Effect of Complementary Split-ring Resonators on Beam Scanning in the CRLH-leaky Wave Antennas Based on Split-ring Resonators and Slotline

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Abstract— In this paper, a new leaky wave antenna (LWA) based on complementary split-ring resonators (CSRRs) and slot line are proposed. Effects of CSRRs on beam scanning in a composite right/left handed (CRLH) LWA based on split-ring resonators (SRRs) are investigated. Actually, the effects of these structures on the scan angles have been compared. The commercial Ansoft HFSS software is adopted for the simulations. The proposed LWA is analyzed in S and C band frequency, and the results reveal that the CSRR improves the gain in backward leaky wave radiation. The CSRR-LWA just scans the negative angles. Furthermore, the simulation results demonstrate the potential of the SRR-LWA to radiate from backward to forward scanning angles. As a result this miniaturized CSRR-LWA main beam can scan the space for C-band from −115 to −170 degree in phi = 0 (deg) plane. In the other word, the CSRR-LWA only scans in the negative ranges of theta, but SRR-LWA scans the space from +94° to +156° in positive ranges and −1334° to −177° in negative ranges of theta.

1. INTRODUCTION

A leaky wave antenna (LWA) uses a guiding structure that supports wave propagation along the length of the structure, with the wave radiating or leaking continuously along the structure. LWAs have been investigated since the 1940s, when an LWA consisting of a slotted rectangular waveguide was introduced. A microstrip line that is periodically modulated in order to turn the non-radiating microstrip mode into a radiating leaky mode has been reported in [1, 2]. Advantages of LWA are the ability to offer sharp directional beams with a frequency scanning over a large bandwidth. Other benefits of LWA are the simple structure, cheap and simple feed network that these advantages of LWA have been announced in [1–3]. The composite right/left handed (CRLH) LWA is one of the kinds of LWAs that is part of the periodic LWAs.

In this paper, we have presented two LWA based on split-ring resonators (SRRs) and complementary split-ring resonators (CSRRs). Beam scanning is one of the most important parameters of LWAs and we have reported it here. In plain English, we have investigated the effect of these structures on scan angles. These structures against the SRR-LWA that reported in [3], have only three unit cell. So we explain the improving the gain in CSRR-LWA here.

2. ANTENNA DESIGN AND SIMULATION

2.1. Split-ring Resonator-leaky Wave Antenna

First of all, we propose the SRR-LWA with the three unit cells. Each unit cell of this antenna consists of a slot line in the upper plane and SRR in the ground plane. You can see the part of unit cell of SRR-LWA in Figure 1(a).

2.2. Complementary Split-ring Resonators-leaky Wave Antenna

Figure 1(b) demonstrates the unit cell of CSRR-LWA. The gray parts show metal on the upper and lower planes. The upper plane is same as the upper plane of the SRR-LWA.

3. COMPARISON AND SIMULATION RESULTS

The commercial *Arlon Cuclad 250-LX* substrate with dielectric constant $\varepsilon_r = 2.43$ and thickness $h = 0.49\,\text{mm}$ has been used for simulation.

Figure 2 illustrates S-parameter of proposed LWAs. These antennas work about C and S-band.

As it was mentioned above these LWAs have three cells that it shows in Figure 3. These antennas are simulated by commercial Ansoft HFSS software.

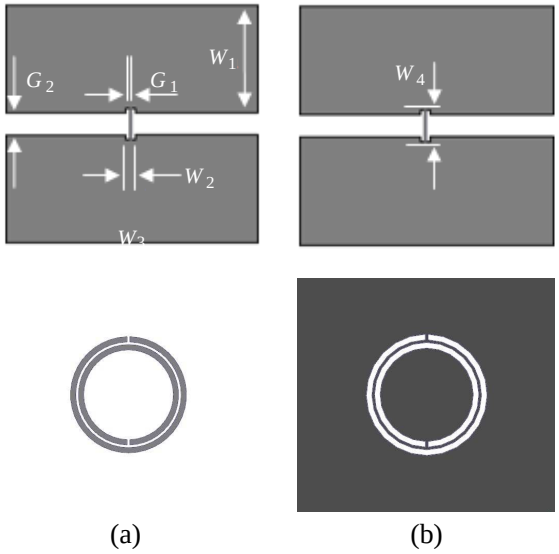

Figure 1: Unit cell of LWA with the same upper plane.Grey parts indicate metal on the planes. (a) Top and bottom view of proposed SRR-LWA unit cell. The external radius, rings width, and rings gap of the SRRs are 5.5, 0.5, and 0.25 mm. Parameter values are $W_1 = 10\,\text{mm}$, $W_2 = 0.85\,\text{mm}$, $W_3 = 23.5\,\text{mm}$, $G_1 = 0.25\,\text{mm}$ and $G_2 = 2\,\text{mm}$. (b) Top and bottom view of proposed CSRR-LWA unit cell. Parameter value is $W_4 = 2.8\,\text{mm}$. The external radius, rings width, and rings separation of the CSRRs are 5.5, 0.5, and 0.25 mm.

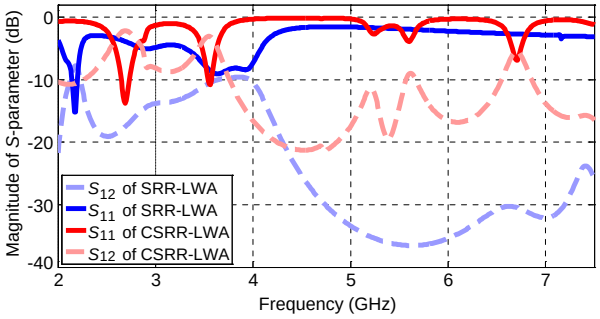

Figure 2: Magnitudes of S-parameters in proposed LWAs.

