Radiation Characteristics of Triangular Microstrip Antenna Array Using Dumbbell Defected Ground Structure (DGS)

Eko Tjipto Rahardjo #, Fitri Yuli Zulkifli, and Lestari Amirullah
Antenna propagation and Microwave Research Group (AMRG)
Center for Information and Communication Engineering Research (CICER)
Department of Electrical Engineering, University of Indonesia
Kampus Baru UI Depok, West Java,16424, Indonesia
Email: eko@ee.ui.ac.id, yuli@ee.ui.ac.id

1. Introduction

Antenna as an important device for wireless communications of various applications tends to decrease the dimension and still needs to improve its performance characteristics. Microstrip antennas have become an attractive candidate in a variety of commercial applications such as mobile and satellite communications because of its advantages such as low profile and compactness. However, traditionally, microstrip antennas suffer from surface wave which are excited on microstrip antennas whenever the dielectric permittivity of substrate $\varepsilon_r > 1$.

Surface wave has a substantial impact to the radiation properties of microstrip antennas. It can reduce antenna efficiency and gain, increase end-fire radiation and give rise to coupling between various elements of an array [1]. Photonic Band Gap (PBG) or in the microwave community, known as Electromagnetic Bandgap (EBG) is one solution available now to reduce the surface wave problem.

PBG engineering is periodically loading the substrate in such a way that the surface wave can not propagate along the substrate; a forbidden frequency range, stopband or bandgap, around the antenna's operating frequency is designed. PBG can control the propagation of electromagnetic waves; however in implementing PBG, a wide area is needed for the periodic structures. Likewise PBG, Defected Ground Structure (DGS) can also modify guided wave properties but the geometry of DGS is much simpler because it can be one or few etched structure in the ground plane. The defect in the ground plane disturbs the shield current distribution in the ground plane which leads to a rejection of the surface wave at a certain frequency band determined by the shape of the defect.

Different shapes of defects have been studied mostly for filters, but there are not many DGS applied to array microstrip antennas. In reference [2] and [3] Electromagnetic Bandgap (EBG) were implemented to array microstrip and only in reference [4], DGS is applied to array microstrip antennas in which the research shows only simulation results.

In this paper we propose a dumbbell DGS unit applied in a two element triangular patch linear array microstrip antenna that suppresses surface waves which improve the radiation properties of the microstrip antenna and also reduce the mutual coupling effect between the two elements array antenna.

2. Antenna Design and Fabrication

The Dumbbell DGS is implemented to a triangular patch microstrip antenna array based on reference [5] where the antenna operates at frequency 2.6 GHz with circular polarization. The triangular patch with modified Y-shaped slot is for circular polarization excitation. The equilateral-triangular patch has a side length of l = 46 mm. The optimum feed point is approximately located in the distance a = 21 mm at the bottom side of the patch. A single stub-tuner is embedded to obtain an optimum impedance matching. The stub length is 12 mm and placed at 16 mm from the bottom side triangular patch.

The antenna was designed and fabricated using Taconic substrate which has properties of dielectric substrate relative permittivity $\varepsilon_r = 2.2$ and loss tanδ = 0.0009. The ground plane area is of 130 mm x 105 mm and the dielectric substrate thickness is of 1.57 mm. The dumbbell shape DGS is then inserted in the ground plane of the antenna as shown in Fig. 1. The radiation properties of the antenna are then characterized by varying the dimension of the DGS and by varying the position of the DGS at specific position which is found experimentally.

3. Results and Discussions

The proposed antenna design as shown in Fig.1 was simulated using method of moment. The simulation result shows that the antenna design with and without DGS has similar impedance bandwidth from 2.59 to 2.66 GHz of VSWR < 2, however the antenna design with DGS shows better return loss at the resonant frequency 2.61 GHz of -59.5 dB, whereas the reference antenna shows -33.3 dB. This means an improvement of return loss of 78.7%.

The antenna is designed to have circular polarization. The simulation result of axial ratio bandwidth of AR < 3 dB shows no significant change between antenna with and without DGS which is about 50 MHz bandwidth from 2.59 to 2.64 GHz.

