Meandered Inductor Shape of DGS for Coupling Suppression between Adjacent Elements of Array Antenna

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Abstract— Defected ground structure (DGS) has been recently applied to enhance the bandwidth and gain of microstrip antenna, as well as to effectively improve the radiation characteristics by suppressing the higher mode harmonics and coupling between adjacent elements of array antenna. This paper presents the use of DGS which takes meandered inductor (MI) shape to improve the return loss (S_{11}) and to suppress the coupling between adjacent elements (S_{21}) of array antenna. An FR4 epoxy dielectric substrate with the thickness of 1.6 mm is used for deploying the antenna. The MI shape slot is embedded on the groundplane at the bottom side of dielectric substrate between two elements of array antenna which are deployed on the top side. The simulated results show that values of S_{11} and S_{21} have been improved up to 4.4 dB and 1.9 dB, respectively, at the resonant frequency of 2 GHz. This is comparable with the measured results which have achievement up to 8 dB and 5 dB for S_{11} and S_{21}, respectively.

1. INTRODUCTION

It is already well-known that microstrip antennas have some limitations such as having single operating frequency, narrow impedance bandwidth, and low gain, in which these affect to the radiation characteristic of antennas. In overcoming those issues, defected ground structure (DGS) has been involved into the development of microstrip antennas [1]–[2]. Incorporation of DGS embedded into microstrip antennas has some advantages in enhancing the bandwidth and gain of antenna. It is also suppressing the higher order mode of harmonic frequencies and the coupling between adjacent elements beneficial for improving the radiation characteristic [2]–[3].

Basically, the compact geometrical slots embedded on the groundplane of microwave circuits such as antenna and filter are referred to as DGS. A single defect known as a unit cell or a number of periodic and non-periodic defects configurations may be comprised in DGS. In principle, every defect configured on the groundplane of devices disturbs the current distribution of the groundplane. Therefore, this disturbance affects the characteristic of structure positioned above the groundplane such as slot resistance, slot capacitance, and slot inductance to the line resistance, line capacitance, and line inductance, respectively. In case of microstrip line structure, any defects etched on its groundplane changes the effective resistance, capacitance, and inductance of microstrip line by adding slot resistance, capacitance, and inductance.

There are various shapes of DGS which have been embedded on the groundplane of microstrip line. The analysis of DGS embedding effect is usually conducted by representing an equivalent circuit consisting of inductance and capacitance. The shapes of DGS usually implemented for filter, absorber, and antenna applications include dumbbell and spiral shapes [4]–[6], U– and V-shapes [7]–[8], H– and cross shapes [9]–[10], and concentric rings shape [11]–[12]. Furthermore, some complex shapes of DGS have also been investigated such as meander lines [13], bowtie [14], split ring resonators [15]–[16], and fractals [17].

In this paper, a meandered inductor (MI) shape of DGS is proposed for array antenna application to suppress the coupling between adjacent elements of array antenna. The proposed DGS is designed based on its advantages in controlling the coupling between antenna elements in array configuration. The parametric study is also carried out through simulation to show the feasibility of DGS in enhancing the array antenna performance. The configuration of array antenna with DGS is fabricated and experimentally characterized to validate the simulation result.

2. MEANDERED INDUCTOR SHAPE AND ARRAY ANTENNA

Figure 1 shows a configuration of meandered inductor (MI) shape of DGS which is embedded on the groundplane of array antenna. The proposed DGS which is intended to suppress the coupling between adjacent elements of array antenna comprises of 4 MI shape slots with the total dimension of 18 mm $\times$ 49 mm. Each MI shape slot has the height of 10 mm, the width of 18mm, and the separation of 3 mm. To analyze the property of MI shape, basically each MI is divided into straight conductive segments as illustrated in Figure 2. The total inductance of each MI is a sum of self-inductances of all segments (L_a, L_b, etc.) and the negative and positive mutual inductances between all combinations of straight segments (M_1, M_2, etc.) [18]. Meanwhile, the inductor value is calculated by the concept of partial inductance such as contribution of individual segments to the overall inductance.

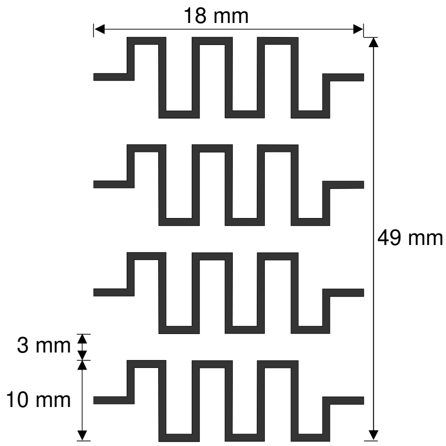

Figure 1: Configuration of meandered inductor (MI) shape of DGS.