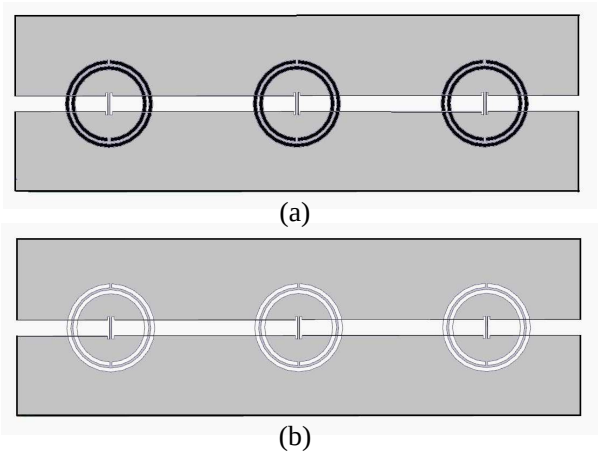

Figure 3: Layout of 3-cells LWAs. Gray and black parts are metals and the white parts are slots. (a) Layout of SRR-LWA with 3 periodic cells. (b) Layout of CSRR-LWA with 3 periodic cells.

3.1. Results of Simulation for SRR-LWA

In the designed LWA with SRRs grounded, the main beam scans from $\theta_1 = -133$ degree to $\theta_2 = -177$ degree with increasing the frequency from 2.45 GHz to 2.8 GHz. This scanning investigated in $\varphi = 0^\circ$ plane. Also the main beam scans from $\theta_3 = +156$ degree to $\theta_4 = +94$ degree with increasing the frequency from 3 GHz to 4 GHz in right handed (RH)-plane.

Figure 4 shows the scanning phenomena for right handed (RH) and left handed (LH)-planes in SRR-LWA.

3.2. Results of Simulation for CSRR-LWA

In the designed LWA with CSRRs grounded, the main beam scans from $\theta_1 = -115$ degree to $\theta_2 = -170$ degree with increasing the frequency from 5.5 GHz to 7.23 GHz. Figure 5 demonstrates that CSRR-LWA scans only negative ranges of theta in $\varphi = 0^\circ$ plane.

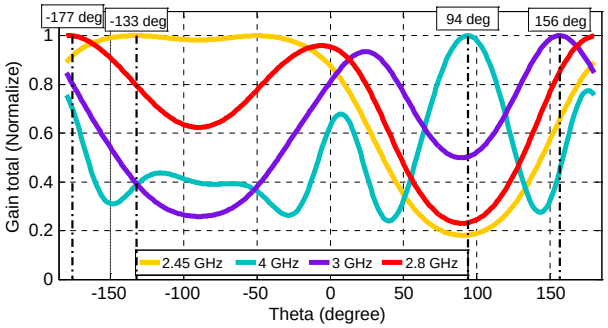

Figure 4: Radiation pattern of SRR-LWA and scanning interval.

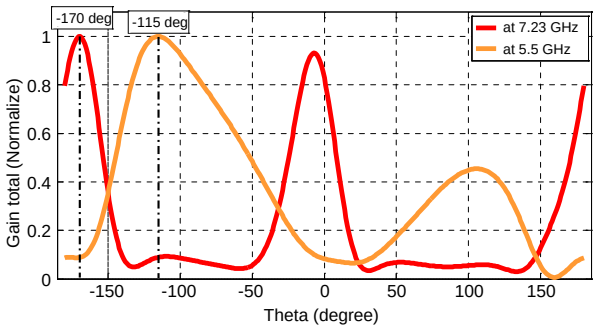

Figure 5: Radiation pattern of CSRR-LWA and scanning interval.

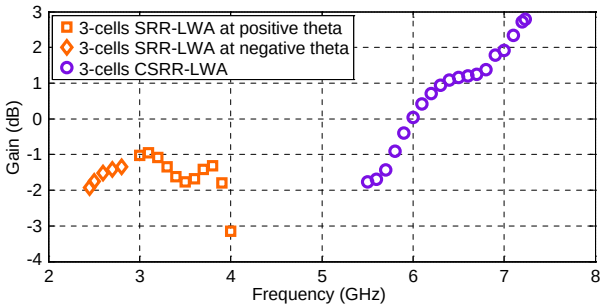

Figure 6: Details of magnitude of the gain in both proposed LWAs when frequency changes and improving the gain in CSRR-LWA.

3.3. Comparative Results

Figure 6 and simulation show that the gain of CSRR-LWA in negative ranges of theta improves and its more than the gain of the SRR-LWA.

4. CONCLUSION

This paper presented two miniaturized periodic LWAs based on CSRR and SRR. The effects of these structures on the scan angles have been compared. It has been shown that SRR-LWA scans the space from $+94°$ to $+156°$ in positive ranges and $-133°$ to $-177°$ in negative ranges of theta but the CSRR-LWA scans only from $-115°$ to $-170°$. Although CSRR-LWA scans only negative thetas, it improved the gain in the left handed plane.

REFERENCES

1. Jackson, D. R. and A. A. Oliner, *Leaky-wave Antennas in Modern Antenna Handbook,* Wiley, New York, 2008.
2. Caloz, C., D. R. Jackson, and T. Itoh, "Leaky-wave antennas," *IEEE Trans. Antennas Propag.*, Vol. 100, No. 7, 2194–2206, Jul. 2012.
3. Zamora, G., S. Zuffanelli, F. Paredes, F. J. Herraiz-Martinez, F. Martin, and J. Bonache, "Fundamental-mode leaky-wave antenna (LWA) using slotline and split-ring-resonator (SRR)-based metamaterials," *IEEE Antennas and Wireless Propag. Letts.*, Vol. 12, 1424–1427, Oct. 2013.