Broadband Circularly Polarized Rectangular Loop Antenna With Impedance Matching

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***Abstract*—A broadband circularly polarized rectangular loop antenna is developed. The broadband performance is achieved by adding a pair of parasitic loops inside the rectangular loop. Good impedance matching is obtained by introducing a broadband balun. The proposed rectangular loop has a bandwidth of 46% for axial ratio $\leq$ 2 dB and 50% for VSWR$\leq$2 with a gain of around 8 dBi.**

***Index Terms*—Broadband antenna, circular polarization (CP), impedance matching, loop antenna.**

I. Introduction

It IS well known that the most commonly used broadband planar circularly polarized (CP) radiating element is the spiral antenna [1]. However, when a spiral antenna is backed by a conducting planar reflector (i.e., a ground plane) for unidirectional radiation, its broadband performance can be significantly deteriorated. It was demonstrated in [2] that the bandwidth for an axial ratio (AR) of less than 3 dB of an Archimedean spiral antenna in the presence of a conducting reflector was less than 20%. Recently, it has been found that a rectangular loop can also serve as a CP antenna. In [3], a rectangular loop antenna with an AR ($\leq$3 dB) bandwidth of 18% and a VSWR ($\leq$2) bandwidth of 22% has been developed.

In this letter, we propose a new rectangular loop antenna whose bandwidth can be significantly enhanced by adding a pair of parasitic loops inside the original loop. The impedance matching of the proposed antenna is achieved by incorporating a broadband balun into the feeding structure.

II. Antenna Structure

The configuration of the proposed CP rectangular loop antenna is shown in Fig. 1. The antenna includes a primary rectangular $(L_1 \times W_1)$ loop, a pair of parasitic rectangular $(L_2 \times W_2)$ loops, and a feeding structure (i.e., a broadband balun). There is no direct electrical connection (i.e., only electromagnetic coupling) between the primary loop and the parasitic loops, helping improve the bandwidth of the rectangular loop antenna. To produce a CP wave, there is a small gap on each of two longer sides

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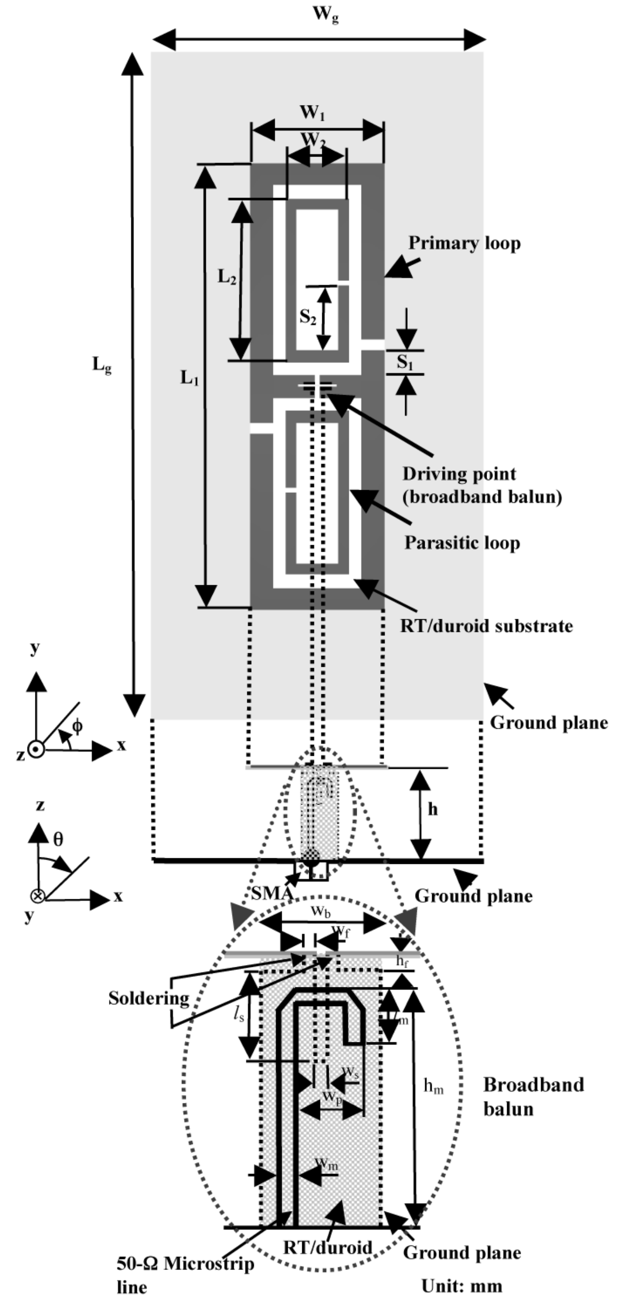

