Broadband L-probe Fed Patch Antenna Combined with Passive Loop Elements

Karlo Queiroz da Costa, Victor Dmitriev, D. C. Nascimento, and J. C. da S. Lacava

***Abstract*—A new broadband L-probe fed rectangular patch antenna electromagnetically coupled to parasitic loop elements is presented. The proposed antenna is analyzed numerically using IE3D and HFSS software. The calculated results are in a good agreement with measured data. The impedance bandwidth of a prototype manufactured using a dielectric substrate with the relative permittivity $\varepsilon_r = 2.55$ is about 15%.**

***Index Terms*—Patch antennas, compound antennas, L-probe.**

I. Introduction

Microstrip antennas have several advantages such as easy integration with impressed circuits and low cost and profile. However they have a relatively small impedance bandwidth [1]. In the case of linear antennas (Fig. 1), a known technique used to improve the impedance bandwidth is to combine orthogonal electric and magnetic dipoles [2-4]. Appling this technique, it is possible to improve significantly the antenna impedance bandwidth. This effect is based on minimizing the reactive energy stored in the near zone of the radiator.

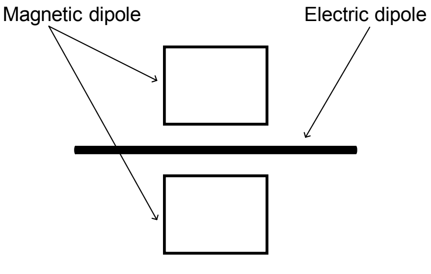

Fig. 1. Orthogonal combination of one electric dipole and two magnetic dipoles.

In this letter, a new broadband L-probe fed microstrip antenna composed by rectangular patch and two horizontal rectangular loops is analyzed (Fig. 2). The loops are placed on a plane above the patch and there are no electrical contacts between all elements of the antenna. The rectangular patch plays the role of electrical dipole and the rectangular loops can be considered approximately as magnetic dipoles in the scheme of Fig. 1. The proposed antenna is numerically analyzed using IE3D and HFSS software and one prototype was manufactured and measured. The impedance bandwidth of the proposed antenna is compared to that of the L-probe fed patch antenna with no loops.

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II. Antenna Structure

The geometry of the proposed antenna is shown in Fig. 2. This antenna is composed by one rectangular patch with dimensions L and W. The patch is printed on a substrate with thickness H. Two equal rectangular loops with dimensions L_e, W_e, W_1 and W_2 are placed parallel to the patch on the second dielectric layer with thickness d. The parasitic loops are positioned symmetrically near the edges of the patch. This allows one to provide an effective electromagnetic coupling between the patch and the loop elements [3]. The L-probe [5-6] has the length $L_v + L_h$. The horizontal segment L_h of the probe is a strip with width W_s, and the vertical segment L_v is a cylindrical conductor with radius $a = W_s / 4$. The parameter b defines the distance between the fed and the patch extremity.

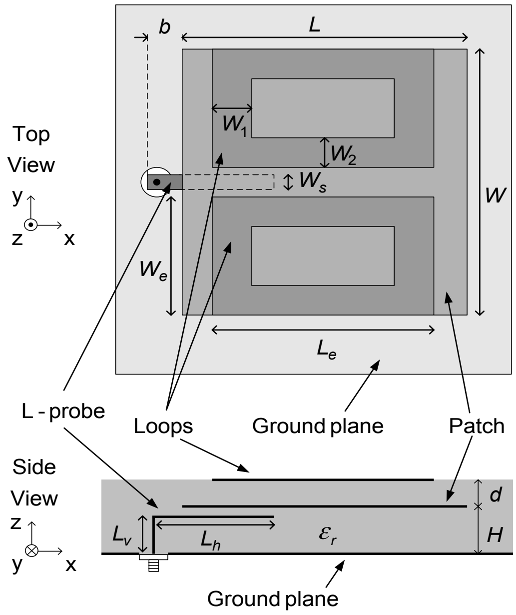

Fig. 2. Geometry for proposed L-probe fed patch antenna coupled to rectangular loops.

