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A Low-Cost L-Probe Fed Dual-Polarized Slot Antenna for C-Band Phased-Array Applications

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Abstract—A dual-polarized L-probe fed microstrip patch antenna with high isolation and low cross-polarization levels is proposed. The proposed antenna has been designed and analyzed by using commercially available software — High Frequency Structure Simulator (HFSS) based on the finite element method algorithm and a simple resonant equation and Computer Simulation Technology Microwave Studio (CST MWS) based on the finite-difference-time-domain algorithm. A prototype antenna is built and tested. The return loss has been compared between measured and simulated data under the criterion of VSWR less than 2 through out the designed 4.95 to 5.05 GHz frequency range. The measured isolation between two ports is higher than 22 dB and the gain is larger than 3 dBi. The cross-polarization levels in both E and H planes are better than -21 dB, along with fair regular radiation patterns.

1. INTRODUCTION

Phased-array antennas (PAAs) have been developed considerably due to their low antenna radar cross section, wide scan range, high directivity and quick steering without physical movement, etc. [1–3]. Dual-polarization capabilities of the antenna are necessary to enhance the channel performance, since a polarization-diversity scheme can be used to mitigate the multi-path fading, polarization mismatch between the transmitter and receiver, or furnish frequency reuse to double the capacities [4, 5].

The realization in printed technology is particularly attractive, due to its low-profile, low-weight, low-cost, easy integrability into arrays or with microwave integrated circuits, or polarization diversity [6, 7]. Microstrip patch antenna using L-probe feeding technique [8] has numerous desirable features compared to other feeding methods such as non-contacting feed transition and easy to built [9]. A 2×1 dual-polarized L-probe stacked patch antenna array is proposed in [10], the patches are excited by four L-probes under the corners of the lower patch, the structure which comprises of two identical feeding networks are used to feeding the L-probes of the $-45°$ and the $+45°$ polarization for two input ports respectively.

In this paper, a new low-cost vertically placed L-probe fed dual-polarized antenna for phased-array applications is presented. Low cost and light weight are taken into account due to the usual implementation of arrays have an extremely high number of elements [11]. Promising features in terms of high isolation between the input ports, reduced cross-polarization, scanning capability, and regular radiation patterns are obtained.

This paper is structured in the following manner. In Section 2, a description of the antenna is presented. The input return loss and the radiation parameters of the fabricated prototype are measured and compared to software simulation, as presented in Section 3 and followed by the conclusion drawn in Section 4.

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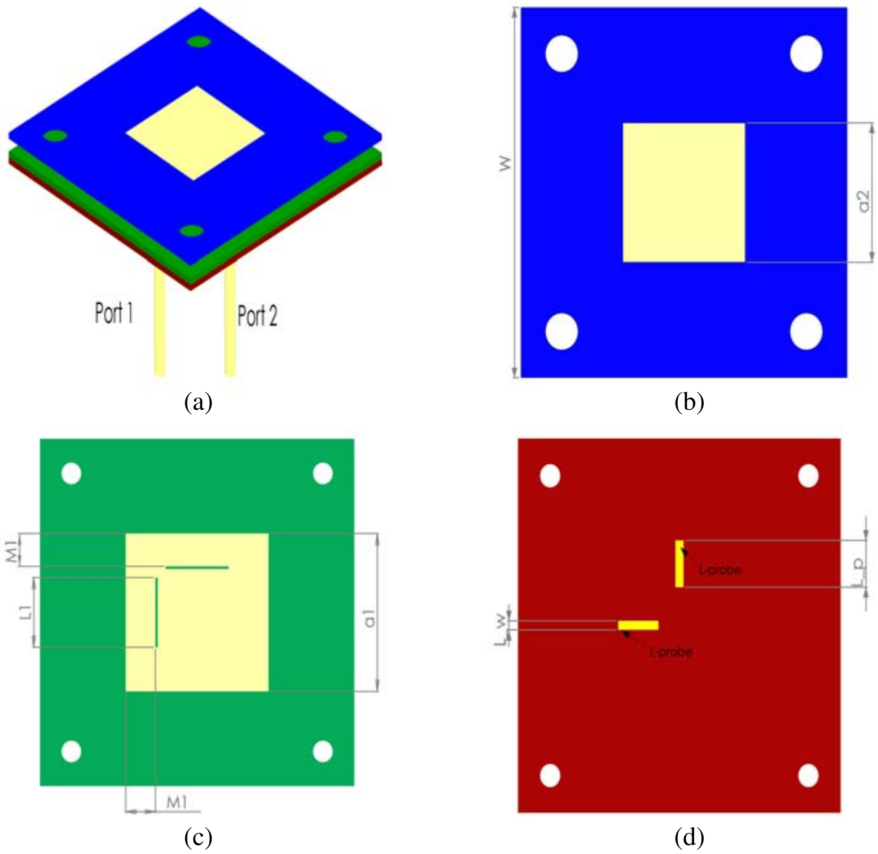