Fig. 1. Broadband circularly polarized rectangular loop antenna with impedance matching. (The strip widths of the primary loop and of the parasitic loops are 2.0 mm and 1.0 mm, respectively; the gap widths on the primary loop and on the parasitic loops are 1.0 and 0.5 mm, respectively; $L_{\rm g} = 60$ mm, $W_{\rm g} = 30$ mm, $W_{\rm b} = 6.0$ mm, $W_{\rm f} = 0.6$ mm, $W_S = 0.5$ mm, $W_{\rm m} = 0.8$ mm, $W_{\rm p} = 3.2$ mm, $h_{\rm f} = 1.0$ mm, $h_{\rm m} = 13$ mm, $l_S = 5$ mm, $l_{\rm m} = 3$ mm.)

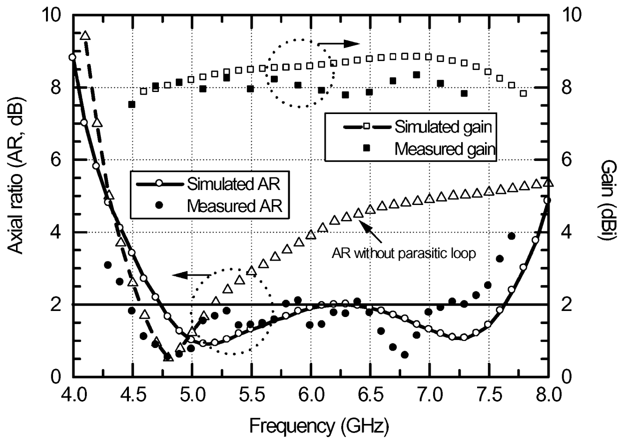

Fig. 2. Simulated and measured results for axial ratio and gain of the broadband circularly polarized rectangular loop antenna.

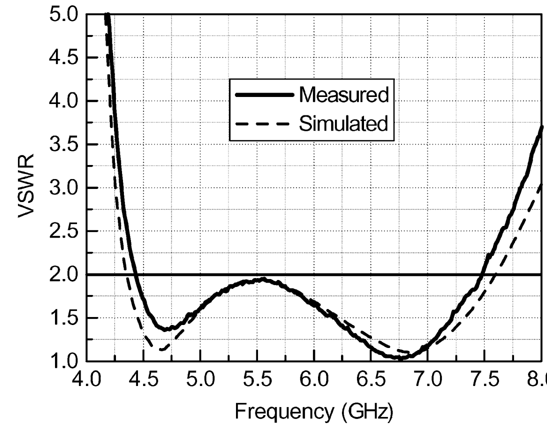

Fig. 3. VSWR of the broadband circularly polarized rectangular loop antenna with impedance matching.