The dumbbell DGS antenna is used to reduce mutual coupling between the elements of the microstrip antenna array. The simulation result shown in Fig.2 shows a reduction of mutual coupling of 10.56 dB at the resonant frequency of 2.61 GHz.

Measurement results were taken in anechoic chamber after fabrication of the antenna. The measurement was taken for both antennas, with and without DGS. Fig.3 shows the measurement result of the return loss of the antenna. The measurement shows an improvement of the return loss from -30.3 dB for the antenna without DGS to - 40.1 dB for the antenna with the dumbbell DGS at requency 2.66 GHz. This means an improvement of return loss of 32.3%. The impedance bandwidth of both antennas shows similar results *i.e.* from 2.62 – 2.68 GHz.

In addition, the antenna with DGS succeeded in reducing the mutual coupling to 18.62 dB which is shown in Fig. 4. It is shown that the simulation and measurement results agree well that the dumbbell DGS improved the performance of the reference antenna.

4. Conclusion

A dumbbell shape DGS is inserted between the patches of two element triangular array microstrip antenna. Measurement results show the insertion of the dumbbell succeeded to reduce the mutual coupling between the elements to 18.62 dB and improve the return loss of 32.3%, without any significant change of the axial ratio bandwidth.

5. Acknowledgment
This work is supported in part by the University of Indonesia under the Competitive Research Grant contract no. 240AS/DRPM-UI/NI.4/2008

References

[1] Garg, R., Bhartia, P, Bahl, I., dan Ittipiboon, A., "*Microstrip Design Handbook*", Artech House Inc., Norwood, MA, 2001.

[2] Yu, A. ang Zhang, X.,"A Novel Method to Improve the Performance of Microstrip Antenna Arrays using Dumbbell EBG Structure", *IEEE Antennas and Wireless Propagat Letters*, Vol2, 2003

[3] Yang, Li.; Feng,Z.; Chen, F.; and Fan, M., "A Novel Compact EBG Structure and its Application in Microstrip Antenna Arrays", *IEEE MTT-S Digest*, pp.1635-1638, 2004

[4] Salehi, M.; Motevasselian, A.; Tavakoli, A.; and Heidari, T.; "Mutual Coupling Reduction of Microstrip Antennas using Defected Ground Structure", *10th IEEE Internat. Conference on Communication systems (ICCS)*, pp.1 – 5, Oct. 2006

[5] Rahardjo, E.T., Zulkifli, F.Y., and Martin, M.., "Design of Circularly Polarized Equilateral Triangular Microstrip Antenna Array for Satellite Communication" *Proc. of Internat Symp. On Antennas and Propagat. (ISAP)*, Aug 2007, Niigata, Japan.

