Meander Line Technique for Size Reduction of Quadrifilar Helix Antenna

Daniel K. C. Chew and Simon R. Saunders, *Member, IEEE*

***Abstract*—A method to reduce the axial length of a conventional printed quadrifilar helix antenna (PQHA) using a meander line technique is described. The design approach and the measurement results for the meander printed quadrifilar helix antenna (MPQHA) are presented. A 53% size reduction and considerable bandwidth increase of a conventional PQHA is achieved by using this technique.**

***Index Terms*—Antennas, microstrip antennas, mobile antennas.**

I. Introduction

THE MOST widely proposed hand-held antenna for mobile satellite communication systems is the quadrifilar helix antenna (QHA) [1]. The QHA is preferred to the crossed dipole and the patch for its small structure, insensitivity to ground or hand proximity effects, easily shaped radiation pattern, and wide circularly polarized beam [2]. The printed QHA (PQHA) is also usually preferred over a wired QHA since it offers the advantages of lightweight low cost high-dimensional stability and ease of fabrication. It is desirable that antennas for portable hand-held terminals be as small and lightweight as possible. Although the conventional PQHA structure is already small, further size reduction is necessary to satisfy the space limitations of the hand-held terminal. In this letter, the meander line technique is used to reduce the size of the conventional PQHA [3].

The meander line antenna was proposed by Rashed and Tai [4] for antenna size reduction such that the antennas were made from continuously folded wire intended to reduce the resonant length. The meander line antennas tend to resonate at frequencies much lower than an ordinary antenna of equal length. Nakano *et al.* [5] investigated the meander line dipole experimentally and found that it has a similar radiation pattern to a conventional half-wavelength dipole antenna. Tsutomu *et al.* [6] also derived a formula for the relationship between the geometrical size and the resonant frequency of the meander line dipole antenna and a calculation formula for the radiation efficiency was also derived.

II. Design Procedures

The four elements of the meander printed (MP)QHA were printed onto a flexible dielectric film and rolled into a cylindrical structure. The geometry and planar unwrapped representation of the MPQHA and PQHA is illustrated in Fig. 1. The meander line elements were made by bending the linear element into continuous square waves in order to shorten its overall element length. By meandering the elements, the capacitance per unit length and inductance per unit length is increased. This reduces the wave velocity propagating in the meander line element, which effectively shortens the overall physical length. In Fig. 1, the meander line element geometrical parameters ΔA and ΔL represent the vertical and horizontal extent of the printed traces, respectively.

Manuscript received July 24, 2002; revised September 19, 2002. This work was supported by Mobile VCE, a collaborative venture of more than 20 industrial companies and seven U.K. universities, with the financial support of the U.K. Government.

The authors are with the Centre for Communications Systems Research, Department of Electronic Engineering, University of Surrey at Guildford, Surrey GU2 7XH, U.K. (e-mail: d.chew@eim.surrey.ac.uk).

Digital Object Identifier 10.1109/LAWP.2002.806051

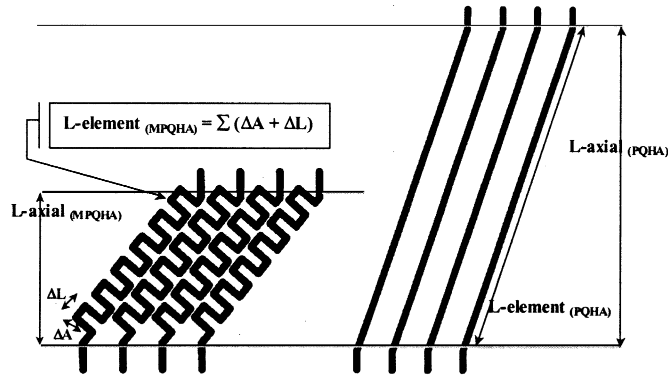

Fig. 1. Planar representation of MPQHA and PQHA.

TABLE I
Physical Characteristics of Ref-PQHA and MPQHA.