Figure 1. Detailed view of the dual polarized antenna. (a) Side view of the dual polarized antenna. (b) Geometry of the top substrate. (c) Geometry of the middle substrate. (d) Geometry of the bottom substrate.

2. ANTENNA CONFIGURATION

The basic geometry of the novel dual-polarized radiation element proposed here is shown in Fig. 1(a), which is a two-port antenna with symmetric structures at two ports. In order to simplify the antenna fabrication process, the antenna is separated into three parts as shown in Figs. 1(b)–(d) and one air layer which can be realized by using a foam substrate or air spacers. Square patches with length of $a1$ (excited patch: the patch excited by vertically placed L-probes to get orthogonal dual-polarization) and $a2$ (reflecting plane: the patch placed above the excited patch to improve the antenna performance) are printed on the center of middle and top substrates respectively. A pair of L-probes is employed on the the bottom substrate to excite the square patch in orthogonal directions. Coaxial cables penetrate the substrate from bottom to connect the L-probes by welding spot. Besides, dual slot are opened in the excited patch as shown in Fig. 1(c). To grant an inexpensive realization, 0.5 mm thickness commercially available substrate Rogers RT/duroid 5880(tm) ($\varepsilon_r = 2.2$, $\tan\delta = 0.0009$) which is commercially available has been chosen for middle and bottom substrates, and it is FR_4 ($\varepsilon_r = 4.8$, $\tan\delta = 0.016$) with the same thickness for top substrate.

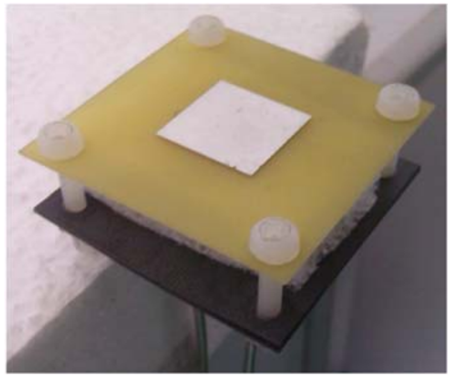

Figure 2. Photograph of proposed antenna.

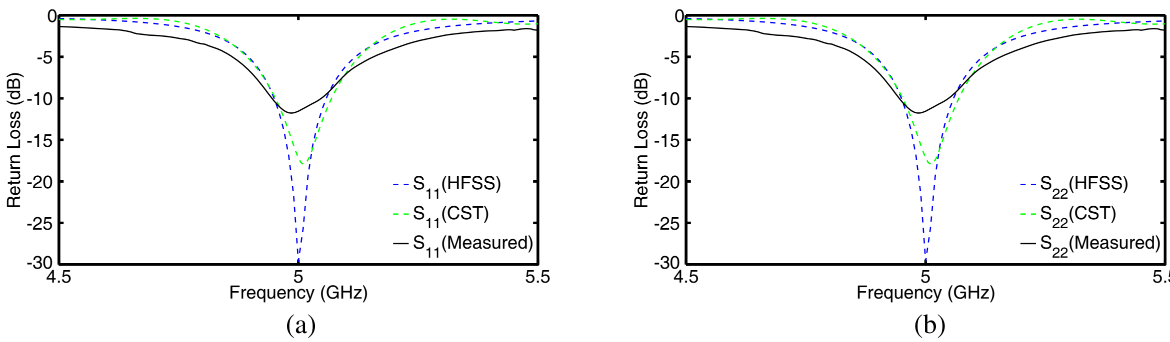

Figure 3. Simulated and measured return loss for both ports of the dual polarized antenna. (a) For port 1. (b) For port 2.

