Communications

Broadband Dual Polarization Patch Element for Cellular-Phone Base Stations

Yong-Xin Guo, Kwai-Man Luk, and Kai-Fong Lee

***Abstract*—A broadband dual polarization patch antenna double fed by an L-shaped probe and a near-resonant aperture is presented. The proposed antenna achieves a 1.5:1 standing wave ratio bandwidth of $>20\%$ at the two ports. Input isolation exceeding 25 dB has been obtained in the wide bandwidth. Thus, it can potentially be used as a base station antenna for cellular-phone networks.**

***Index Terms*—Broadband operation, dual polarization, microstrip antennas.**

I. Introduction

MICROSTRIP antennas have become the favorite choice of antenna designers because they offer the attractive features of low profile, light weight, and compatibility with integrated circuit technology. During the last few years, the capacity issue for wireless communication applications is not easily solved with the expansion in mobile communication systems and the number of people using their services. Many studies have been made to improve the bandwidth of microstrip antennas. However, the improvement of the bandwidth is not sufficient to satisfy the increasing requirements and actually only a limited bandwidth is available for commercial communications. In order to fulfill these increasing demands on capacity, designers have to employ frequency reuse involving the use of two orthogonal polarization components to solve their problems. Furthermore, in order to reduce the installation and investment costs, the $\pm 45^\circ$ dual-polarized antennas have been used in cellular-phone base stations. For dual polarization radiation, a square patch is coupled to a pair of microstrip lines through either two separated offset orthogonal slots [1], or two centered crossed slots to match the antenna [2]. For the offset orthogonal slots form [1], investigation of patches excited in this manner revealed that input port decoupling was of the order of -18 dB, which cannot meet most wireless communication requirement, -25 dB. For the centered cross-slot case [2], although it has good isolation characteristics, it is difficult to expand it into a large array antenna because an air bridge is necessary to avoid intersection between the feed lines. Then several papers have been published successively to improve the dual-polarized antenna [3]–[5]. The use of bars or grids etched on the patch directing the surface currents improved input-port decoupling and polarized purity [3]. With proper choice of the feed line and aperture geometry, the decoupling and radiation characteristics are improved in [4], [5]. Their broadband operation in [3], [4] were obtained using aperture-coupled stacked patch antenna, with a nonresonating slot as in [6].

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In this paper, we demonstrate a new feed mechanism for broadband dual-polarization operation with high-input isolation. The key point in this design is that, at one-input port, we use our recently proposed L-probe feed [7], [8] to replace the regular microstripline-slot-coupled feed. A single-layer patch fed by the L-shaped probe and a near-resonant aperture as in [9], [10] is in wideband operation. The proposed antenna achieves a 1.5:1 standing wave ratio (SWR) bandwidth of $>20\%$ at the two ports. Input isolation exceeding 25 dB has been obtained in the wide bandwidth. The design is simple in structure and easy for fabrication in comparison with other techniques based on crossed slots [2], [5]. Thus, it can potentially be used as a base station antenna for cellular-phone networks.

II. Description of Antenna

The geometry of the antenna is shown Fig. 1. The square patch, separated from the ground plane by a thick foam substrate, is double fed by two perpendicular striplines etched on the feed layer, one through a small circular hole and the other through a near-resonant aperture formed in the upper ground plane. These two lines have characteristic impedance $Z_c = 50\ \Omega$. At port 1, an L-shaped probe is connected at the end of the line via the small circular hole to cancel the inductance introduced by the thick substrate. At port 2, a short open-ended stub is needed to tune out the large inductive reactance delivered to the feedline by the aperture. To reduce the back radiation the antenna has a stripline structure. A finite-difference time-domain (FDTD) code developed in house [8] is used to design the double-fed antennas presented here. For the L-probe feed case, a tight loop around the center of the Smith chart is observed with a thicker substrate. However, for the aperture-feed case, a tight loop appears with a thinner substrate. In the design process, tradeoffs include the substrate height, L-probe parameters, hole and aperture size, and stub length.

III. Measured Results

Fig. 2 shows the measured SWR and input-port isolation of the antenna. It is observed that, for $\mathrm{SWR} \leq 1.5$, the frequency range is 1.68–2.06 GHz, or $\mathrm{BW} = 20.5\%$ for port 1 and 1.59–2.03 GHz, $\mathrm{BW} = 24.9\%$ for port 2, respectively. Over the bandwidth, input-port isolation is below -25 dB. The radiation patterns at 1.8 GHz for the two ports are shown in Figs. 3 and 4, respectively. The 3-dB beamwidths for the L-probe feed case are 70° and 71° in the E- and H-planes, respectively. The corresponding values for the aperture-feed case are 60° and 72°, respectively. The measured gain at each of the two ports is >6.0 dBi over the bandwidth. It can be observed that the level of back radiation is high, which is due to a relatively small-ground plane used in the measurement and can be reduced through the use of a larger-ground plane. Furthermore, the techniques in [11], [12] are also efficient ways to reduce back radiation. The stripline feed structure can reduce considerably back radiation. On the other hand, back radiation from the aperture is trapped between the upper- and lower-metallic planes, resulting in the appearance of higher modes, which enhances the cross-polarization components. It is seen in Figs. 3 and 4 that the cross-polarization is quite high. The cross-polarization and efficiency can be improved with the use of shorting pins between the two-ground planes as [13]. The high cross-polarization can also be overcome in array design using balanced feed mechanism [14].