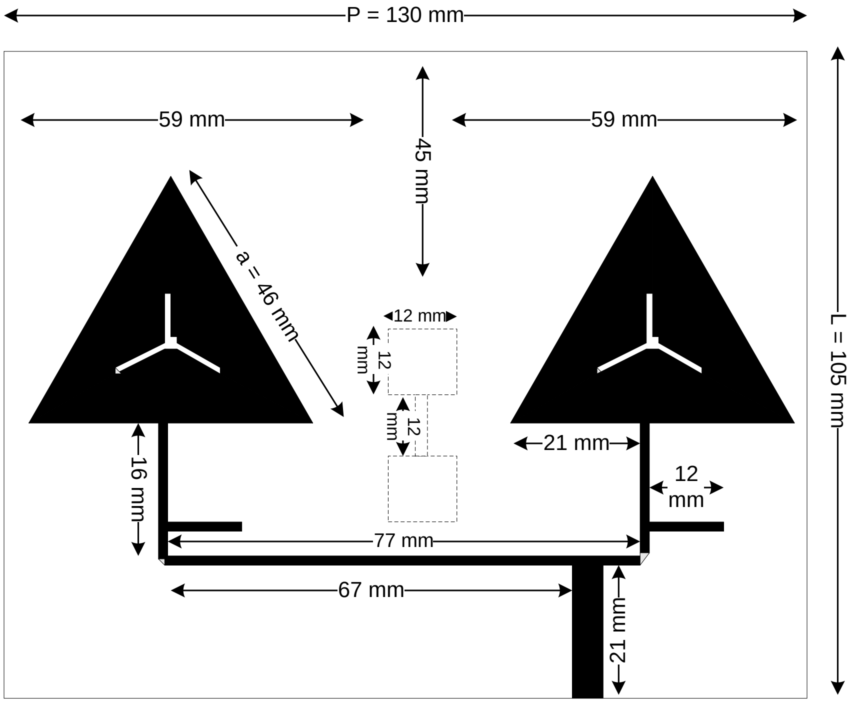

Fig.1 Design of the Proposed Antenna Array

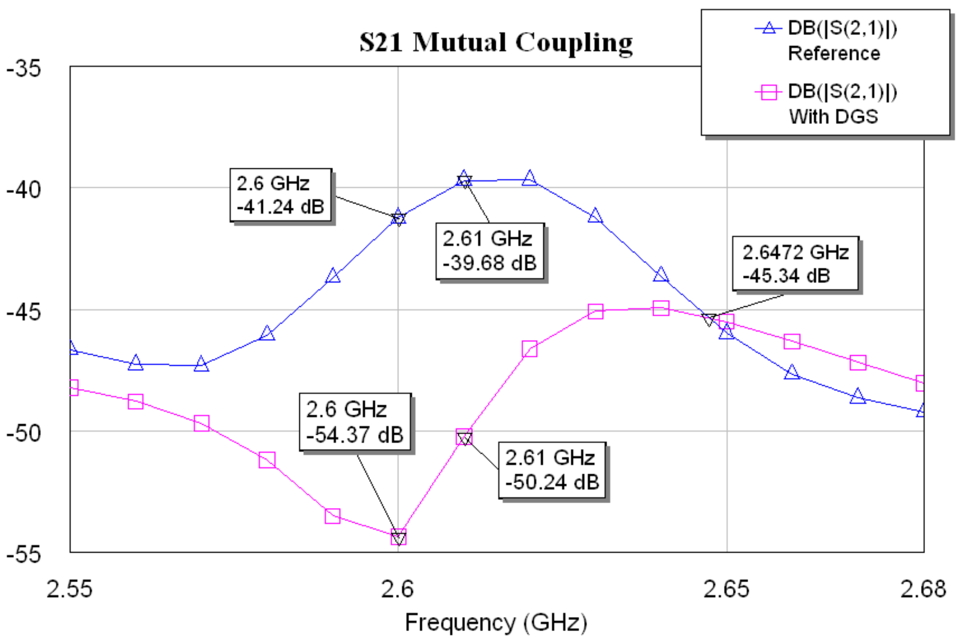

Fig.2. Simulation Result of Mutual Coupling