	REF-PQHA	MPQHA
L-axial (mm)	83	38.9
L-element (mm)	89.3	124
Radius (mm)	7	7
Track width (mm)	2	2
Number of turns (N)	0.75	0.75
ΔA (mm)	---	6
ΔL (mm)	---	4
Resonant Frequency (GHz)	2.02	2

III. Results and Analysis

In order to investigate the effect of the meander line on the resonant frequency, a large number (53) of MPQHA prototypes were fabricated by varying the values of ΔA and ΔL while retaining the same element length, radius, and number of turns as the conventional PQHA. The physical characteristics of the PQHA are given in Table I. The resonant frequencies of the MPQHA models were measured using a network analyzer and the results were analyzed. From the analysis, the MPQHA has

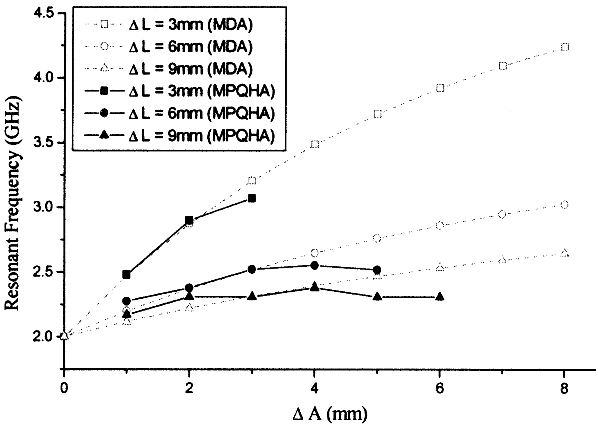

Fig. 2. Comparison of resonant frequency of MDA and MPQHA.

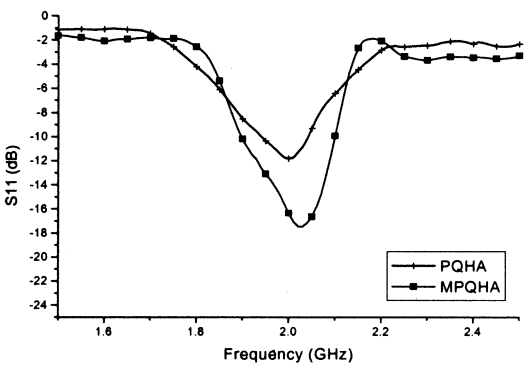

Fig. 3. S11 measurement of the MPQHA compared to the PQHA.

similar characteristics to the meander dipole antenna (MDA) in [6]. The comparison between the calculated resonant frequency of the MDA and the measured resonant frequency of the MPQHA is shown in Fig. 2. The deviation between the measurements and calculated results for large values of ΔA is due to the mutual coupling between the opposite elements of the MPQHA, which does not exist in the case of an MDA. From the MPQHA prototypes, the lowest resonant frequency is 2.17 GHz. This MPQHA has geometric parameters of $\Delta A = 6$ mm, $\Delta L = 8$ mm, and L-axial $= 38.9$ mm. An optimization process was performed on the MPQHA by increasing the element length and decreasing the value of ΔL while retaining the L-axial value at 38.9 mm to achieve a resonant frequency of 2 GHz. The physical characteristics of the MPQHA that resonates at 2 GHz is given in Table I.

In Fig. 3, the S11 of the MPQHA and PQHA are presented. For S11 of -10 dB, the PQHA has an impedance bandwidth of 90 MHz, while the MPQHA has an impedance bandwidth of 190 MHz, which is significantly wider. In Figs. 4 and 5, the radiation pattern for both the PQHA and MPQHA were measured over the frequency range of 1.9–2.2 GHz to evaluate the boresight gain of the two antennas. The PQHA shows a 3-dB bandwidth between 1.9–2.1 GHz, while the MPQHA shows a 3-dB bandwidth between 1.9–2.2 GHz. The results show that the MPQHA has a wider radiation pattern bandwidth compared to the PQHA although the efficiency was lower. The radiation patterns of the MPQHA and PQHA measured at 2 GHz are shown in Fig. 6. The radiation pattern of the MPQHA displays almost identical characteristics to the radiation pattern of the PQHA. The PQHA has a maximum gain of $G_{\max} = 0.33$ dBiC at $\theta_{\text{Gmax}} = 32°$ from the zenith. The half-power beam width (HPBW) point $\theta_{3\text{dB}}$ occurs at 76°. The MPQHA has a maximum gain of $G_{\max} = -2.0451$ dBiC at $\theta_{\text{Gmax}} =$

