法政大学学術機関リポジトリ
HOSEI UNIVERSITY REPOSITORY

PDF issue: 2025-12-04

Circularly polarized open-loop antenna

LI, Rong-Lin / NAKANO, Hisamatsu / FUSCO, Vincent F.

(出版者 / Publisher)
IEEE
(雑誌名 / Journal or Publication Title)
IEEE Transactions on Antennas and Propagation / IEEE Transactions on Antennas and Propagation
(号 / Number)
9
(開始ページ / Start Page)
2475
(終了ページ / End Page)
2477
(発行年 / Year)
2003-09

The H-cross polarization levels for the ordinary shorted patch antenna shown in Fig. 3(b) are extremely high. This is common for shorted patch antennas and is a result of the discontinuity on the patch conductor associated with the shorting posts [1]. Given the major source of cross-polarization is the probe feed and shorting posts, their radiation characteristics will be similar to a monopole radiation pattern, which typically has a maximum at about 75° from the normal. Since the PBG structure is two-dimensional and is able to suppress surfaces waves close to 90° from the normal, it is postulated that the radiation generated by the probe and shorting pins is also being suppressed by the PBG, hence significantly lowering the H-plane cross-polarization level.

IV. Conclusion

A shorted microsrip patch with a PBG ground plane has been designed and tested, and the results compared to a shorted patch of identical dimensions on a conventional ground plane. The use of a PBG significantly improves the gain and reduces the cross-polarization levels for a shorted patch antenna.

References

[1] R. B. Waterhouse, S. D. Targonski, and D. M. Kokotoff, "Design and performance of small printed antennas," *IEEE Trans. Antennas Propagat.*, vol. 46, pp. 1629–1633, Nov. 1998.

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

[3] R. Coccoli, F. Yang, K. Ma, and T. Itoh, "Aperture-coupled patch antenna on UC-PBG substrate," *IEEE Trans. Microwave Theory Tech.*, vol. 47, pp. 2123–2130, Nov. 1999.

Circularly Polarized Open-Loop Antenna

Rong-Lin Li, Vincent F. Fusco, and H. Nakano

***Abstract*—A printed circular open-loop antenna is introduced as a simple structure for producing circular polarization, the antenna is fed with a coaxial probe. By introducing a gap within the circular loop a traveling-wave current is excited and thus circularly polarized radiation can be achieved. An optimized circularly polarized antenna is designed through numerical analysis using a so-called parametric method of moment technique. Experimental verification of the new antenna is presented. The antenna has a 3-dB axial ratio bandwidth of 12% with an input VSWR of less than 2.**

***Index Terms*—Circular polarization, method of moments, printed loop antenna.**

I. Introduction

It is well known that a large circular closed-loop antenna (the circumference of the loop is of the order of one wavelength) serves as a standing-wave resonant antenna and radiates a linearly polarized wave [1]. When the closed-loop antenna is printed on a grounded dielectric substrate no obvious change occurs for the polarization characteristics [2], [3]. Recently it was shown theoretically [4] that by introducing a gap with a certain width at the printed loop and feeding the antenna with a coaxial probe a traveling-wave current distribution on the loop could be excited, and as a result, circular polarization (CP) may be achieved. No experimental verification, however, was given in [4].

In this paper, we will present for the first time a comprehensive description of the numerical and experimental results for a validation demonstrator at 1.4 GHz for this class of circularly polarized printed circular open-loop antenna. It will be shown that the antenna has a wide bandwidth over which good CP properties and desirable input impedance performance can be maintained.

Manuscript received December 13, 2000; revised February 5, 2002. This work was supported in part by the U.K. Engineering and Physical Research Council under Grant GR/M8865 and in part by the Hosei International Fund (HIF, Japan).

R.-L. Li and V. F. Fusco are with the School of Electrical and Electronic Engineering, Queens University Belfast, Belfast, BT9 5AH, N. Ireland, U.K. (e-mail: V.Fusco@ee.qub.ac.uk).