of the primary loop and on each of the parasitic loops. The primary loop is driven at its center by the broadband balun, which has been widely used to excite a dipole antenna [4]. Both the primary loop (with the parasitic loops) and the broadband balun are printed on a thin dielectric substrate (substrate thickness = 0.254 mm) with a low dielectric constant (RT/duroid 5880, $\varepsilon_r = 2.2$). The broadband balun can excite the balanced mode by making use of the coupling between the microstrip line printed on one side of the substrate to the slot which is etched on the other side (which also serves as the ground plane for the microstrip line) of the substrate. A good impedance matching can be achieved by adjusting the length (l_S) of the slot, the height (h_m), and the length (l_m) of the microstrip line. The printed CP loop antenna is backed by a rectangular ($L_g \times W_g$) copper plate (i.e., a ground plane) at a height h for unidirectional radiation and fed through an SMA connector.

We designed and fabricated a broadband CP rectangular loop antenna for operating at C-band (4–8 GHz). The antenna was initially designed using a method-of-moment based software—*NEC* 1.1, and optimized by a full-wave (transmission-line matrix method based) design tool—*Microstripes* 6.5. By adjusting the loop sizes (i.e., $L_1 \times W_1$ for the primary loop and $L_2 \times W_2$ for the parasitic loops), the gap positions (i.e., S_1 and S_2), and the height h, a broadband performance for circular polarization can be achieved. By simulation, the optimized geometrical parameters for the CP rectangular loop antenna were found to be $L_1 = 40$ mm, $W_1 = 12$ mm, $L_2 = 14.6$ mm, $W_2 = 5.6$ mm, $S_1 = 5.8$ mm, $S_2 = 2.2$ mm, and $h = 16$ mm. The geometrical parameters optimized for the broadband balun are included in Fig. 1.

III. Results

Fig. 2 shows the simulated and measured results for the on-axis (in the z direction) axial ratio and gain of the broadband CP rectangular loop antenna. It is found that the bandwidth for AR$\leq$2 dB of the rectangular loop antenna is about 46%. For comparison, the axial ratio simulated for the rectangular loop antenna without the parasitic loops is also plotted in this figure, which shows a 2-dB AR bandwidth of less than 12%. Obviously, the parasitic loops play an important role for the bandwidth enhancement. The reason for this phenomenon is that the primary loop can only create one minimum AR point while the parasitic loops can produce an additional minimum AR point. An appropriate combination of the two minimum AR points results in a significant enhancement for the CP bandwidth. The gain of the antenna maintains around 8 dBi over the 2-dB AR bandwidth. The simulated and measured results for the voltage standing-wave ratio (VSWR) are presented in Fig. 3. The bandwidth for VSWR$\leq$2 is about 50%, entirely covering the AR$\leq$2 dB bandwidth. Fig. 4 shows the radiation patterns simulated and measured in the principle planes ($\phi = 0^\circ$ and $\phi = 90^\circ$ planes) at 5, 6, and 7 GHz. Good agreement is observed between the simulated and measured results. No significant change is observed for the radiation patterns over the 2-dB AR bandwidth. As expected, the beamwidth in the $\phi = 0^\circ$ plane is wider than that in the $\phi = 90^\circ$ plane because the length (L_1) of the primary rectangular loop is more than three times longer than its width (W_1).

IV. Conclusion

A new broadband CP rectangular loop antenna has been designed, fabricated, and measured for operating at C-band. By introducing a pair of parasitic loops inside the original rectangular loop, the AR bandwidth is significantly enhanced. It is demonstrated that the proposed CP rectangular loop antenna achieves a 2-dB AR bandwidth of 46% with a gain of around 8 dBi. A good impedance matching has been realized by incorporating a broadband balun into the CP loop antenna. An additional important feature of the CP loop antenna is that the sense of circular polarization may be adjusted by changing the positions of the small gaps on the loops using RF switches, such as MEMS or PIN diodes.