III. Results and Comments

The dimensions of the analyzed antenna are summarized in Table 1, and $d = 3.048$ mm and $b = 2$ mm. The geometric parameters of the loop elements are chosen in order to increase the antenna bandwidth. The relative permittivity of the dielectric layers used in calculations and in the prototype is $\varepsilon_r = 2.55$, and the loss factor of the dielectric is 0.0022. The ground plane of the antenna has the size 50×50 mm^2, and the characteristic impedance of the feeding line is 50 Ω. Fig. 3 shows the calculated and measured input impedance of the proposed antenna. One can observe in this Figure a patch's resonance around 2.85 GHz and the loop's resonance close to 3.2 GHz. In Fig. 4, the measured and calculated results of the return loss are presented. The impedance bandwidth for the return loss, considering values lower than –10 dB (frequency ranging from 2.72 to 3.17 GHz), is about 15%. The theoretical and experimental results are in a good agreement. The impedance bandwidth calculated by HFSS of the antenna with the parameters given in Table 2 and with no loops (return loss better than –28 dB at 2.82 GHz), is about 5%. These results show that the antenna with loops has the bandwidth approximately three times larger than the L-probe fed patch antenna with no loops.

Radiation patterns calculated at 3 GHz are shown in Fig. 5. In the simulations using the HFSS software the dielectric layers and the antenna ground plane were considered finite (50×50 mm^2). On the other hand, using the IE3D, only the ground plane was set to be finite. This fact introduced a null in the IE3D simulation for the radiation pattern in the plane *x–y* and a different behavior for the co-polarized radiation in the antenna backside region. The

TABLE I
Dimensions (in millimeters) of the proposed antenna

L	W	H	L_e	W_e	W_1	W_2	L_v	L_h	W_s
26	30	3.81	25	14	4.5	3.5	3.048	10	2.4

TABLE II
Dimensions (in millimeters) of the antenna with no loops

L	W	H	L_v	L_h	W_s	b
26	30	3.81	3.048	5.7	2.4	2

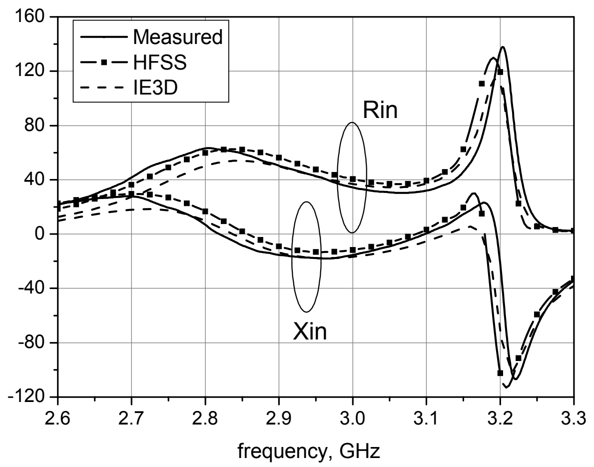

Fig. 3. Calculated and measured input impedance for proposed antenna.

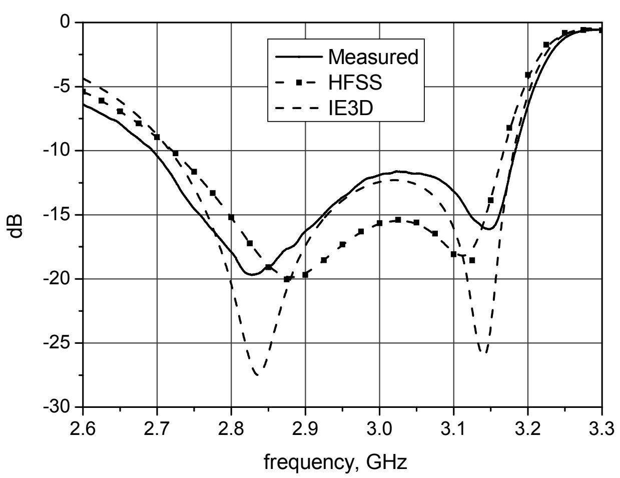

Fig. 4. Calculated and measured return loss for proposed antenna.

