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Mutual Coupling Reduction between Patch Elements Using Split-Ring DGS

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Abstract: *A defected structure etched in the metallic ground plane effectively disturbs the shield current distribution in the ground plane and thus, DGS potentially obtains wide reject-band, which meet the emerging application challenges. Microstrip patch antenna arrays are very popular for today's wireless communication system. In this paper a new scheme is proposed to reduce the mutual coupling between two elements of a patch antenna arrays operated in 5.8 GHz. A split ring DGS cell is placed in between patch elements, which enable to reduce the surface wave and able to reduce the mutual coupling between them. This method may be adopted to reduce the overall real estate of a multi-element patch array system.*

I. Introduction

The demand of currently expanding communication systems within finite spectrum resources sets lots of stringent requirements on the microwave circuit design. A defected structure etched in the metallic ground plane of a microstrip line effectively disturbs the shield current distribution in the ground plane and thus, introduces high line inductance and capacitance of the microstrip line. Dumbbell shaped defected ground structure (DGS) has been proposed by D. Ahn first time and applied successfully to design a low pass filter [1-3]. Their frequency characteristics indicated one-pole response and modeled by 1st order Butterworth LPF function. They are used for designing all poletype filters. A filter with elliptic function response has attenuation poles and zeros at finite frequencies and shows sharp transition band. Few DGSs with quasi-elliptic responses were reported [4-8] in recent time.

In this work, we are exploring the square split-ring type DGS cell. The frequency characteristics show an attenuation zero close to the attenuation pole frequency and therefore modeled it as 3rd order elliptic LPF. Moreover, owing to the increased equivalent inductance and capacitance, the required area for this DGS is seen to be smaller than the dumbbell DGS. A split ring DGS cell is placed in between patch elements, which enable to reduce the surface wave and finally reduce the mutual coupling between them. This method may be adopted to reduce the overall real estate of a multi- element patch array system.

II. Dgs Underneath A Microstrip Line

Figure 1(a) shows our proposed DGS cell etched off on the backside metallic ground plane underneath a microstrip line. The frequency characteristics are investigated by CST studio. The different dimensions are considered as b = 1 mm, a = 8 mm, and g =
0.2 mm. A substrate with a dielectric constant of 3 and thickness of 0.75 mm is considered. The width (w) of the conductor strip is obtained as 1.8 mm, corresponding to characteristic impedance of 50Ω .

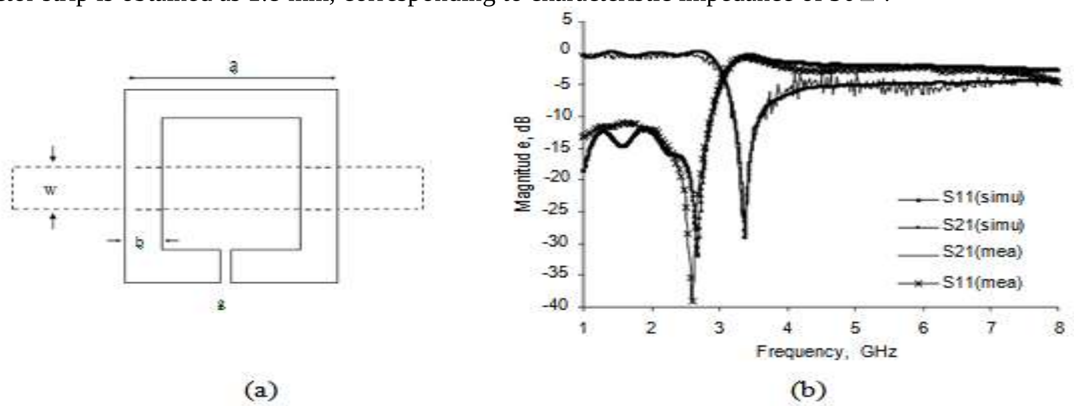


Figure 1(a) schematic of split-ring DGS
(b) simulated and measured s-parameters

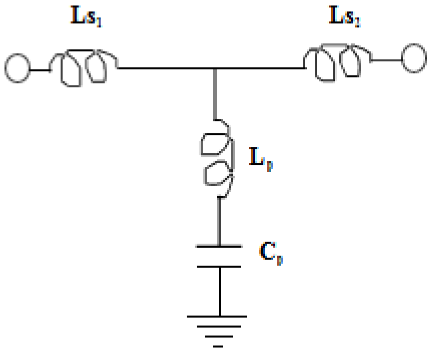


Figure 1 (c) Proposed equivalent circuit of the DGS unit

From the S-parameters results as shown in Figure 1(b), the cutoff frequency, pole frequency and insertion losses are obtained as 3.01 GHz, 3.35 GHz and 0.96 dB in measurement, whereas, the values are 3.03 GHz, 3.37 GHz and 0.75 dB in simulation. The attenuation zero frequency is observed at 2.79 GHz in simulation and 2.89 in measurement results. Thus, S-parameter response exhibits a sharpness factor of 76dB/GHz. The 20 dB rejection-bandwidth is obtained as 3% only and introduces small amount of insertion loss (0.96 dB) in the pass band. The DGS is modeled by T-network as shown in Figure 1(c)