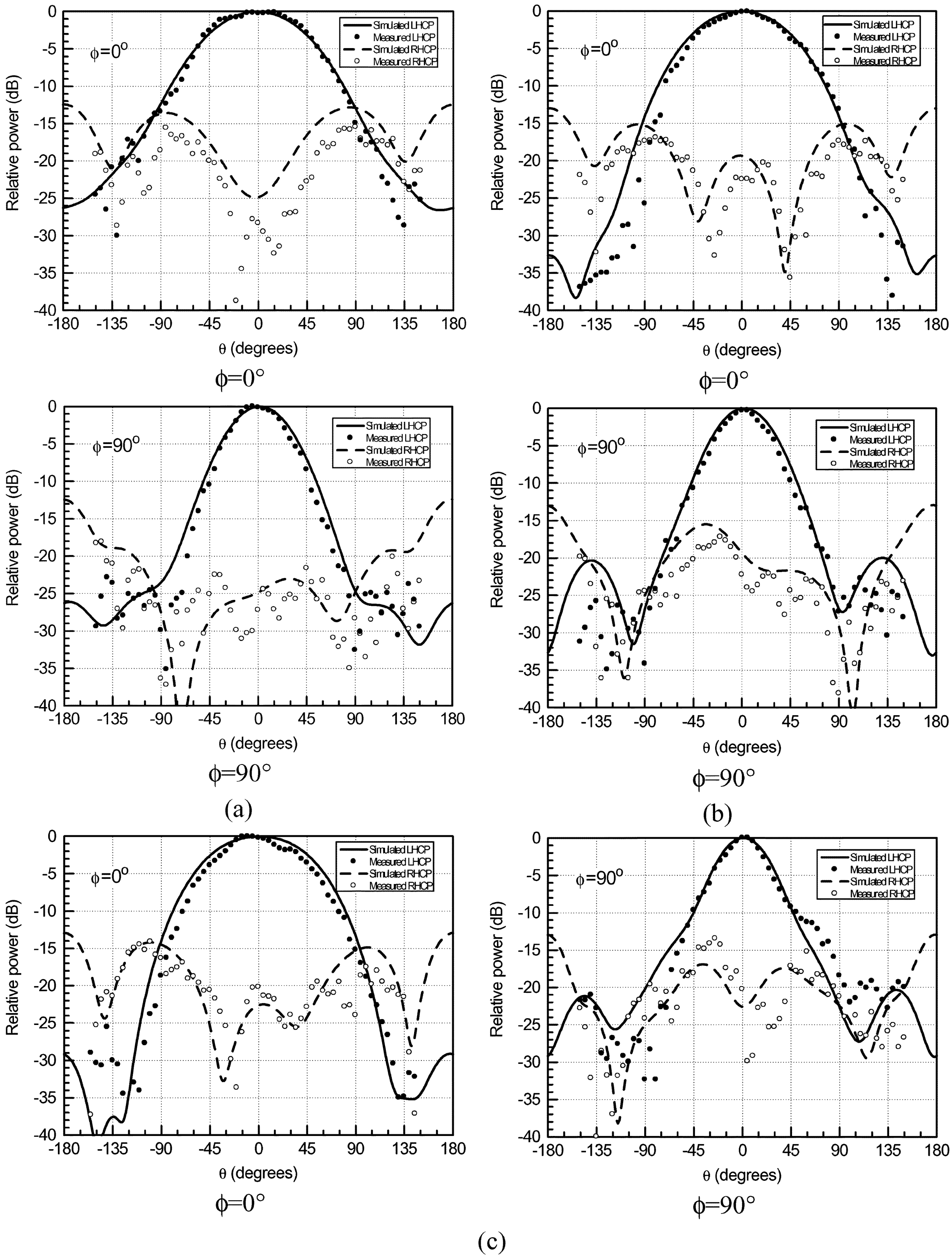

Fig. 4. Radiation patterns of the broadband circularly polarized rectangular loop antenna (LHCP= Left-hand circular polarization and RHCP= Right-hand circular polarization). (a) At 5 GHz. (b) At 6 GHz. (c) At 7 GHz.

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