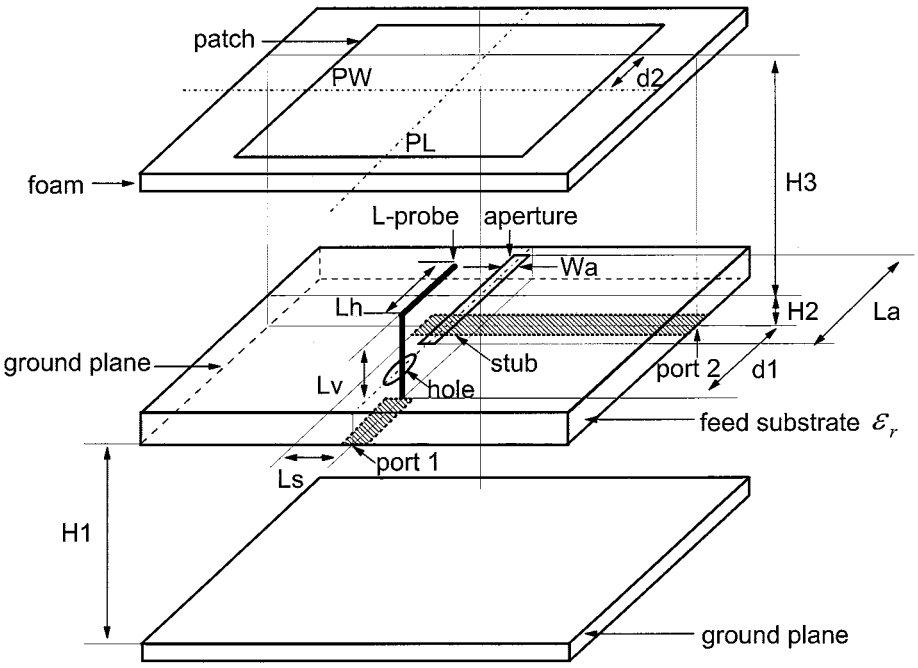

Fig. 1. Geometry of antenna. Dimensions: $H1 = 10$ mm, Lh $= 34$ mm, Lv $= 12$ mm, La $= 48$ mm, Wa $= 1$ mm, Ls $= 10$ mm, $d1 = 30$ mm, $H2 = 1.6$ mm, $H3 = 18$ mm, PL $=$ PW $= 59.5$ mm, $d2 = 8$ mm.

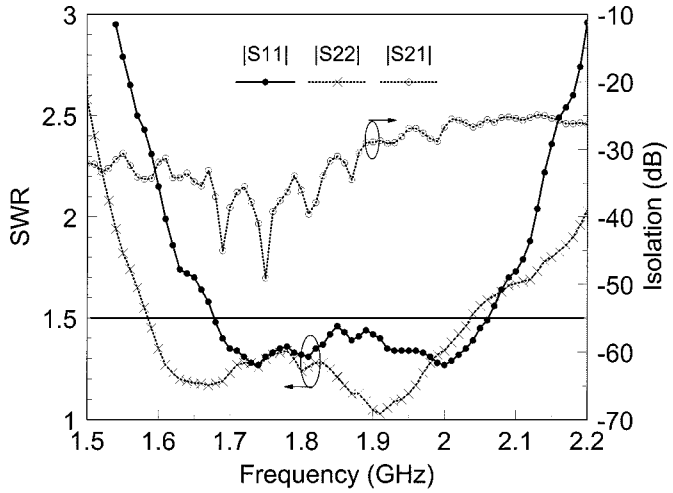

Fig. 2. Measured reflection and coupling coefficients.

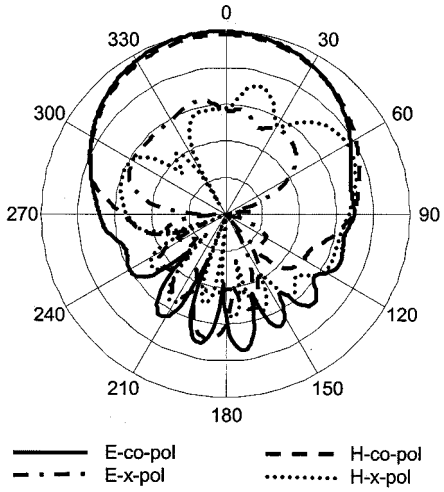

Fig. 3. Measured patterns for port 1 at 1.8 GHz, 10 dB/div.