III. Two-Element Patch Array Integrated With Dgs Cell

A microstrip line inset fed rectangular patch antenna is designed at centre frequency of 5.8 GHz on a high dielectric substrate board. A Rogers RO 3010 substrate having dielectric constant of 10.2, thickness of 1.27 mm and copper thickness of 0.07 mm is used for simulation. The patch element have length, L=15.3 mm, and width, W=12 mm as shown in Figure 2. The feed line has a width (h) of 1.2 mm, and inset have length of 4 mm and width of 0.4mm in both side of the feed line. The resonant frequency is observed at 5.86 GHz with maximum attenuation of 13.6 dB in simulated return loss response as shown in Figure 3 (a).

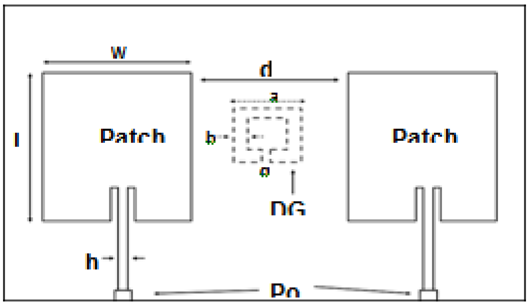
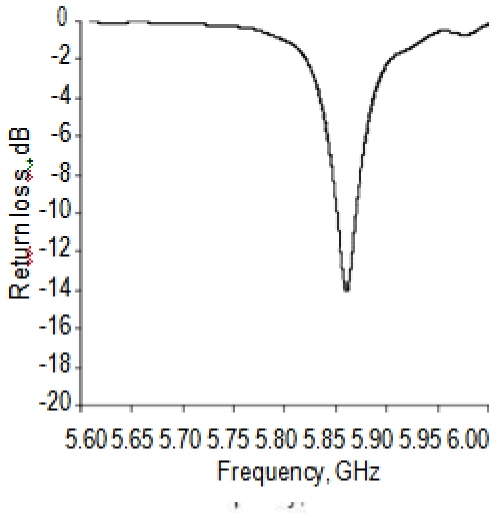


Figure 2 Schematic view of two-element patch array integrated with DGS cell

For the two-element array configuration, the distance between two elements (d) is taken as 8 mm. A square shaped split-ring DGS unit of side-length (a) of 2.1 mm, width

(b) of 0.4 mm and gap of 0.2 mm is incorporated at centre position in between two elements as shown in Figure 9. The return loss with DGS is obtained as 12.2 dB at centre frequency of 5.799 GHz, whereas it is 12.86 dB at centre frequency 5.781 GHz without DGS. The maximum mutual coupling between two elements is obtained as 9.53 dB due to DGS whereas, it is 8.29 dB without DGS. So, a reduction of 1.24 dB observed when a DGS cell is incorporated between elements as shown in Figure 3(b) & (c). Also centre frequency shifted by 180 MHz, when DGS is taken.



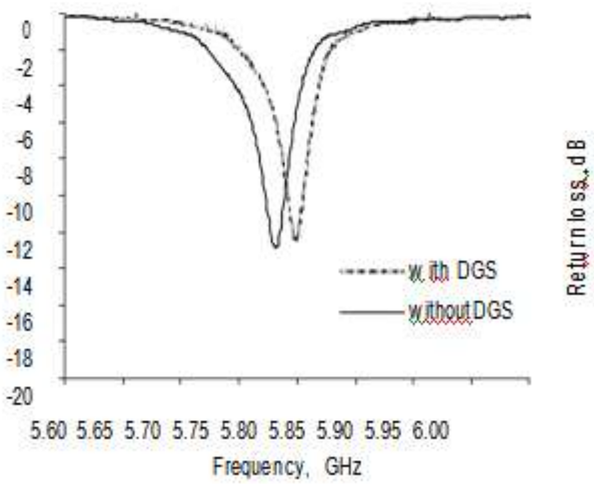


Figure (a) return loss characteristic of single element Figure (b) return loss of patch array with/without DGS