H. Nakano is with the College of Engineering, Hosei University, Koganei City, Tokyo 184, Japan.

Digital Object Identifier 10.1109/TAP.2003.809845

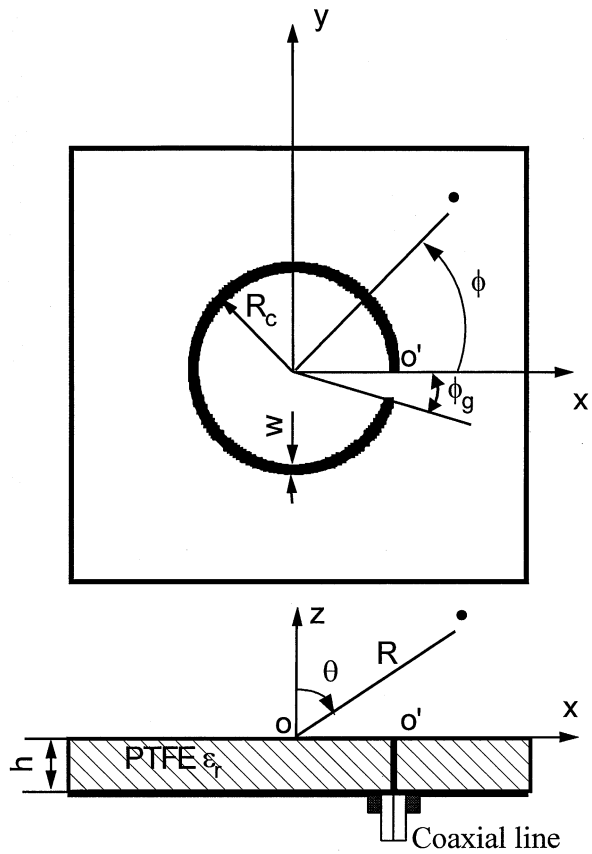

Fig. 1. Geometry of probe-fed printed circular open-loop antenna.

II. Antenna Geometry and Design

The geometry of the printed circular open-loop wire antenna under consideration is shown in Fig. 1. This antenna is designed to operate at a frequency of 1.4 GHz (corresponding to a free-space wavelength of $\lambda_0 = 214$ mm). The loop has gap width defined by angle ϕ_g, Fig. 1. For modeling purposes a cyclindrical wire of radius $a_s = 1.6$ mm $(0.0075\lambda_0)$ is used. In the experiment this wire is replaced with a microstrip line of width of $w = 4a_s$, [1]. The radius of the circular loop is represented as R_c, in Fig. 1. The antenna was designed with the help of a so-called parametric method of moment (P-MoM) analysis, [4]. To achieve optimal CP performance, the values of R_c and ϕ_g were adjusted. It was found through repeated simulation that the optimum value for the loop radius R_c was 33.5 mm ($0.156\lambda_0$) and that axial ratio is sensitive to the gap width angle ϕ_g. The simulated variation of the axial ratio on the z axis as a function of ϕ_g is plotted in

0018-926X/09$17.00 © 2003 IEEE

Authorized licensed use limited to: HOSEI UNIVERSITY KOGANEI LIBRARY. Downloaded on October 2, 2009 at 02:11 from IEEE Xplore. Restrictions apply.

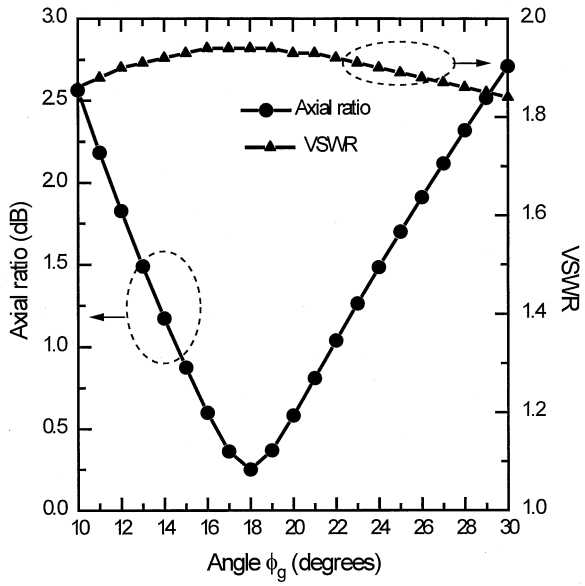

Fig. 2. Variation of on-axis axial ratio ,VSWR as a function of the gap angle ϕ_g.