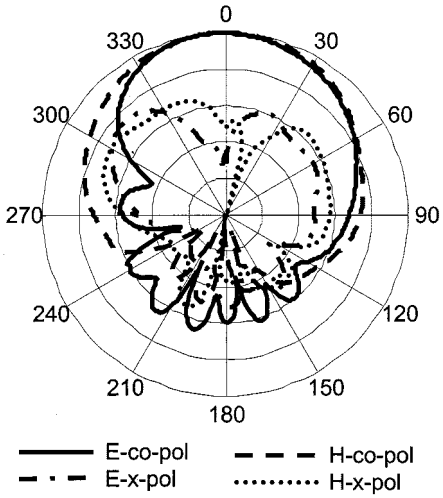

Fig. 4. Measured patterns for port 2 at 1.8 GHz, 10 dB/div.

IV. Conclusion

A thick foam substrate patch antenna double fed by an L-shaped probe and a near-resonant aperture is presented to achieve broadband dual polarization operation. The resulting antenna appears to have a wide bandwidth, high-input isolation, and simple in structure. This antenna can be used in the base stations of dual-polarization telecommunication systems.

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References

[1] A. Adrian and D. H. Schaubert, "Dual aperture-coupled microstrip antenna for dual or circular polarization," *Electron. Lett.*, vol. 23, pp. 1226–1228, Nov. 1987.

[2] C. H. Tsao, Y. M. Hwang, F. Kilburg, and F. Dietrich, "Aperture-coupled patch antennas with wide-bandwidth and dual-polrization capabilities," in *Proc. IEEE Antennas Propagat. Symp. Dig.*, Syracuse, New York, June 1988, pp. 936–939.

[3] L. Habib, G. Kossiavas, and A. Papiernik, "Cross-shaped patch with etched bars for dual polarization," *Electron. Lett.*, vol. 29, no. 10, pp. 916–918, May 1993.

[4] M. Edimo, A. Sharaiha, and C. Terret, "Optimized feeding of dual polarized broadband aperture-coupled printed antenna," *Electron. Lett.*, vol. 28, no. 19, pp. 1785–1787, Sept. 1992.

[5] M. Yamazaki, E. T. Rahardjo, and M. Haneishi, "Construction of a slot-coupled planar antenna for dual polarization," *Electron. Lett.*, vol. 30, no. 22, pp. 1814–1815, Oct. 1994.

[6] F. Croq and D. M. Pozar, "Millimeter wave design of wide-band aperture-coupled stacked microstrip antennas," *IEEE Trans. Antennas Propogat.*, vol. 39, pp. 1770–1776, Dec. 1991.

[7] K. M. Luk, Y. X. Guo, K. F. Lee, and Y. L. Chow, "L-probe proximity fed U-slot patch antenna," *Electron. Lett.*, vol. 34, no. 19, pp. 1806–1807, Sept. 1998.

[8] Y. X. Guo, C. L. Mak, K. M. Luk, and K. F. Lee, "Analysis and design of L-probe proximity fed patch antenna," *IEEE Trans. Antennas Propagat.*, vol. 49, pp. 145–149, Feb. 2001.

[9] F. Croq and A. Papiernik, "Wide-band aperture coupled microstrip antenna," *Electron. Lett.*, vol. 26, pp. 1293–1294, Aug. 1990.

[10] S. D. Targonski, R. B. Waterhouse, and D. M. Pozar, "Design of wide-band aperture-stacked patch microstrip antennas," *IEEE Trans. Antennas Propogat.*, vol. 46, pp. 1245–1251, Sept. 1998.

[11] ——, "Wideband aperture coupled microstrip patch array with backlobe reduction," *Electron. Lett.*, vol. 33, no. 24, pp. 2005–2006, Nov. 1997.

[12] D. Sievenpiper, L. Zhang, R. F. J. Broas, N. G. Alexopolous, and E. Yablonovitch, "High-impedance electromagnetic surfaces with a forbidden frequency band," *IEEE Trans. Microwave Theory Tech.*, vol. 47, pp. 2059–2074, Nov. 1999.

[13] P. Brachat and J. M. Baracco, "Dual-polarization slot-coupled printed antennas fed by stripline," *IEEE Trans. Antennas Propogat.*, vol. 43, pp. 738–742, July 1995.

[14] K. Levis, A. Ittipiboon, and A. Petosa, "Probe radiation cancellation in wideband probe-fed microstrip arrays," *Electron. Lett.*, vol. 36, no. 7, pp. 606–607, Mar. 2000.

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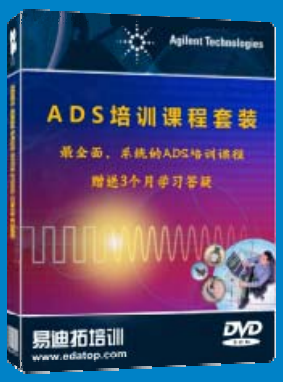

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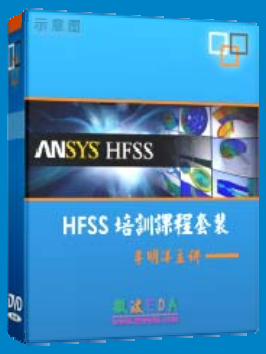

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