A Dual-Band Rectangular Patch Antenna With Two Pairs of Parallel Slits

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1. Introduction

Nowadays many efforts in the field of dual-band microstrip antennas have been carried out, mainly to improve bandwidth, which is normally small for probe-fed single-layer microstrip antennas [1]. Regarding this matter, this paper presents a novel type of microstrip antenna with two pairs of parallel slits properly designed to achieve dual-band operation. Effects of the slit geometry variations on the antenna parameters are analyzed. The guideline for the design optimization will be discussed during the oral presentation.

2. Dual-Band Antenna Analysis

One of the common methods of feeding a microstrip antenna is by means of a coaxial probe. When such a method is used to drive a diagonal-fed nearly square patch antenna both TM_{01} and TM_{10} modes are excited, and a circularly polarized radiation can be produced [2]. In this case, the antenna presents a narrow bandwidth. On the other hand, moving the feed point location, dual-band operation can be obtained but the linear polarization of the first mode is orthogonal to the polarization of the second one. Recently, it has been shown that wide-band operation can be achieved by using two parallel slits properly designed on a microstrip rectangular patch (*E-shaped* antenna) with thick air or foam substrates [3,4]. However, when miniaturization by increasing the substrate permittivity was applied to an *E-shaped* antenna, it was found that it is not simple to achieve dual-band operation with two close modes and the antenna input impedance is predominantly capacitive as will be shown. To overcome this problem, two new slits (F_2) were introduced at the opposite side of the patch, as shown in Fig. 1. The purpose of these two new slits is to improve the design flexibility increasing the number of design parameters, changing the current pattern on the patch, and making the antenna more inductive. Numerical analyses were performed using the IE3D™ and the ESEMBLE™ 8.0 simulators. The calculations were performed for the *Arlon CuClad 250GX* substrate: $\varepsilon_r = 2.55 \pm 0.04$, $tg\delta = 0.0022$ and h = 6.35 mm (substrate thickness). Firstly, using the ESEMBLE™ simulator, an antenna with infinite ground plane was designed for dual-band operation: 1725 and 1825 MHz. After that, under the finite ground plane condition, the antenna parameters were optimized utilizing the IE3D™ software. The final antenna dimensions are: a = 26.4 mm, b = 4.8 mm, c = 5.85 mm, L = 56.6 mm, W = 50.6 mm, W_1 = 5.8 mm, L_1 = 21.5 mm, W_2 = 10.8 mm, L_2 = 23.9 mm and ground-plane size = 66 mm x 60 mm, where W_1 and L_1 are the width and the length of slits F_1 and W_2 and

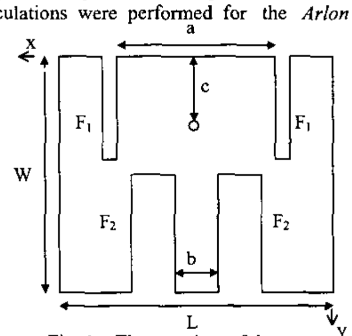

Fig. 1 – The top view of the new proposed patch.

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L_2 are the same for slits F_2. For the optimized structure, the VSWR response is illustrated in Fig. 2, where it can be clearly observed the dual-band operation and the effect of the substrate tolerance. Radiation patterns for the E_θ and E_ϕ components, plotted in the E-plane, are shown in Fig. 3. The antenna is linearly polarized in y-z plane for the entire analyzed frequency range, as we can see through Fig. 3. In addition, the front-to-back ratio is 10 dB at maximum despite of the small ground-plane size. At the lower frequency the level of the surface currents that flow parallel to x-z plane is greater than that for the upper frequency. For this reason the cross-polarization level is of about -20 dB at 1.725 GHz and -25 dB at 1.825 GHz. The patch surface current distributions were also studied. Fig. 4 shows the simulated results for the lower and the upper operation frequencies. In this case, we can see a similar behavior for the surface current distribution excited on the antenna patch.

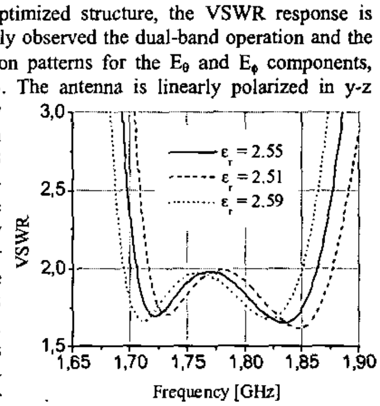

Fig. 2 – VSWR response.

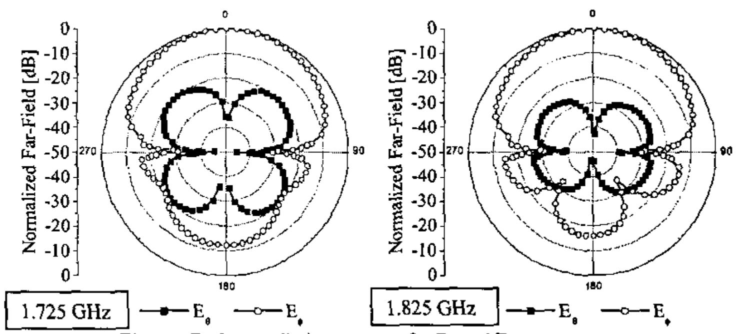

Fig. 3 – E-plane radiation patterns for E_θ and E_ϕ components.

