High Isolation Dual-Polarized Patch Antenna Using Integrated Defected Ground Structure

Younkyu Chung, *Student Member, IEEE*, Seong-Sik Jeon, *Student Member, IEEE*, Dal Ahn, *Member, IEEE*, Jae-Ick Choi, and Tatsuo Itoh, *Fellow, IEEE*

***Abstract*—This letter presents a high isolation dual-frequency orthogonally polarized rectangular patch antenna utilizing microstrip feed line integrated with a defected ground structure (DGS). The demonstrated approach results in a significant improvement in port isolation in comparison to a conventional dual-polarized antenna fed by simple microstrip lines. Measurements show an improvement of 20 dB in port isolation relative to the conventional antenna, operating at 2 and 2.5 GHz. Image impedance of a microstrip line with DGS is controlled by the DGS geometry without modifying the dimension of the line. A 150 Ω high impedance line is effectively implemented using a microstrip line with 75 Ω line width by incorporating the DGS.**

***Index Terms*—Characteristic impedance, defected ground structure, dual polarization, isolation, patch antenna.**

I. Introduction

MICROSTRIP patch antennas have been widely used in high performance satellite and wireless communication applications. This is because the antennas offer attractive features such as low profile, light weight, easy and inexpensive manufacturability, conformal structure, and compatibility with integrated circuit technology [1]. The concept of dual-polarization is becoming popular with the increasing demand for polarization diversity. In spite of their attractive features, however, the dual-polarized microstrip antennas are generally associated with low efficiency, high Q, narrow frequency bandwidth, and poor isolation performance.

A microstrip feed line is easy to fabricate, simple to match by controlling the inset position and rather simple to model [1]. However, for a dual-frequency orthogonally polarized patch antenna with two feeding points at different operating frequencies, this feeding method may not be used to control the antenna impedance as in the simple feed case. The horizontal and vertical dimensions of the dual-polarized antenna, which define the resonant frequencies, affect each other so that the resonant frequencies themselves are changed by adjusting the position of the inset. In practice, using this method it is difficult to make reasonable antenna impedance by controlling the position of the inset while maintaining resonant frequencies for the dual orthogonal polarization. Therefore, often a high impedance microstrip line with narrow width is used to act as a quarter-wave length transformer to transform the high antenna input impedance to 50 Ω. Because of the fabrication tolerance of this structure it is also difficult to implement. Some studies have been made to improve isolation performance of the microstrip dual-polarized patch antennas using different feeding structures [2], [3]. Chiou *et al.* demonstrated a high isolation patch antenna at L-band by utilizing two in-phase aperture-coupled feeds at port 1 and two out-of-phase gap-coupled probe feeds at port 2. Higher than 40 dB isolation was demonstrated [2]. Haneishi *et al.* presented better than 30 dB port isolation performance at 5 GHz using dog-bone slots [3]. Despite the excellent performances, however, these structures require multi-layer structures. In this work, a simple and new feeding structure for a planar patch antenna is presented by employing a microstrip feed line integrated with DGS patterns.

Similar to periodic structures [4], the DGS provides slow wave and stopband characteristics [5]–[7] [9], [10]. The former can be utilized to reduce circuit size [5], while filter design and harmonic tuning of power amplifiers can be accomplished using the latter [5], [6]. Furthermore, the image impedance of the line can also be controlled by integrating the DGS to the line without modifying the dimensions of the line [9], [10].

In this letter, a high port isolation dual-polarized microstrip patch antenna operating at 2 and 2.5 GHz has been demonstrated. We use both the stopband and impedance transformation characteristics of the DGS in the design of the antenna. The image impedance of the microstrip line embedding DGS section was calculated by considering its equivalent circuit.

II. Design of DGS-Integrated Microstrip Antenna

A dual-frequency orthogonally polarized rectangular patch antenna was designed by adjusting the length and width to have resonant frequencies at 2 and 2.5 GHz. The DGS-integrated microstrip feeding structure which was used to feed the 2 GHz port, as depicted in Fig. 1(a), consists of a typical microstrip line on the top side and a spiral-shaped DGS pattern located on the metallic ground plane. Its equivalent circuit for a unit cell, obtained by curve fitting, is illustrated in Fig. 1(b). It is composed of a series inductor, Ls to describe cross coupling between etched defected lines, and a short-circuited stub with a characteristic impedance of Z_S to represent periodic frequency response [7]. Fig. 2 shows the HFSS simulation result of the DGS-integrated microstrip feed line, shown in Fig. 1(a), on 0.787 mm thick RT Duroid with $\varepsilon_r = 2.33$ for the 2 GHz excitation port. As clearly shown in the figure, the feed line shows a stop band at 2.4–2.8 GHz. When the DGS is inserted along the microstrip

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Y. Chung, S.-S. Jeon, and T. Itoh are with the Department of Electrical Engineering, University of California, Los Angeles, CA 90095 USA (e-mail: ykchung@ee.ucla.edu).