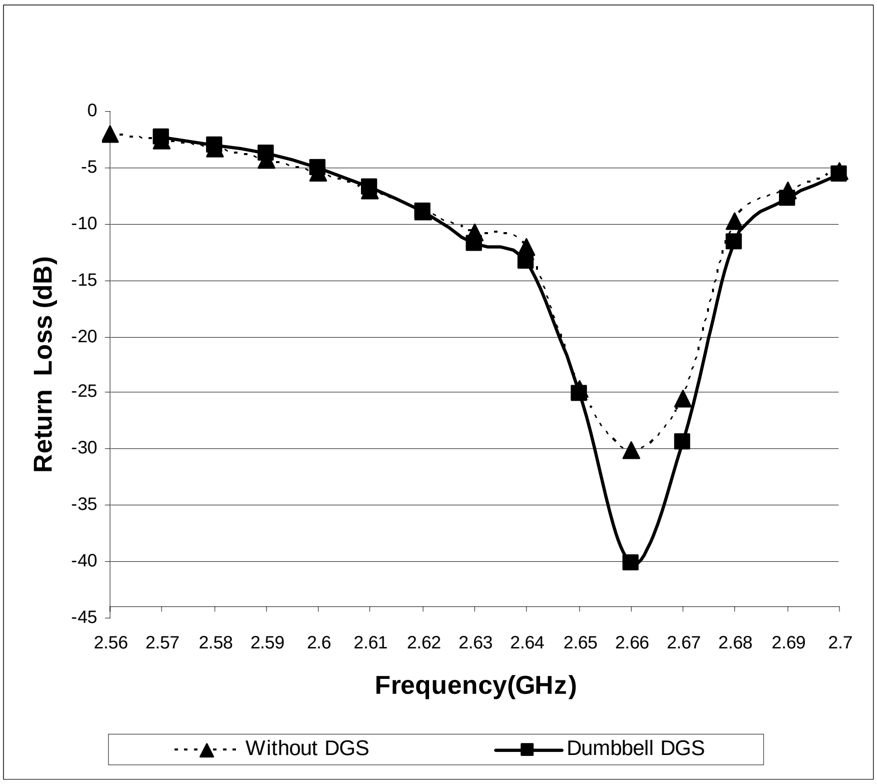

Fig.3. Measurement Result of Return Loss

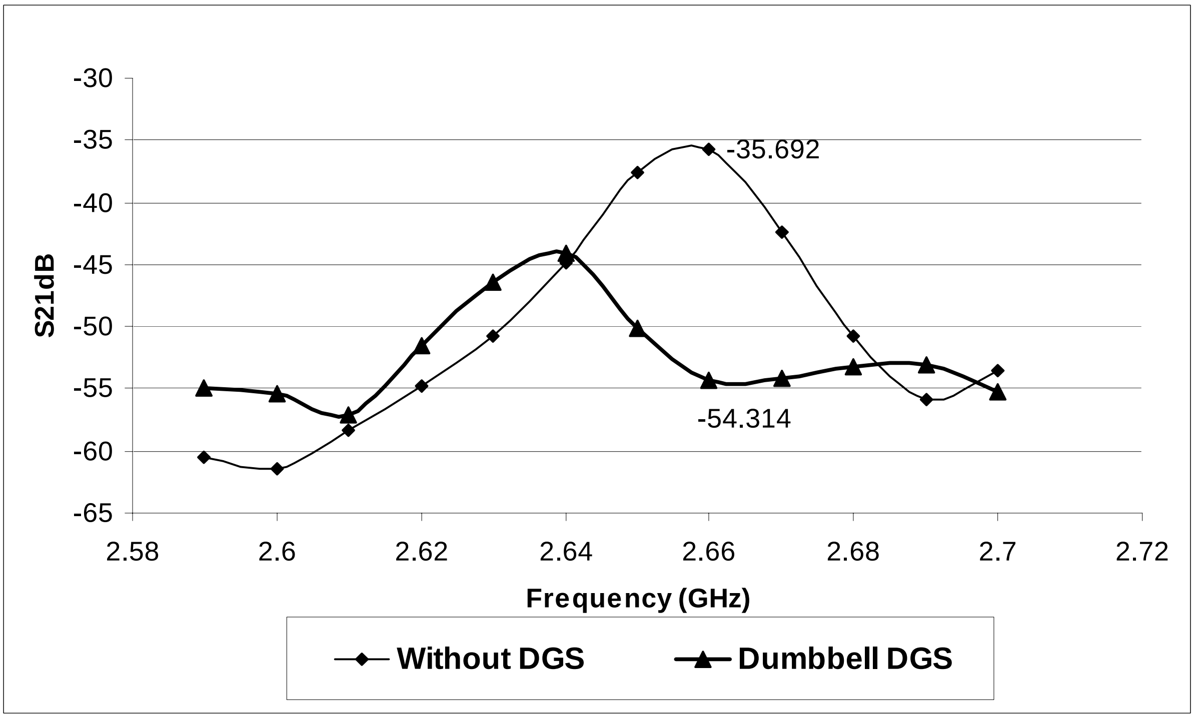

Fig.5. Measurement Result of Mutual Coupling