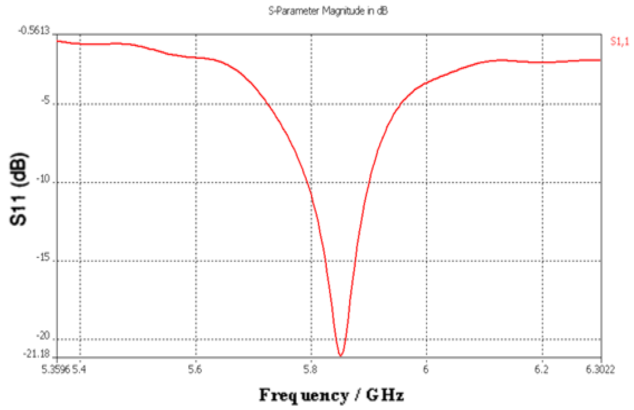

Fig3.S11 of the reference antenna

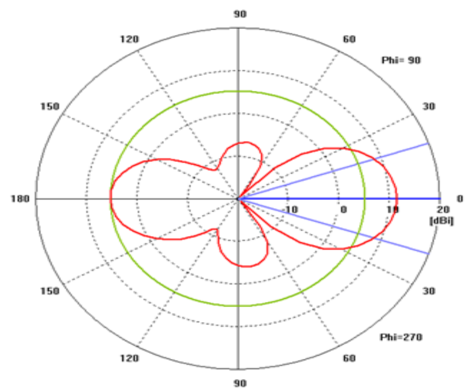

Fig4.Farfield pattern of the reference antenna

CASE 2.Reference antenna with Diode OFF

When the diode is turned OFF frequency shifted 6.48 GHz it's S11 is -14.32 dB. In this case only two of four patches radiates and remaining two are not fed so remain ideal as shown in fig5.

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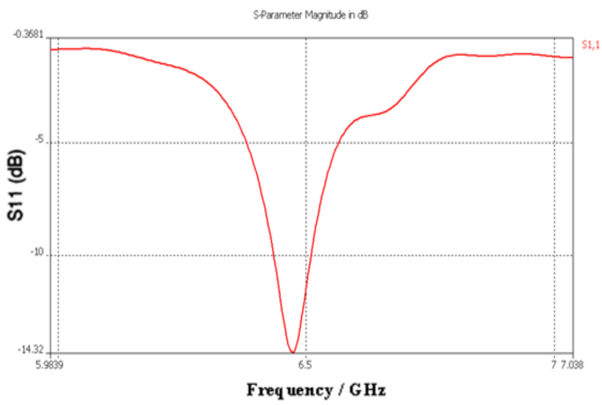

Fig5. S11 of referance antenna with diode OFF

The farfield pattern of the antenna when the diode is turned OFF is shown in fig6., the direction of maximum radiation is along 5 degree and magnitude is 10.2 dBi. The side lobe magnitude is -12.5 dBi. The angular width of the farfield pattern is 36 degrees i.e. 18 degrees on both side from direction of maximum radiation.

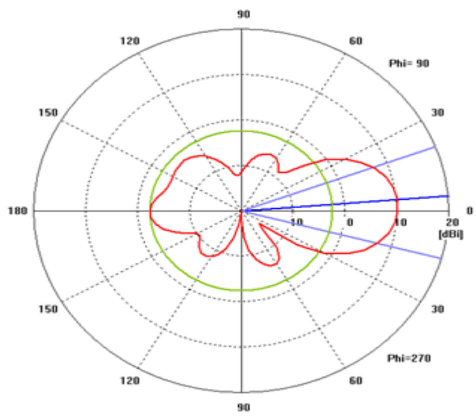

Fig 6. Farefield pattern when diode is OFF of reference antenna

CASE 3. With DGS diode ON

When the dumbbell shape DGS were introduced in the ground plane the resonant frequency remains the same but S11 at this frequency is -29.77 dB as shown in the fig7. and as in section we will see that there is considerable increase in the bandwidth of the antenna with introduction of the DGS structure .

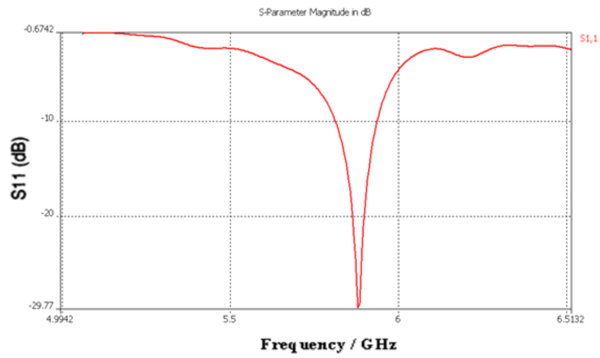

Fig7. S11 of frequency reconfigurable antenna with DGS

Farfield pattern of the antenna is shown in fig8, it's main lobe magnitude is 11.1 dBi, direction of the maximum radiation is 0 degree and Side lobe magnitude is -6.2 dB. In this case radiation efficiency of the antenna is improved as compared to the reference antenna.

