Size Reduction of Patch Antenna Array Using CSRRs Loaded Ground Plane

H. A. Jang, **D. O. Kim**, **and C. Y. Kim**
School of Electronics Engineering, Kyungpook National University, South Korea

Abstract— Recent theoretical and experimental studies have shown that microstrip patch antennas loaded by ground plane partially filled with a negative permeability metamaterial may in principle provide a resonant radiating mode, even if the size of the patch antenna is smaller than the wavelength of operation. However, those studies have investigated only a single microstrip patch antenna. To extend the research for patch antenna with metamaterial, this paper offers a novel patch array antenna mounted with the rectangular complementary split ring resonators (CSRRs). The antenna consists of two patch arrays, and they are constructed on Rogers4003 substrate with the thickness of 0.812 mm and relative permittivity of 3.55. The CSRRs are arranged on area of the ground plane surrounding the radiating patch. The designed and fabricated antenna has the operating frequency of about 3.8 GHz, whereas the resonant frequency of an ordinary array antenna having the same patch size without the CSRRs is about 5 GHz. It means that the occupied area of our suggested array antenna can be reduced by 47% to that of the ordinary one. The miniaturized antenna maintains the high directivity performance required by an array antenna, which are confirmed by both simulation and measurement.

1. INTRODUCTION

In modern wireless communication systems, the microstrip patch antennas are commonly used in the wireless devices. Therefore, the miniaturization of the patch antenna has become an important issue in reducing the volume of entire communication system. The common method for reducing the microstrip patch antenna size is to utilize a high permittivity dielectric substrate. But, the antennas are more expensive, less radiation efficiency, and have narrow bandwidth. To overcome the above drawbacks, many design techniques of the patch antenna have already been proposed. These antennas have the inserted slot [1], the corrugation structure [2], the iris structure [3], and the shorting pin [4]. However, all of these design strategies have limitation in their design, which are a complex structure and low performance for miniaturization. So, the design methods of the miniaturized patch antenna with metamaterial technology have been reported on some authors, recently [5, 6]. These would include the SRR or CSRR on the microstrip patch, although those antennas have been restrictively researched in single patch antenna. In other words, achievement of size reduction of antenna with the SRR or CSRR has a special meaning in the field of array antenna. In this paper, the miniaturized 2-elements patch array antenna with CSRRs is presented. The proposed antenna takes an advantage over the previously published miniaturized patch array antennas

2. ANTENNA CONFIGURATION

The SRR was originally proposed by Pendry in 1999, and is the metamaterial resonator having the negative permeability [7]. The SRR structure is formed by two concentric metallic rings with a split on opposite sides. This behaves as an LC resonator with distributed inductance and capacitance that can be excited by a time-varying external magnetic field component of normal direction of resonator. This resonator is electrically small LC resonator with a high quality factor. Based on the Babinet principle and the duality concept, the CSRR is the negative images of SRR, and the basic mechanism is the same to both resonators except for excited the axial electric field. With adjustment of the size and geometric parameters of the CSRR, the resonant frequency can be easily tuned to the desired value. Figure 1 shows the geometry and dimensions of the finalized design CSRR.

Figure 2 shows the finalized shape and dimension of antenna with CSRRs. This antenna is constructed on Rogers 4003 dielectrics substrate with 0.812 mm thickness, a relative permittivity of 3.35, and a loss tangent of 0.0027. The top plane of the proposed antenna was designed by forming typical 2 elements microstrip patch array antenna which has operating band at 5 GHz. The bottom plane of antenna is periodically etched the CSRRs on ground plane. The T-junction power divider is applied to the feeding line of the proposed antenna, which consists of transmission

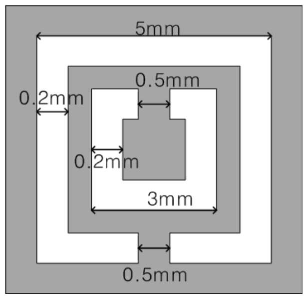
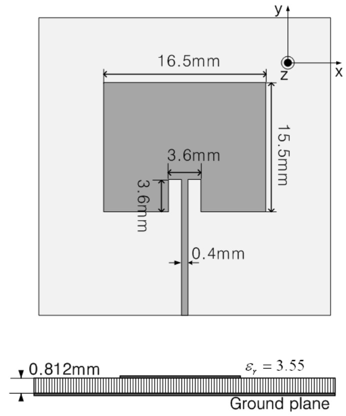
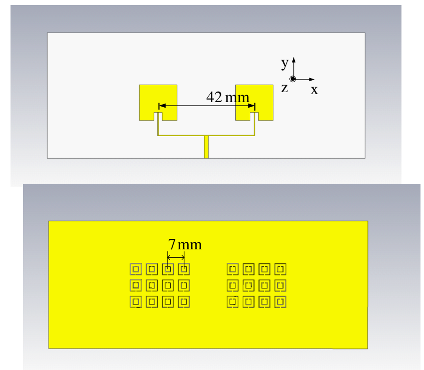


Figure 1: Geometry and dimensions of the proposed CSRR.