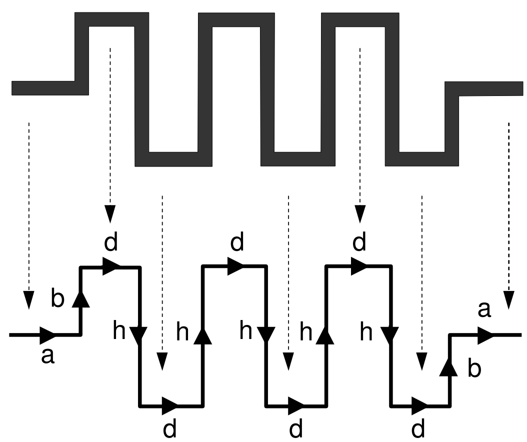

Figure 2: Straight conductive segment of MI for property analysis.

The construction of array antenna in which the MI shape slots are embedded on its groundplane as DGS is shown in Figure 3. An FR4 epoxy dielectric substrate with the thickness of 1.6mm is used to deploy the array antenna with MI shape DGS. The construction with the dimension of 130 mm $\times$ 105 mm is taken from the previous work in [14] except the shape of DGS. It has two antenna elements on the top side and 1 $\times$ 4 MI shape of DGS embedded on the groundplane at the bottom side between two elements of array antenna. Each antenna element is fed separately through a feeding line obtaining the same power excitation. Furthermore, an array antenna without DGS is also investigated to show the feasibility of DGS in reducing the coupling between two antenna elements. The array antenna without DGS is also deployed on the same dielectric substrate with the geometry and design parameter same as the one with 1 $\times$ 4 MI shape of DGS.

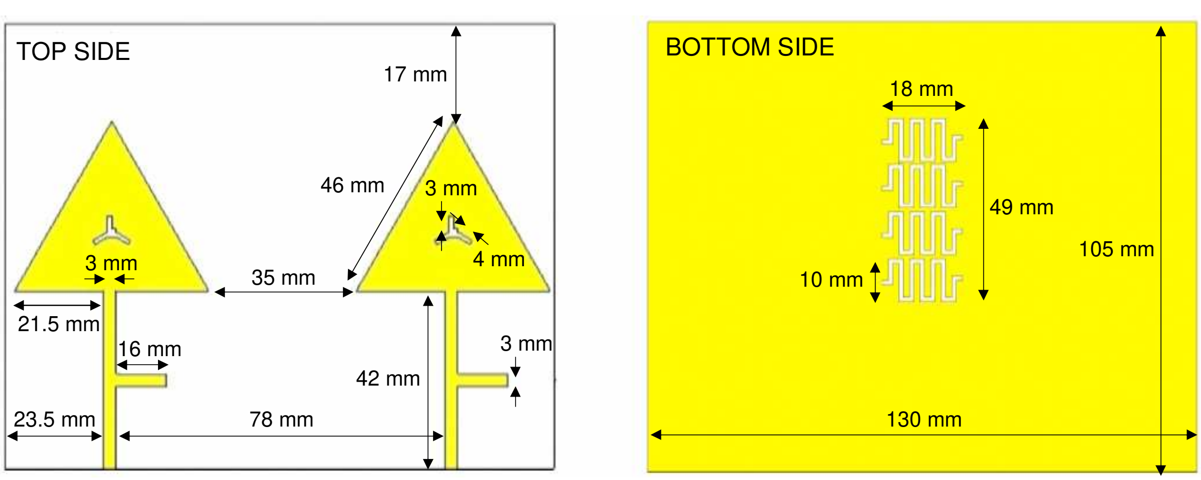

Figure 3: Construction of array antenna with MI shape of DGS; left is top side; right is bottom side.

3. REALIZATION, CHARACTERIZATION, AND RESULT COMPARISON

Figure 4 shows prototypes of array antenna with and without 1×4 MI shape of DGS which are realized on single layer of FR4 epoxy dielectric substrate with the thickness of 1.6 mm. Both prototypes are then characterized to demonstrate the effectiveness of DGS in reducing the coupling level between two adjacent elements of antenna. The characterization results of S_{11} for both array antennas are compared in Figure 5. The results show that both array antennas resonate at the frequency of 2 GHz with the simulated values of S_{11} reach up to 17 dB for the array antenna with 1×4 MI shape of DGS and 12.6 dB for the array antenna without DGS. Whilst the measured values of S_{11} is up to 15 dB for the array antenna with 1×4 MI shape of DGS and 7 dB for the array antenna without DGS. The results indicated that the embedding of 1×4 MI shape of DGS has improved the impedance matching of array antenna.