D. Ahn is with the Division of Information Technology Engineering, Soonchunhyang University, Choongnam, Korea.

J.-I. Choi is with the Electronics and Telecommunications Research Institute (ETRI), Daejeon, Korea.

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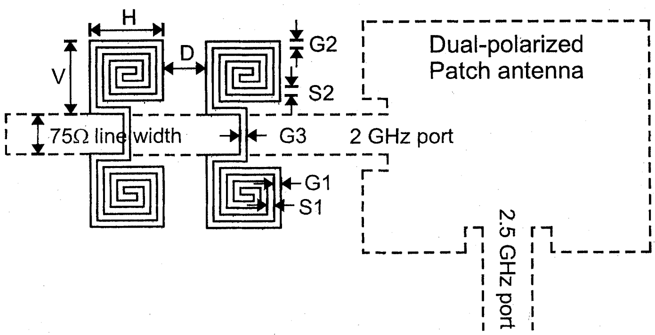
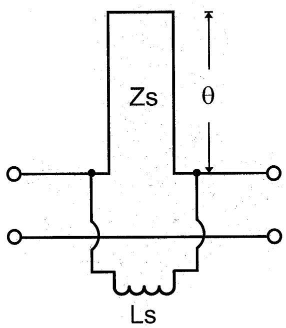


(a)



(b)

Fig. 1. (a) Structure of the DGS-integrated feed line (Bottom-side view). $D = H = V = 5$ mm, $G1 = G2 = 0.6$ mm, and $S1 = S2 = G3 = 0.2$ mm. (b) Equivalent circuit of unit element spiral-shaped DGS. (Θ is the electrical length of the short-circuited stub.)

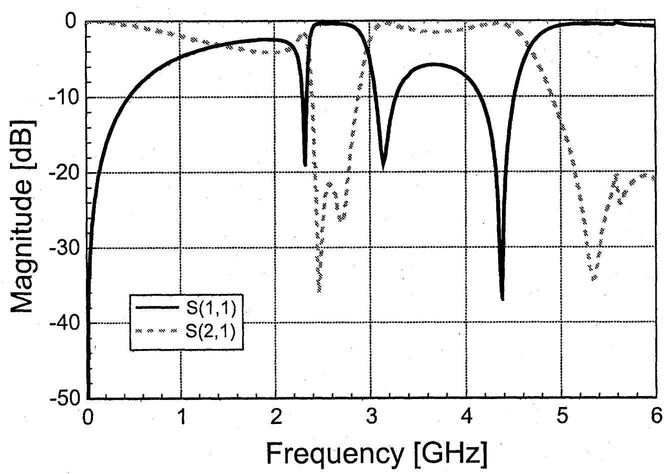


Fig. 2. Simulation results of the microstrip line with two spiral-shaped DGSs shown in Fig. 1(a).

line, the image impedance of this composite structure, treated as a two-port device [8], can be controlled by the DGS geometry. Based on the literature addressing the effect of DGS on image impedance change [9], [10], the simulation result implies that the image impedance is about 150 Ω. Therefore, a microstrip line that is designed to be 75 Ω without DGS, in practice, behaves as a transmission line with 150 Ω characteristic impedance because of the DGS pattern.

The DGS pattern was placed at $\lambda/2$, corresponding with 2 GHz, away from feeding point to avoid a variation of the antenna impedance. By controlling the positions of the inset,

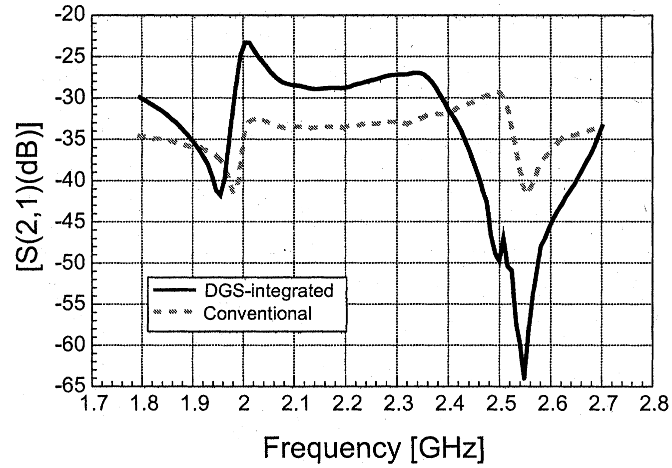


Fig. 3. Measured port isolation characteristics of the patch antennas (DGS-integrated and conventional feed lines).

the rectangular patch antenna was designed to have a relatively high input impedance of 300 Ω. Thus, the DGS-integrated feeding line with 150 Ω image impedance acts as a quarter-wave length transformer. The 2.5 GHz port was terminated with a 50 Ω microstrip line with an inset.