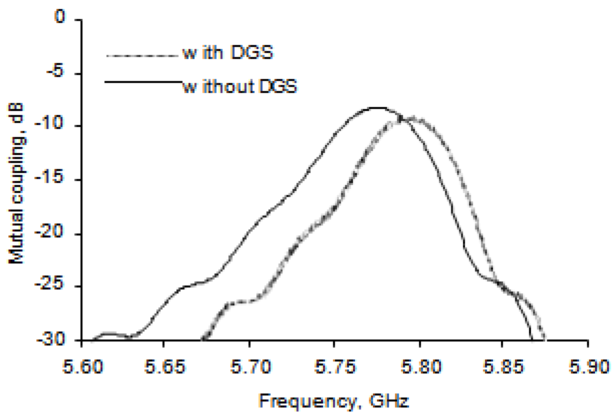


Figure 3 S-parameters of the microstrip patch array (c) Mutual coupling betn elements with/without DGS

The simulated farfield patterns are shown in Fig. 4. The side lobe level of maximum -5.9 dB is obtained due to inclusion of DGS as observed in simulated results in Figure 4.

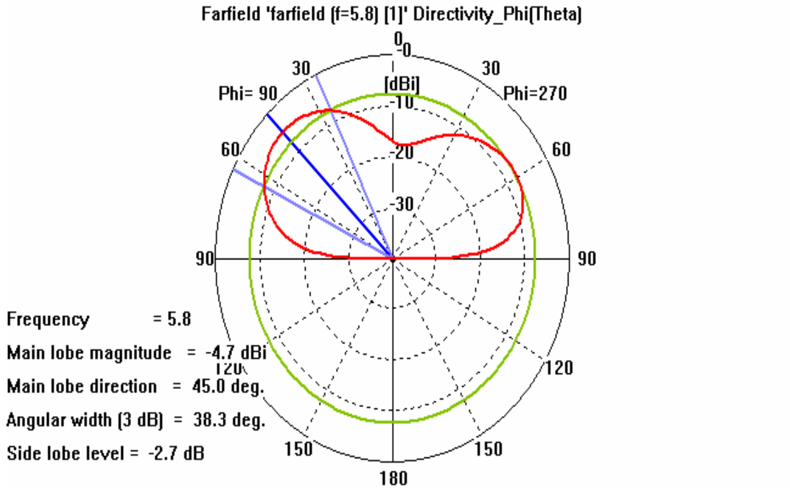


Figure (a) Directivity of Phi

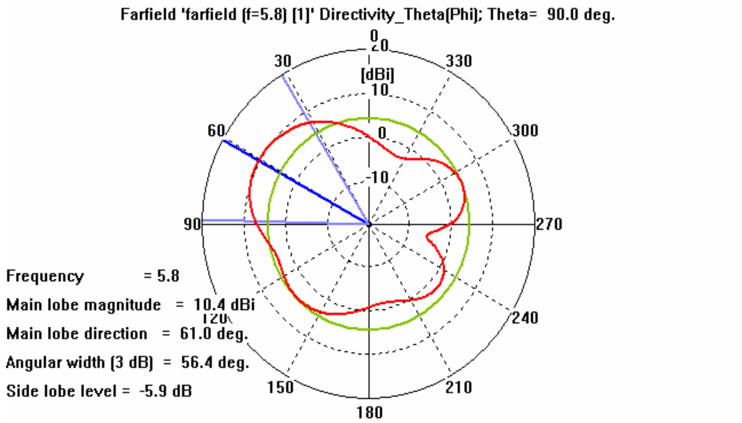


Figure 4 Far-field patterns at 5.8 GHz (b) Directivity of theta

IV. Conclusions

The frequency characteristics of proposed split-ring DGS cell show very sharp transition knee due to attenuation zero close to attenuation pole frequency. The DGS cell is modeled by 3rd order elliptic lowpass filter function. A microstrip line inset fed two element rectangular patch antenna arrays is designed at centre frequency of 5.8 GHz on a high dielectric substrate board. For the array configuration, the distance between two elements is taken less to observe the high mutual coupling. In this scheme, the mutual coupling has been reduced to some extent by incorporated a split-ring DGS cell in between antenna elements. Also the centre frequency is shifted due to slowwave factor. The simulated farfield patterns show an increase of side lobe level due to inclusion of DGS. The work may be extended for multi element array system in near future.

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