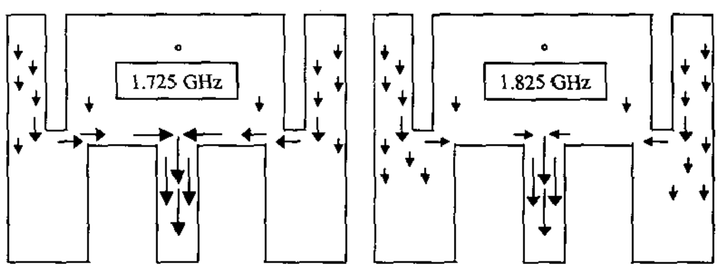

Fig. 4 – Simulated surface current distributions on the antenna patch.

The calculated gain G_o for the proposed antenna over the 1.7 GHz to 1.85 GHz frequency range is shown in Fig. 5. A comparison between the input impedance of the new antenna and the *E-shaped* one when both are operating under the same conditions (frequency range: 1.65 to 1.9 GHz) is presented in Fig. 6. In spite of the optimization done for the *E-shaped* antenna, it is clear that the rectangular patch antenna with two pairs of parallel slits had better performance than the former one for the analyzed frequency range.

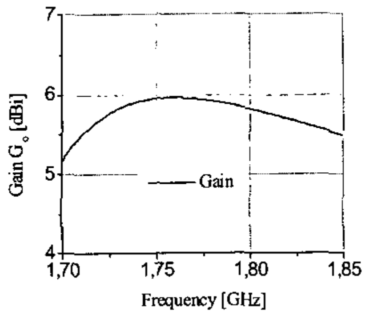

Fig. 5 – Gain G_o.

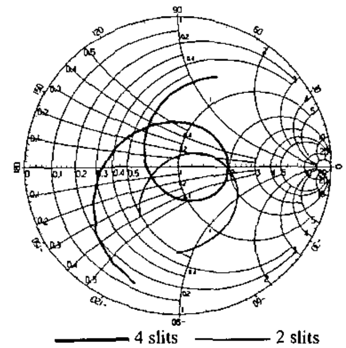

Fig. 6 – Input impedance of *E-shaped* and four parallel slit antennas.

3. Effects of the slit geometry variations on the antenna input impedance

It is quite difficult to properly model the quantitative effects on the antenna characteristics caused by changes in the slit geometry. So, utilizing the ENSEMBLE™ software, several slit geometry combinations were analyzed. For brevity, only two representative results for variations in the F_2 slit parameters are discussed in this paper. Both analyses were performed from 1.65 to 1.9 GHz. Fig. 7 shows the antenna input impedance behavior when the distance between the F_2 slits (b parameter) varies from 2.8 mm to 10.8 mm with steps of 2 mm, except for the last simulation (step of 4 mm). In this case it is possible to observe that the antenna response is quite sensitive to this parameter

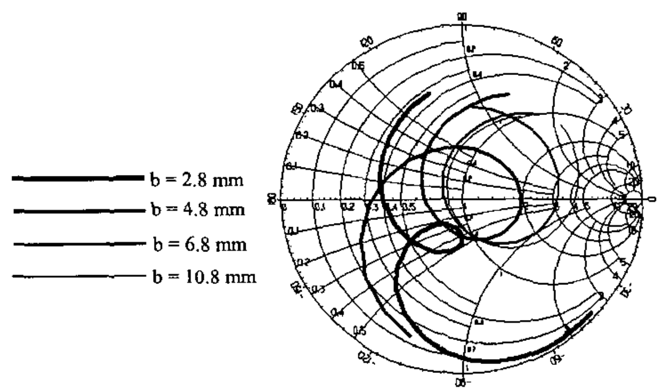

Fig. 7 – Antenna input impedance against b parameter variations.

variations, where just 1 mm can easily make great changes in the antenna input impedance. Results for L_2 parameter variations, from 22.8 mm to 25.8 mm, are presented in Fig. 8. Also in this case, the antenna input impedance presents great sensitivity to L_2 parameter. Combining these results with those for F_1 slits it is possible to adjust the optimized configuration to obtain the widest bandwidth as well as the best impedance matching within a specified VSWR criterion.

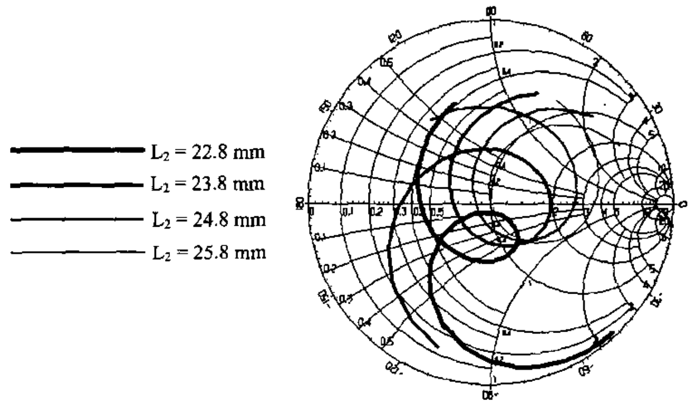

Fig. 8 – Antenna input impedance against L_2 parameter variations.

5. Conclusions

A microstrip antenna with a new configuration of parallel slits was presented and its main characteristics were analyzed. Effects on the antenna input impedance produced by changes in the slit geometry were presented. The addition of the two new slits improved the design flexibility increasing the number of design parameters, changing the current pattern on the patch, and making the antenna more inductive. This new structure is potentially useful for mobile communications.

Acknowledgment: This work was sponsored by Motorola's PCT-M Program under the coordination of Eldorado Research Institute.

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