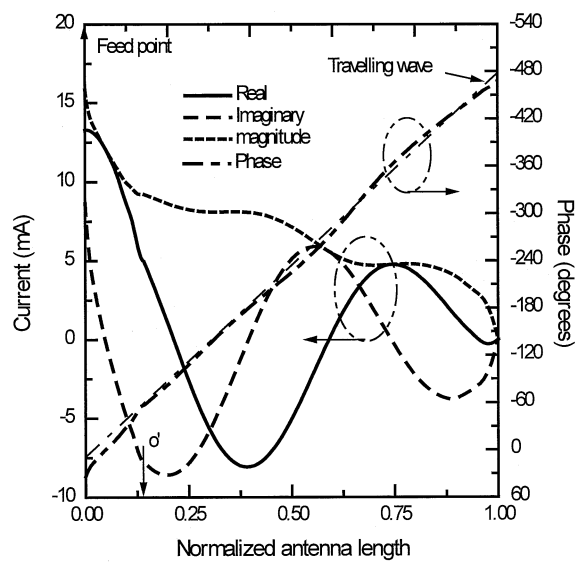

Fig. 3. Current distribution.

Fig. 2. The best on-axis axial ratio (0.25 dB) was found to occur at $\phi_g = 18^\circ$, which corresponded to a total antenna length of $L_a = 231$ mm ($1.08\lambda_0$). In addition, we observed that ϕ_g has very little effect on the input impedance characteristics of the antenna with the input voltage standing-wave ratio (VSWR) which remains around 1.9±0.1 over ϕ_g variation from 10° to 30° (see Fig. 2).

For experimental validation the open-loop antenna was printed on a 300 mm × 300 mm grounded dielectric substrate with a dielectric constant of $\varepsilon_r = 2.1$ and thickness $h = 33$ mm ($0.154\lambda_0$), excited at $o\prime$, Fig. 1 by a vertical wire probe of radius $a_v = 1.843$ mm ($0.0086\lambda_0$), feeding a microstrip line of width of $w = 6.4$ mm ($0.03\lambda_0$). The vertical feed probe is connected to the inner conductor of a 50-Ω coaxial transmission line whose outer conductor is connected to the ground plane.

The printed circular open-loop antenna considered here operates in a traveling-wave mode. A traveling-wave current distribution can be seen on the antenna, as illustrated in Fig. 3. The phase constant associated with the traveling-wave current on the open loop is about

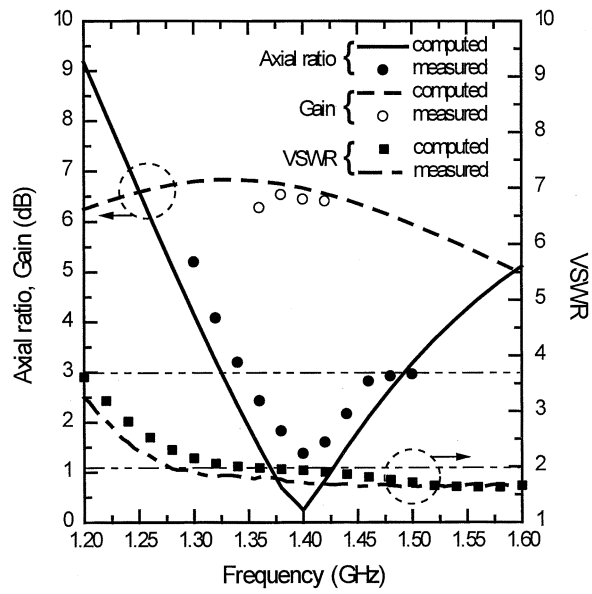

Fig. 4. Computed and measured axial ratio, gain, and input VSWR.