3. ANTENNA PERFORMANCE

The performance of the antenna is studied numerically and verified experimentally. The numerical results are obtained by using HFSS and CST MWS.

The dual-polarized antenna configuration finally selected has the following dimensions: $W = 40\,\text{mm}$, $a2 = 15\,\text{mm}$, $a1 = 18\,\text{mm}$, $M1 = 4\,\text{mm}$, $L1 = 8\,\text{mm}$, $L\_w = 1\,\text{mm}$, $L\_p = 5\,\text{mm}$. The height of the air layer which is realized by using a foam is 3 mm and the slot width is 0.3 mm.

The antenna discussed above has been realized, and a photograph of the antenna is shown in Fig. 2. The S parameters are measured using an Agilent E8362B vector network analyzer. The simulated and measured S parameters are shown in Figs. 3 and 4. The proposed antenna offers a impendence bandwidth form 4.95 to 5.05 GHz for 2 : 1 VSWR. Based on the simulation and measurement results (as shown in Fig. 4), the isolation between the two input ports of the dual-polarized antenna is better than 22 dB over the desired bandwidth.

The radiation characteristics of the proposed antenna in E and H principal planes for both ports are shown in Figs. 5 and 6. The proposed antenna exhibits cross-polar discrimination of better than -21 dB along the boresight direction. As expected, a broad beamwidth is observed, where in the E plane,the half power beamwidth for port 1 is 36°, and that for port 2 is 66°. For the H plane, port 1 has a 30° beamwidth, while that for port 2 is 34°. The measured gain of the proposed antenna in designed frequency band is higher than 3 dBi for both ports throughout the designed frequency.

The numerical results obtained by HFSS and CST are generally in good agreement. Differences between the measured and simulated results may be due to manufacturing inaccuracies in the feed-point implementation and the additional losses that are associated with the surface roughness of the metallic plating.

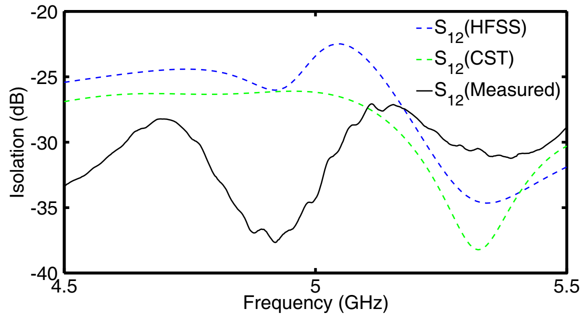

Figure 4. Simulated and measured isolation for both ports of the dual polarized antenna.