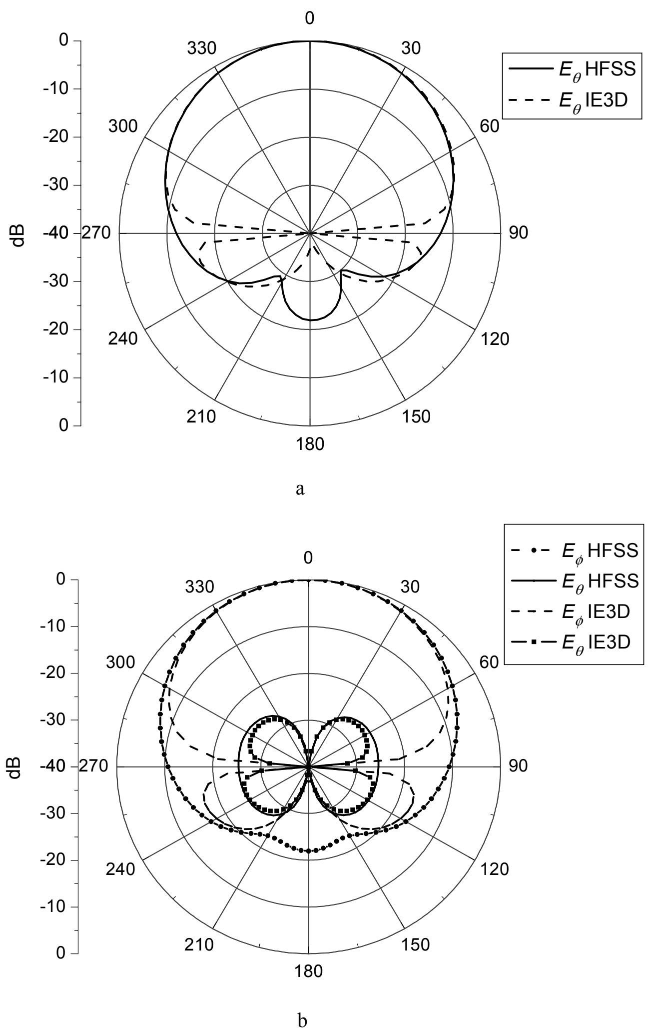

Fig. 5. Calculated radiation pattern at frequency 3 GHz.
(a) *x–z* plane; (b) *y–z* plane.

radiation pattern in the plane x–z (Fig. 5a) is slightly asymmetric due to the asymmetric position of the feeding line. The pattern in the plane y–z is symmetric because of the symmetry of the antenna with respect to this plane. The L-probe fed excites at 3 GHz just one mode of the rectangular patch, causing a linear polarization in both planes in Fig. 5. The level of cross-polarization (E_θ in Fig. 5b) in the plane y–z for the proposed antenna is better than –25 dB.

The antenna gain computed in the z-direction is presented in Fig. 6. The results show that this important parameter is relatively flat along the antenna bandwidth.

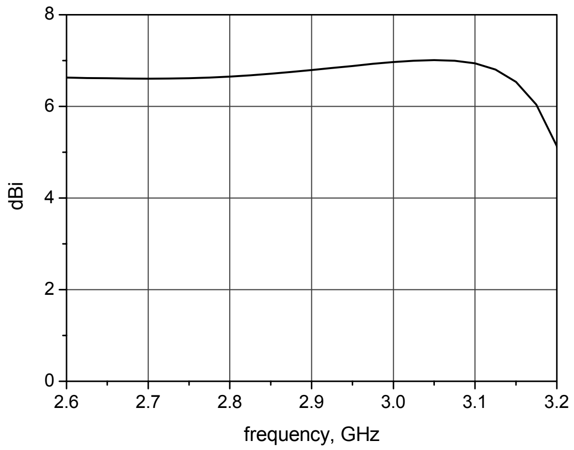

Fig. 6. Antenna gain computed in the z-direction.

IV. Conclusions

A broadband L-probe fed rectangular patch antenna with two parasitic loop elements was proposed. Although this antenna requires a slightly thicker substrate, it has the impedance bandwidth three times larger than the antenna with the same geometric parameters but without loops. Due to symmetric position of the loop elements, this combined antenna presents linear polarization at the center frequency of the matching band just as the conventional rectangular microstrip antenna.

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