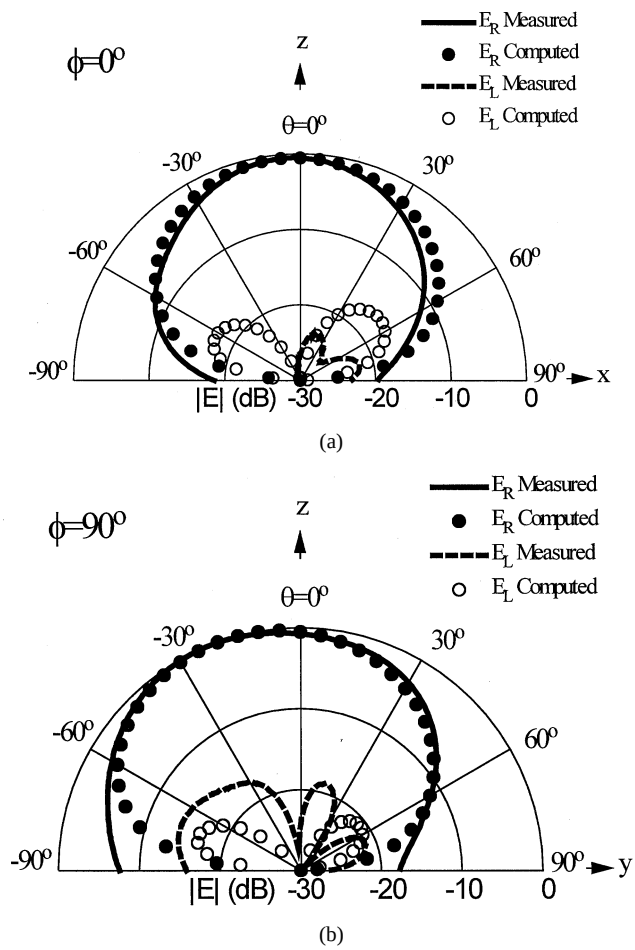

Fig. 5. Computed and Measured radiation patterns in the $\phi = 0^\circ$, and 90° planes. (a) $\phi = 0^\circ$(b) $\phi = 90^\circ$.

$2\pi(480^\circ/360^\circ)/L_a = 1.235k_0$, which is very close to the expected phase constant in an effective dielectric: $k_0\sqrt{\varepsilon_{\rm reff}} = 1.245k_0$ (where $\varepsilon_{\rm reff}$ is the effective dielectric constant: $\varepsilon_{\rm reff} = (\varepsilon_r + 1)/2 = 1.55$), [1]. As mentioned above, the total antenna length is $1.08\lambda_0$ which is commensurate with the requirements given in [5] for CP production

Authorized licensed use limited to: HOSEI UNIVERSITY KOGANEI LIBRARY. Downloaded on October 2, 2009 at 02:11 from IEEE Xplore. Restrictions apply.

by traveling wave action from a suitably terminated circular wire loop. The fundamental basis for the physics underlying this process is given in [6].

III. Numerical and Experimental Results

The computed and measured frequency responses of the on-axis axial ratio, gain (for co-polarization component, right-hand CP in this case), and the input VSWR are illustrated in Fig. 4. Good agreement can be seen between the simulated and experimental results. The 3-dB axial ratio bandwidth is about 12%, and the maximum directivity gain is on the order of 6 dB. The input VSWR is less than 2 over the 3-dB axial ratio bandwidth.

The computed and measured radiation patterns in the $\phi = 0$, and 90° planes are shown in Fig. 5. The computed and measured results match well over the range $\theta = \pm 60^\circ$. The discrepancy near $\theta = \pm 90^\circ$ is due to the finite size of the actual substrate and the invalidation of the stationary phase method used in [4] when $\theta = \pm 90^\circ$. The half power beamwidth is found to be larger than 70°, and the cross-polarization (in this case left-hand CP, E_L) level is about 20 dB lower than the maximum gain.

IV. Conclusion

A printed open-loop antenna excited by a vertical coaxial probe can serve as a nonresonant traveling-wave antenna and thus be made to radiate circularly polarized waves with a selected CP sense. The circular open-loop antenna was investigated numerically and experimentally. It is found that the gap width of the open loop plays an important role in CP performance. An optimized geometry is presented for a certain dielectric substrate. The 3-dB axial ratio bandwidth is found to be more than 12% and the input VSWR is less 2. Although not investigated here, the sense of CP may be changed by introducing a singe-pole double-throw switch, such that the switch selectively connects the coaxial feed probe to one or other of the antennas ports with the other port kept open circuited. Due to its structure simplicity and CP sense flexibility this antenna should find significant applications in a variety of personal communication products.

References

[1] C. A. Balanis, *Antenna Theory: Analysis and Design*. New York: Wiley, 1995.

[2] H. A. N. Hejase, "Analysis of a printed wire loop antenna," *IEEE Trans. Microwave Theory Tech.*, vol. 42, pp. 227–233, Feb. 1994.