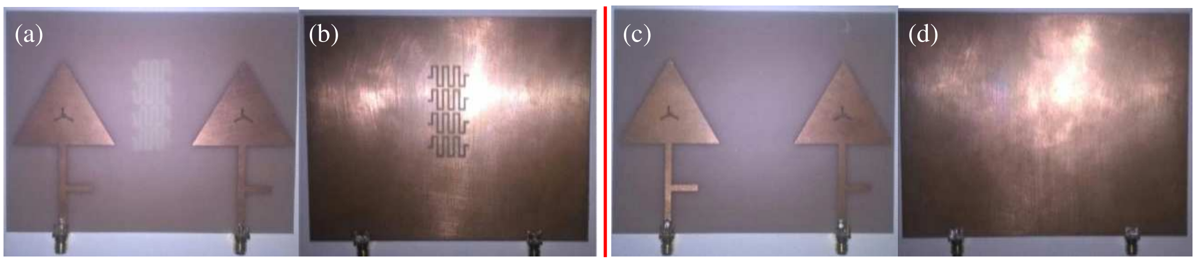

Figure 4: Prototypes of array antenna; (a) top side with 1×4 MI shape of DGS; (b) bottom side with 1×4 MI shape of DGS; (c) top side without DGS; (d) bottom side without DGS.

Figure 6 plots the characterization results of S_{21} also known as coupling between two antenna elements for both array antennas. The simulated coupling values at the resonant frequency of 2 GHz are -26.5 dB and 24.6 dB for the array antenna with and without 1×4 MI shape of DGS, respectively. It showed that there is coupling suppression of 1.9 dB for the array antenna with 1×4 MI shape of DGS. While the measured coupling values for the array antenna with and without 1×4 MI shape of DGS are 35 dB and 30 dB, respectively. This also indicated that the coupling was suppressed about 5 dB for the array antenna with 1×4 MI shape of DGS. Therefore, both simulated and measured couplings for the array antenna with 1×4 MI shape of DGS provide the improvement of 1.9 dB and 5 dB, respectively.

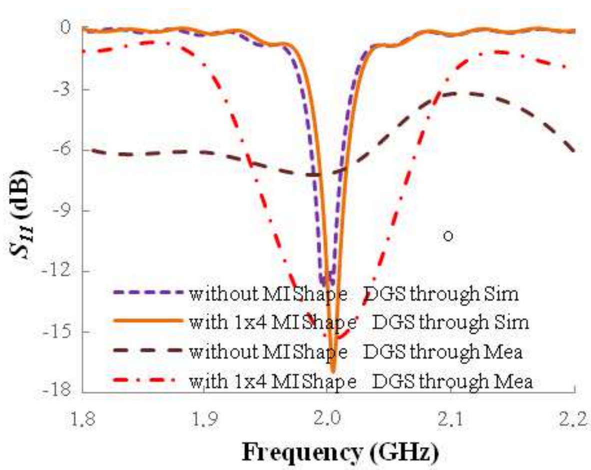

Figure 5: Characterization results of S_{11} for array antenna with and without 1×4 MI shape of DGS.

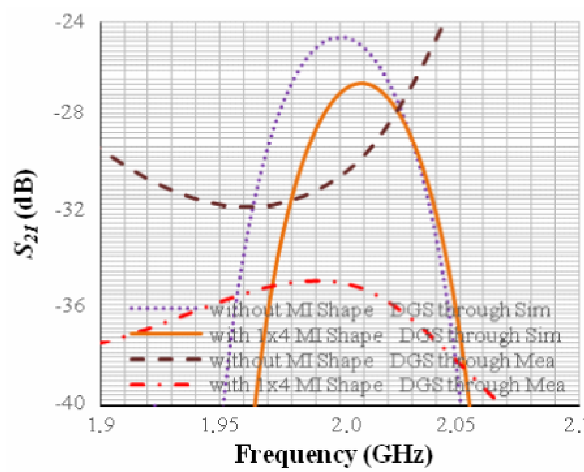

Figure 6: Characterization results of S_{21} for array antenna with and without 1×4 MI shape of DGS.

4. CONCLUSION

The coupling suppression between two antenna elements of array antenna has been investigated by embedding 1×4 MI shape of DGS into the groundplane of array antenna. The construction of array antenna with 1×4 MI shape of DGS has been characterized through simulation and experimentation to show the feasibility of DGS in enhancing the performance of array antenna, which was compared to the array antenna without DGS. It has been shown that the embedding of 1×4 MI shape of DGS could suppress the coupling between two adjacent elements of array antenna. The characterization results have shown the coupling suppression up to 1.9 dB and 5 dB for simulation and measurement, respectively, at the resonant frequency of 2 GHz.

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