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Broadband and Dual Circularly Polarized Patch Antenna with H-shaped Aperture

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***Abstract* – A dual circularly polarized (CP) patch antenna design with H-shaped aperture in S band is presented. The dual H-shaped slots are placed in orthogonal direction, and excited by the 3-dB branch-line coupler to obtain both right hand circular polarization (RHCP) and left hand circular polarization (LHCP). According to our simulation results, the proposed antenna element could achieve -10dB-level fractional impedance bandwidth around 17% without the 3-dB branch-line coupler, and around 32.6% with the 3-dB branch-line coupler for the dual circular polarizations, respectively. The antenna element broadside gain is 5.15 dB and the cross-polarization level is lower than -37 dB for dual circular polarizations. The axial ratio (AR) below 3dB is more than 180° in both phi=0° and phi=90° planes in each circular polarization state. And the AR fractional bandwidths are, respectively, 29% when the Co-polarization is RHCP, and 33% when the Co-polarization is LHCP. Moreover, the main beam of the dual circular polarizations of the proposed 1 × 8 linear phased array has a very wide scanning coverage in phi=90° plane (i. e., from -45° to 45°, when AR < 3 dB).**

***Index Terms* — Dual circularly polarized antenna, patch antenna, H-shaped aperture, circularly-polarized scanning.**

I. Introduction

With the development of satellite communication systems, low-profile antennas with excellent radiation characteristics operating in S band, have been widely investigated [1] - [2]. It is desirable in most communication systems that, one antenna not only has the dual circular-polarization (CP), low cross-polarization, high gain, and wide bandwidth (especially the fractional bandwidth higher than 30%), but also maintains its compact size and low profile. In recent years, lots of CP antenna designs have been reported [1-4]. As one of effective methods to design low-profile wideband CP antenna, aperture coupling technology is applied to expand the impedance bandwidth, while maintaining its circular polarization [2-4]. However, even this technology is superior to the design with single patch (with lower than 10% fractional bandwidth), one witnesses a certain drawbacks in the resulting designs. For example, the integration of isolation resistor into the Wilkinson power divider would decrease the radiation efficiency, leading to a certain peak gain decrease [2].

In this paper, instead of usage of Wilkinson power divider, a wideband, wide AR bandwidth, CP patch antenna, which is excited by 3-dB branch-line coupler, is demonstrated. It should be pointed that, benefitting from the advantage of 3-dB branch-line coupler characteristics, besides avoiding Ohmic dissipation of EM power from lumped isolation resistor [2], it could provide good dual circular-polarization performance. Moreover, its wide-angle scanning property is studied by constructing a 1×8 linear array. The simulated results indicate that, it could scan from -45° to 45° with a good circular polarization performance in phi = 90° plane in both RHCP and LHCP states. Hence, the proposed antenna should be very suitable candidate in satellite communication system applications.

II. Antenna Design and Performance

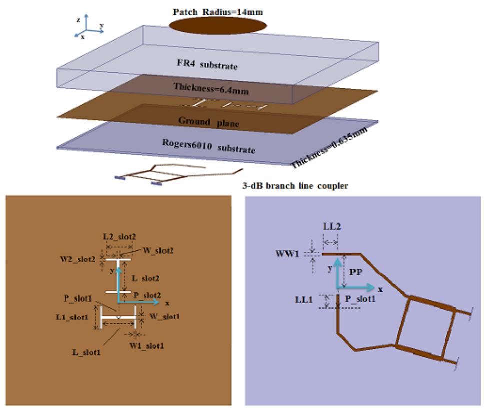

Fig. 1. Configuration of the proposed antenna

The configuration of the proposed antenna element is demonstrated in Fig. 1. Its overall size is L × W × H = 72mm ×72mm×7.67mm. The upper substrate is FR4 with thickness 6.4mm, dielectric constant □$_r$=4.4 and loss tangent tanδ=0.02. A circular shaped patch with radius 14mm is placed in the center on the top side of the FR4 board. The lower substrate is Rogers 6010 with thickness 1.27mm, dielectric constant □$_r$ =10.2 and loss tangent tanδ=0.0023. The two H-shaped slots are etched on the upper side of the lower substrate. The 3-dB branch-line coupler is etched on the lower side of the lower substrate, which offers 90° phase difference to feed the antenna. Thus, two orthogonal linearly polarized TM_{11} modes on the circular patch with 90° phase difference could be well excited, which enable the antenna to operate in excellent dual circular polarization performance. Design parameters are given below (All dimensions are in mm): L_slot1=10, W_slot1=1.01, L1_slot1=8, W1_slot1=0.8, P_slot1=10, L_slot2=10, W_slot2=1, L2_slot2=8, W2_slot2 =0.8, P_slot2=2.5, WW1=0.58, LL1=10, LL2=9.71, PP=8.5.

The simulated S-parameters of the designed antenna with and without the 3-dB branch-line coupler are compared, and the results are shown in Fig. 2. Due to the presence of 3-dB branch-line coupler, the antenna has a much wider bandwidth. The two feeding ports have the similar matching characteristic. It is shown that, without the 3-dB branch-line coupler, the impedance bandwidth is around 17% (from 2.26 to 2.68 GHz). In contrast, it is 32.6% (from 2.08 to 2.89 GHz) with the branch-line coupler. Additionally, we noted in the simulation, in order to increase the bandwidth of the antenna without the 3-dB branch-line coupler, two resonant frequency, i.e., one from H-shaped aperture and the other from the TM_{11} mode which is excited by circular patch, should be fine tuned to be overlapping.