[3] H. Nakano, S. R. Kerner, and N. G. Alexopoulos, "The moment method solution for printed wire antennas of arbitrary configuration," *IEEE Trans. Antennas Propagat.*, vol. AP-36, pp. 1667–1674, Dec. 1988.

[4] R. L. Li and H. Nakano, "Numerical analysis of arbitrarily shaped probe-exited single-arm printed wire antennas," *IEEE Trans. Antennas Propagat.*, vol. 46, pp. 1307–1317, Sept. 1998.

[5] C. Wood, "Curved microstrip lines as compact wideband circularly polarized antennas," *Microwav., Opt. Acoust.*, vol. 3, no. 1, pp. 5–13, Jan. 1979.

[6] H. L. Kundsen, "The field radiated by a ring quasiarray of an infinite number of tangential or radial dipoles," *Proc. IRE*, vol. 41, pp. 781–789, June 1953.

Rectangular Waveguide Excitation of Dielectric Resonator Antenna

K. W. Leung and K. K. So

***Abstract*—In this communication, the waveguide-fed dielectric resonator antenna (DRA) is proposed and investigated. The waveguide is terminated by a baffle ground plane in which a coupling slot is cut, and the DRA resides above the coupling slot. To enhance the coupling, a second DR is placed on the other side of the slot inside the waveguide. The measured return loss, radiation patterns, and antenna gain of this novel configuration are discussed in this communication.**

***Index Terms*—Dielectric antennas, slot coupling, waveguide.**

I. Introduction

Since the work reported by Long *et al.* in 1983 [1], the dielectric resonator antenna (DRA) has been studied extensively [2]–[9]. The DRA has several advantages such as its small size, low loss, low cost, and ease of excitation. Most important of all, the DRA is free from metallic loss, making it very suitable for millimeter-wave applications [1]. A number of excitation schemes were proposed for the DRA, including the coaxial probe feed [1], [2], the aperture coupling associated with a microstripline [3]–[6], the direct microstripline feed [7], [8], and, more recently, the conformal-strip feed [9]. However, feedline losses of these excitation methods are considerable at millimeter-wave frequencies. In this communication, a new and low-loss excitation scheme that employs a rectangular waveguide [10] is reported. Today, the waveguide still plays an important role in microwave and millimeter-wave applications; it is the basic unit of many microwave/millimeter-wave components such as magic Tees, direction couplers, phase shifters, and filters. It is also used as the feed for the planar slot antenna and its arrays [11]–[13]. Since the waveguide has metallic walls, it has an excellent shielding between the exterior and interior, thus avoiding radiation loss of the feedline. As both the waveguide and DRA are very low-loss even in the millimeter-wave band, they form an excellent combination for low-loss millimeter-wave communication systems, although the feasibility of the proposed configuration is demonstrated in the C-band in this communication.

In this communication, the waveguide is terminated by a baffle ground plane, in which a rectangular slot is cut for the excitation of the DRA. A cylindrical DRA is used for the demonstration, which is excited in the fundamental TM_{110} mode [1]. Although it has recently been found that a high-permittivity DRA can efficiently be excited by an empty waveguide [14], it is not the case for DRA's of low dielectric constants. To solve this problem, a second cylindrical DR is placed on the other side of the slot inside the waveguide, as shown in Fig. 1(a). The technique is analogous to that used for the waveguide-fed microstrip antenna [15]. It is also somewhat similar to that of coupling power from a waveguide to a DR, or between two DR's, separated by an iris [16], [17]. The DR inside the waveguide acts like an "antenna" which transmits energy from the waveguide to the slot, and vice versa. Alternatively, it can be viewed as an impedance transformer. The idea has lately been employed to design

Manuscript received June 26, 2001; revised April 9, 2002. This work was supported by a grant from the Research Grant Council of the Hong Kong Special Administrative Region, China (Project CityU 1099/99E).

The authors are with the Wireless Communications Research Centre and Department of Electronic Engineering, City University of Hong Kong, Kowloon, Hong Kong (e-mail: eekleung@cityu.edu.hk).

Digital Object Identifier 10.1109/TAP.2003.816373

0018-926X/03$17.00 © 2003 IEEE

Authorized licensed use limited to: HOSEI UNIVERSITY KOGANEI LIBRARY. Downloaded on October 2, 2009 at 02:11 from IEEE Xplore. Restrictions apply.