(a)



(b)

Figure 2: Geometry and dimensions of antenna (a) unit patch antenna, (b) top and bottom view.

Figure 3: Photograph of the fabricated antenna.

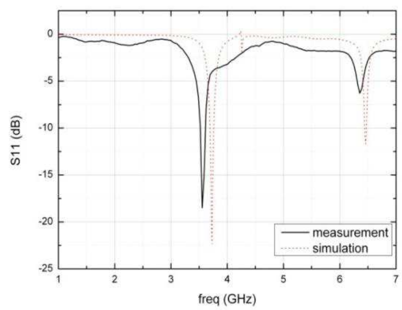


Figure 4: Simulated and measured return loss of the antenna.

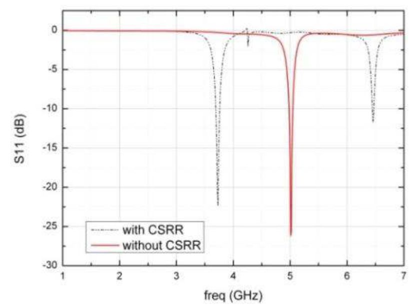
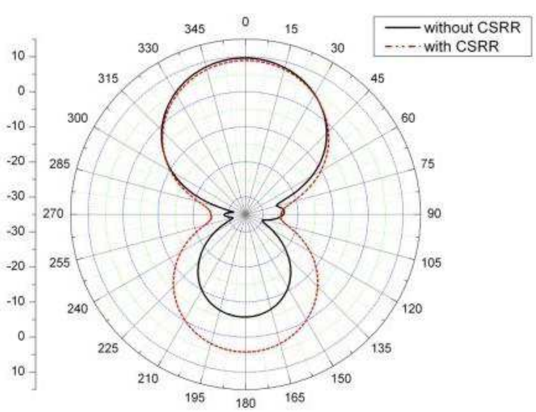
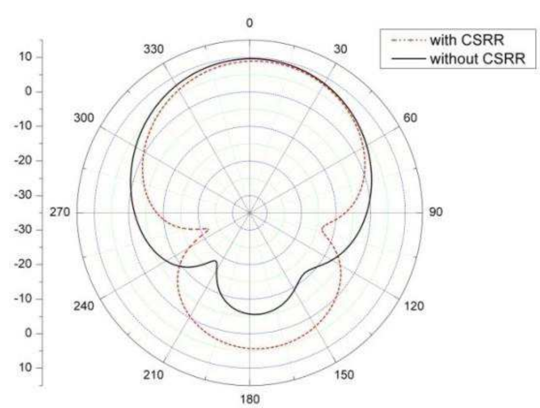


Figure 5: Return loss of antenna with CSRR or without CSRR.



(a)



(b)

Figure 6: Radiation pattern of antenna with CSRR or without CSRR (a) xz plane, (b) yz plane.

line of the characteristic impedance $50\,\Omega$ and $100\,\Omega$. The distance between two patch elements is 47 mm that corresponds to the electrical length of $0.7\lambda_g$. The etched CSRRs are finitely arranged around the radiating patches because the axial electric field to drive the CSRRs is produced only around radiating patches. Strong mutual coupling between negative permeability resonator and antenna patch is yielded by arranging of CSRRs, and it becomes typical high impedance structure. The physical insight for our configuration is similar to the mechanism of electric length reduction on high impedance substrate of [8].

3. SIMULATED AND MEASURED RESULTS

Figure 4 shows the simulated and measured return loss results for the fabricated antenna. The relatively good agreement is seen between the measured and simulated return loss curves. The measurement and simulation were performed by an Anritsu 37397C network analyzer and the Microwave Studio of CST, respectively. Figure 5 shows the return loss of the patch array antenna with and without the CSRRs inclusions. By adding the CSRRs, resonant frequency 5 GHz of typical patch array antenna is shifted to 3.8 GHz without changing the size of radiating patch. From these results, the proposed antenna achieves size reduction of 47% for antenna patch. Figure 6 indicates the radiation pattern of the miniaturized antenna with and without the CSRRs at 3.8 GHz. The antenna peak directivity of the typical array antenna without the CSRRs is 9.7 dB, and the designed antenna with the CSRRs is 8.9 dB which is about 0.8 dB below that of the typical antenna. This result exhibits that the proposed antenna maintains the inherent performance of array antenna.

4. CONCLUSION

This paper proposes a miniaturized 2-elements microstrip patch array antenna without changing the size and dimensions of typical patch array. To realize the size reduction, the CSRRs having the negative permeability characteristics are etched on the ground plane of the antenna. The proposed antenna achieves a 47% size reduction comparison with original patch antenna. To demonstrate the usefulness of the proposed design method, the performance parameters of antenna is simulated and measured. In spite of size reduction of radiating patch, antenna directivity of proposed antenna is only decreased within 1 dB. This reveals that the proposed antenna has more excellent performance compared to other miniaturized array antenna, and it might be useful for constructing the compact 3 GHz WiMAX communication system.

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