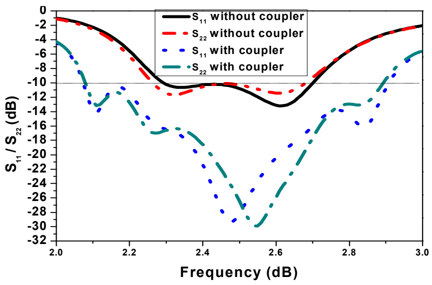

Fig. 2. S-parameters of the proposed antenna

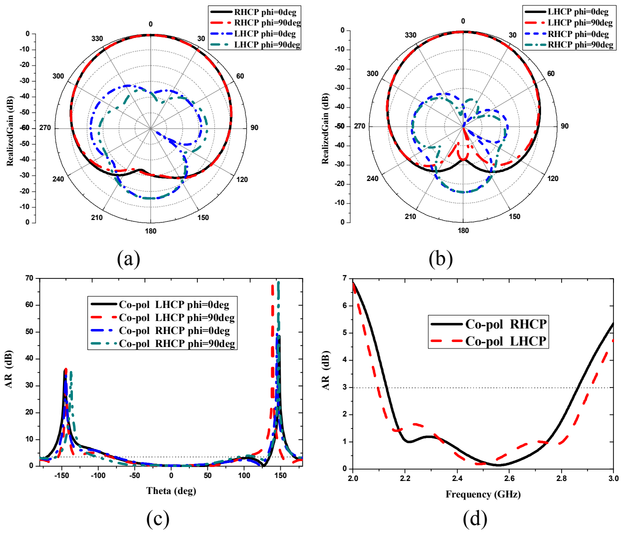

Fig. 3. HFSS simulated far-field characteristics of proposed antenna element: (a) RHCP at 2.5GHz. (b) LHCP at 2.5GHz. (c) AR for dual circular polarization (phi=0° and phi=90°). (d) AR versus frequency for dual circular polarization.

As depicted in Figs. 3 (a) and (b), the proposed antenna has the similar radiation characteristics in both phi=0° and phi=90° planes for dual circular polarizations. Typically at 2.5GHz, in the broadside direction, the gain is 5.15dB and the cross-polarization is -37dB at RHCP operation state, and the gain is 5.16dB and cross-polarization is -38dB at LHCP operation state. More than 180° angular coverage with AR < 3 dB in both phi=0° and phi=90° planes are observed at both RHCP and LHCP states, shown in Fig. 3 (c). The CP characteristics are presented in Fig. 3 (d). The AR fractional bandwidth 29% (from 2.13 to 2.86 GHz) at RHCP operation state and 33% (from 2.09 to 2.91 GHz) at LHCP operation state are achieved, respectively.

Furthermore, a 1×8 linear phased array is designed with uniform elements in Fig. 1. The Distance between the centers of two adjacent elements is $\lambda_0/2$ at 2.5 GHz. The scanning property has been inspected, shown in Fig. 4. Clearly, the array has the scaning coverage from -45° to 45° with AR<3 and lower than 3dB gain varaition in both LHCP and RHCP operation states. It is worthwhile mentioning that, when all the elements are fed with the signal sources with same magnitude and phase, 13.3dB peak gains (along +z-axis) chould be obtained in both states.

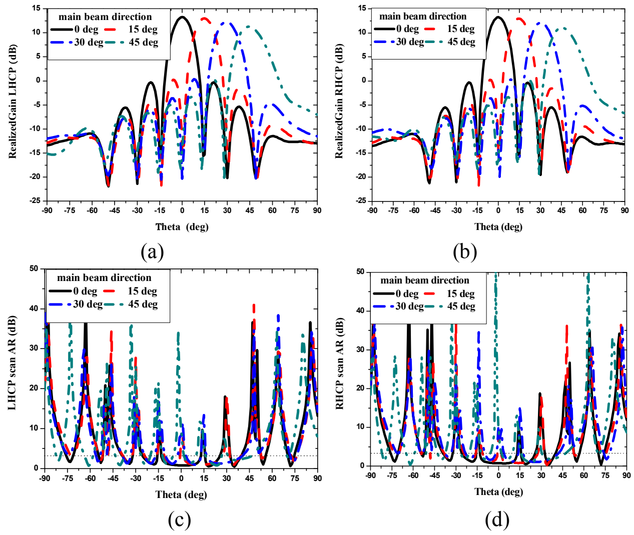

Fig. 3. HFSS simulated 1×8 array scanning characteristics: (a) LHCP main beam scan. (b) RHCP main beam scan. (c) AR for LHCP main beam scan. (d) AR for RHCP main beam scan.

III. Conclusion

A dual circular polarization microstrip antenna element with 3-dB branch-line coupler in S band is presented in this paper. The antenna element has a wide bandwidth, low cross polarization and good circular polarization performance. The 1 × 8 linear phased array constructed by the proposed antenna element is disscussed. It has a wide angular scan property, which covers from -45° to 45° in phi=90° plane on the basis of AR < 3 dB and lower than 3dB gain varaition in both LHCP and RHCP operation states.

Acknowledgment

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