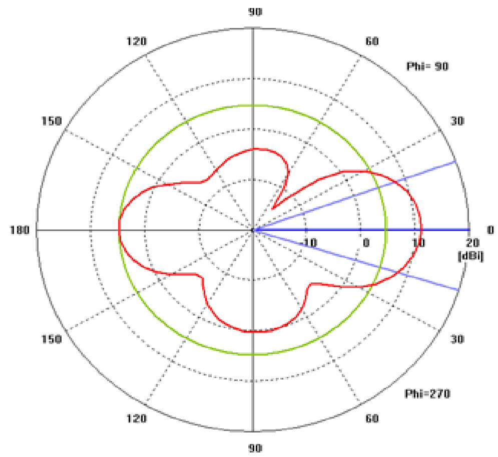

Fig8. farfield pattern of the frequency reconfigurable antenna with DGS

CASE 4. With DGS diode OFF

As it is observed that frequency changes when diode was turned off , so when diode is turned off in this case frequency changes in the similar fashion. But compared to the case 2 S11 in this case is more negative as we will discuss in next section that there is bandwidth improvement in case of DGS structure as compared to the reference structure, From fig9. it is observed that resonant frequency is 6.48 as it was in case 2. Farfield pattern of the antenna is shown in fig10., it's main lobe magnitude is 10.2 dBi, direction of the maximum radiation is 0 degree and Side lobe magnitude is -12.5 dB. In this case radiation efficiency of the antenna is improved as compared to the reference antenna.

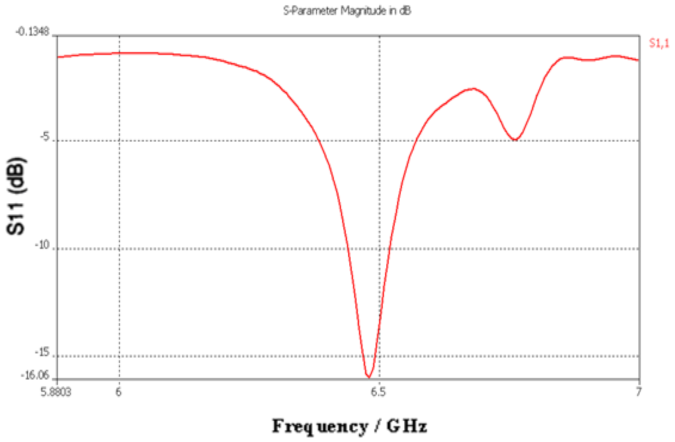

Fig9. S11 of the frequency reconfigurable antenna with DGS and diode OFF

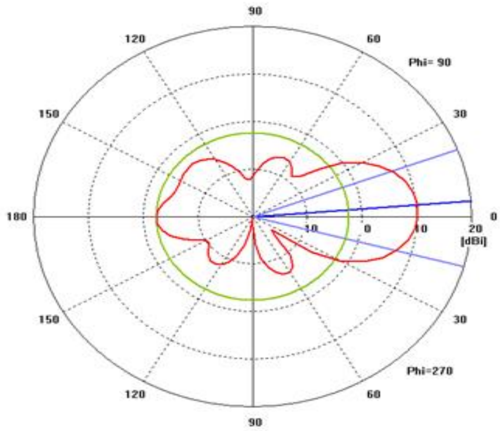

Fig10.farfield of the frequency reconfigurable antenna with DGS and diode OFF

CASE 5. COMPARISON OF RESULTS

The bandwidth of the reference antenna was .102 GHz and it was .187 GHz when DGS was cut in the ground. Thus there is increment of 29% of bandwidth from reference antenna to the DGS structure it can be observed from the fig11. Due to change in inductance and capacitance there is also an increment in the radiation efficiency of the structure.

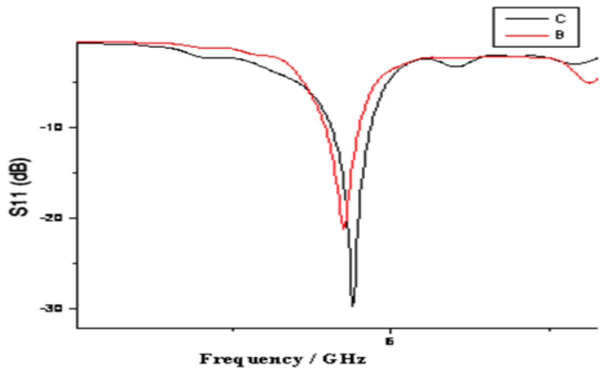

Fig11.S11 of the frequency reconfigurable antenna with DGS and without and diode OFF

In the reference antenna radiation efficiency is .822 and directivity 11.57dBi and in DGS structure radiation efficiency and directivity are .880 and 11.17 dBi respectively. So the gain in two cases are 9.51 dBi and 9.83 dBi, which shows that there is improvement in gain of antenna along with the bandwidth.

IV.CONCLUSIONS

An aperture couple microstrip antenna with bandwidth and gain improvement has been successfully designed and simulated. By comparing reference antenna with DGS, it shows that DGS do gives beneficial results. Antenna with DGS incorporated has shown a 25% increase in bandwidth as compared to the reference antenna. this frequency finds application in many communications applications, including Wi-Fi and cordless phones.

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He is the author/co-author of 85 Research Papers in refereed Journals, International and National Conferences. He received “First prize best student paper platinum award” in 2009 at the IEEE International conference on Antennas, Propagation and Systems (INAS-2009) held at Johor Bahru, Malaysia from December 3-5, 2009. He is visited Malaysia, Japan, and Germany. He is a Member of the IEEE-Microwave Theory and Techniques Society.