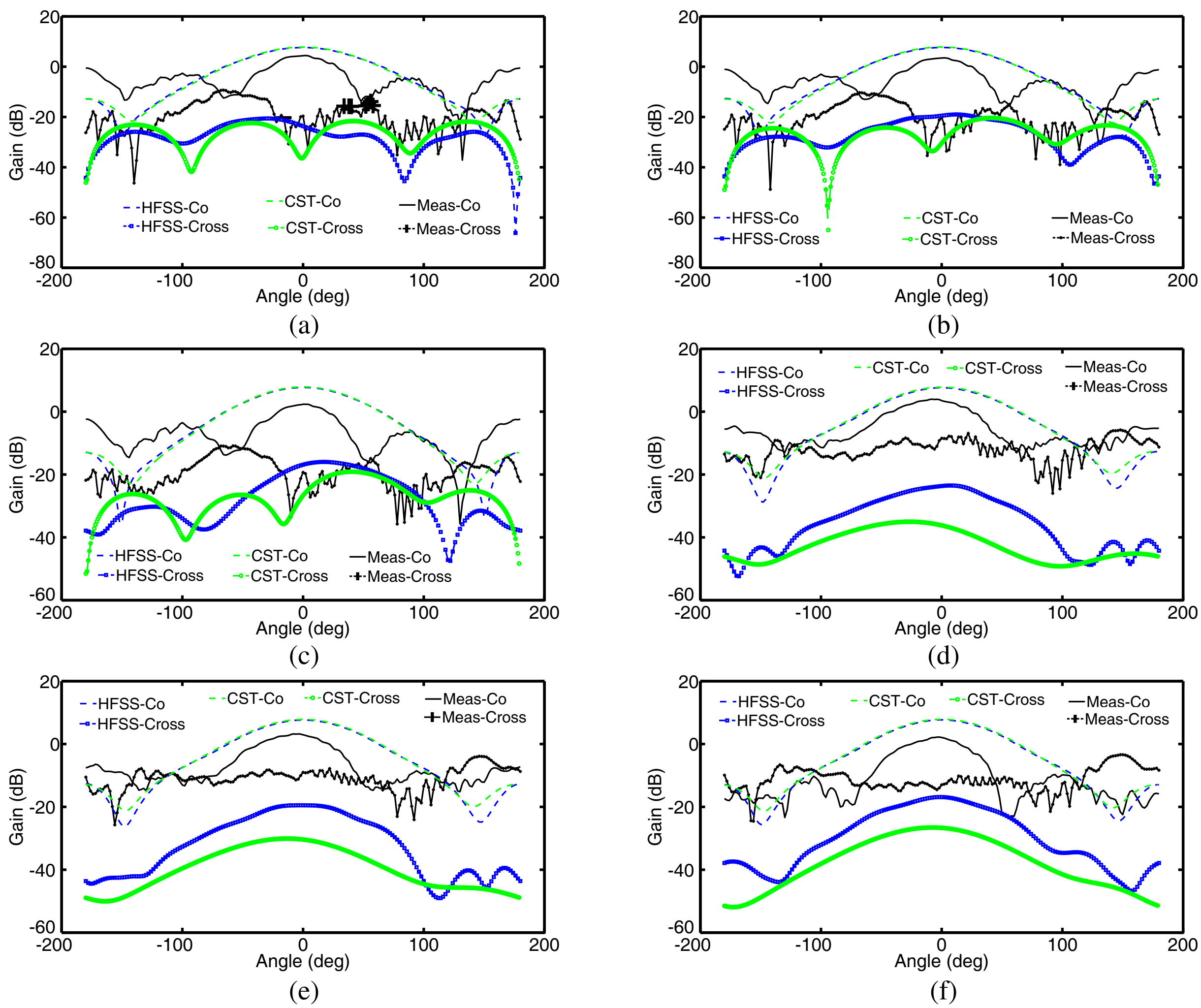

Figure 5. Simulated (blue dashed) and measured (black solid) radiation patterns for port 1. (a) E-plane at 4.95 GHz for port 1. (b) E-plane at 5 GHz for port 1. (c) E-plane at 5.05 GHz for port 1. (d) H-plane at 4.95 GHz for port 1. (e) H-plane at 5 GHz for port 1. (f) H-plane at 5.05 GHz for port 1.