III. Experimental Results

We fabricated a dual-feed microstrip patch antenna on the RT Duroid substrate with thickness of 0.787 mm and $\varepsilon_r = 2.33$ using the DGS-integrated feeding structure. For comparison, another patch antenna was constructed on a substrate with the same parameters as above. However, this dual-polarized antenna was fed by conventional quarter-wave transformer to match the 75 Ω termination for the 2 GHz port. The alignment between top and bottom side patterns has to be done carefully for the DGS-integrated antenna. In practice, the alignment mismatch is within the tolerance of fabrication process.

Both antennas were excited from the 2.5 GHz port, port 1, and the leakage to the 2 GHz port, port 2, was measured by changing input frequency as shown in Fig. 3. More than 20 dB improvement in isolation between the two ports was obtained at around 2.5 GHz, approaching isolation above 60 dB in the DGS-integrated antenna compared to the ordinary antenna. Due to the nature of a microstrip patch antenna such as a small frequency bandwidth of narrower than 10% low isolation performance over frequency range outside the designed frequency does not affect the antenna performance significantly. Fig. 4 shows measured input return losses of the two antennas. The return loss was measured at the 2 GHz input port while the other port was terminated with 50 Ω. For the DGS-integrated antenna, due to the increase of image impedance of the line with DGS, it is clearly seen that the antenna impedance of 300 Ω was well matched to 75 Ω despite the fact that the antenna was fed by a microstrip line with a 75 Ω line width. In Fig. 5, the measured antenna radiation patterns in E-plane are shown for the conventional and DGS-integrated antennas. The antenna radiation patterns were measured with 2 GHz excitation and normalized to 0 dB in the broadside direction. No significant change in antenna radiation performance was observed between these two

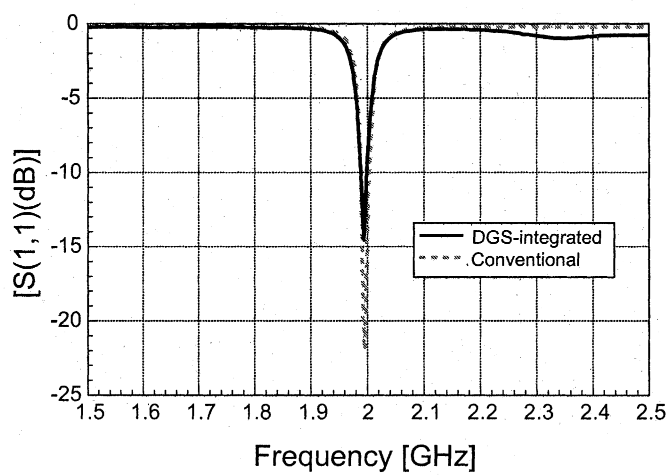


Fig. 4. Measured input return loss characteristics of the patch antennas at 2 GHz port (DGS-integrated and conventional feed lines).

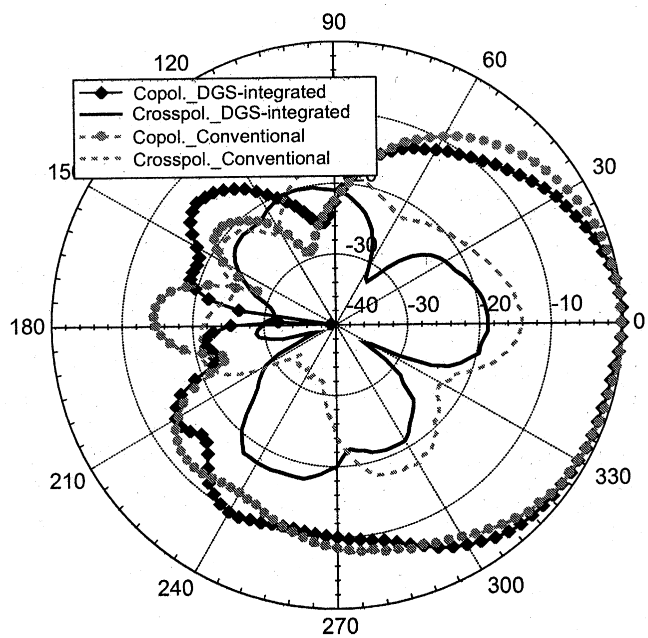


Fig. 5. Measured E-plane radiation patterns of the patch antennas (DGS-integrated and conventional feed lines).

antennas. 4.66 dB and 4.83 dB antenna gains were observed for the conventional and DGS-integrated antennas, respectively, at 2 GHz frequency.

IV. Conclusion

A new microstrip feed line structure for a dual-polarized microstrip patch antenna has been proposed in this work. By placing a spiral-shaped DGS pattern under the feed line, port isolation has been significantly enhanced. Improvement in port isolation by 20 dB relative to a patch antenna with a conventional microstrip feed line was observed. The use of 75 Ω microstrip feed line with DGS provided 150 Ω image impedance without modifying the width of the line. This work demonstrates that DGS can be successfully used to improve port isolation for a dual-frequency orthogonally polarized rectangular patch antenna in a simple way. It provides an effective solution for implementation of very high impedance transmission lines with only moderate line widths.

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