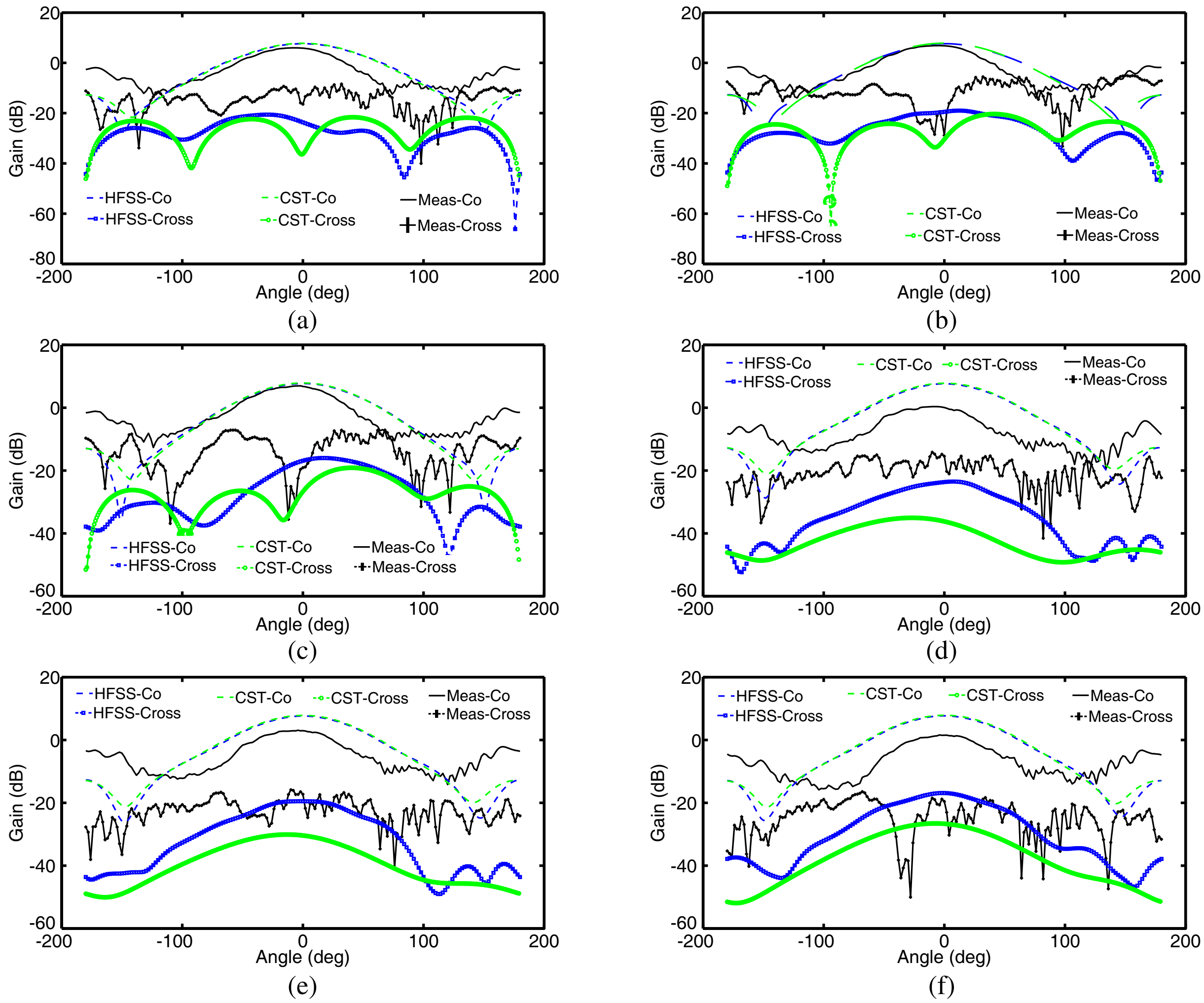

Figure 6. Simulated (blue dashed) and measured (black solid) radiation patterns for port 2. (a) E-plane at 4.95 GHz for port 2. (b) E-plane at 5 GHz for port 2. (c) E-plane at 5.05 GHz for port 2. (d) H-plane at 4.95 GHz for port 2. (e) H-plane at 5 GHz for port 2. (f) H-plane at 5.05 GHz for port 2.

4. CONCLUSIONS

A new dual-polarized radiating element for C-band phased-array applications has been proposed and fully designed. The structure based on two square stacked patches printed on a three-layer substrate with common commercial dielectrics is compact, low-profile, and can be easily arranged in large arrays. The design has been accomplished using commercially available software — HFSS. A prototype has been fabricated and tested. The proposed antenna provides an impedance bandwidth from 4.95 to 5.05 GHz. An isolation level of more than 22 dB between the two ports and better than −21 dB cross-polarization levels are achieved from the dual-feeding mechanism. Promising features in term of reduced cross-polarization, high isolation between the input ports, low-cost, scanning capability and fair regular radiation patterns make it a potential candidate for C-band phased-array applications.

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