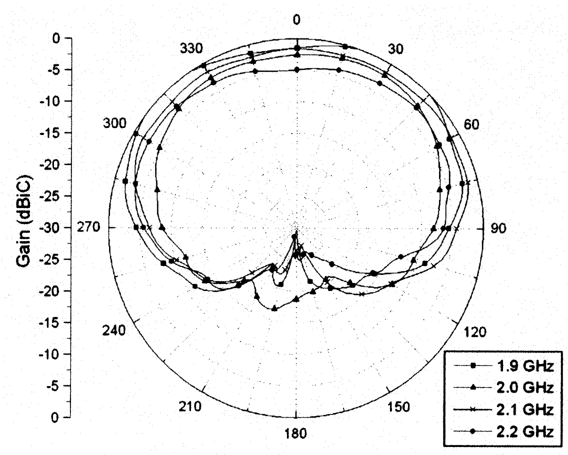

Fig. 4. Elevation angle radiation pattern measurement of PQHA for frequency range of 1.9–2.2 GHz.

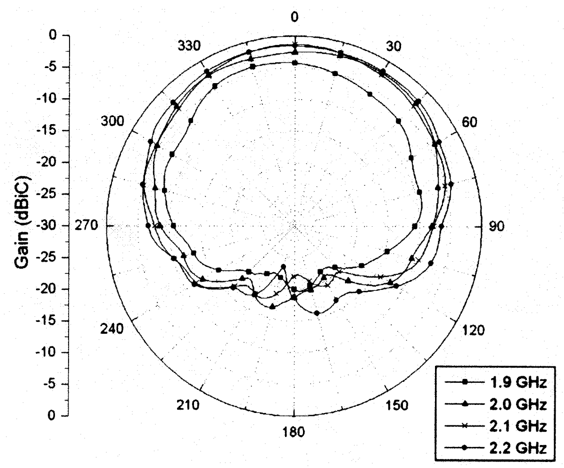

Fig. 5. Elevation angle radiation pattern measurement of MPQHA for frequency range of 1.9–2.2 GHz.

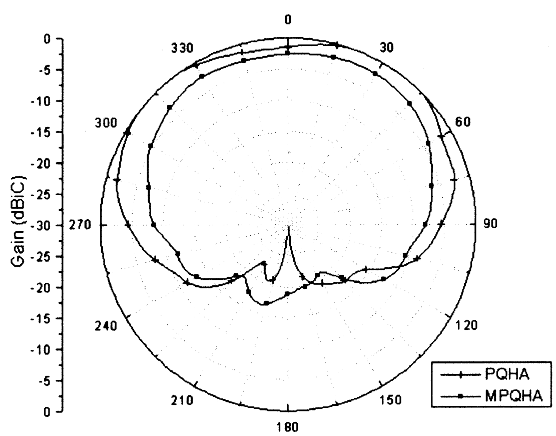

Fig. 6. Elevation angle radiation pattern measurement of MPQHA and PQHA.

$25°$ from the zenith. The HPBW point $\theta_{\rm 3dB}$ occurs at 66°. At elevation angle $= 0°$, the gain difference between the two antennas is 1.13 dB. At elevation angle $= 32°$, which is the direction of maximum gain ($\theta_{\rm Gmax}$) for the PQHA, the difference in gain between the two antenna is about 2.47 dB.

IV. Conclusion

The design approach used to generate the MPQHA has been described. The resonant frequency of the MPQHA is analyzed and compared with the calculated resonant frequency of the MDA. The result shows similar characteristics for small value of ΔA. The measurement results of the MPQHA were presented and compared to that of a conventional PQHA. The meander line technique has been shown useful to reduce the physical length of a conventional PQHA. Using this technique, the axial length of a conventional PQHA was reduced by 53% with a significant increase in operating bandwidth at the expense of a slight reduction in efficiency.

References

[1] C. C. Kilgus, "Shaped-conical radiation pattern performance of the backfire quadrifilar helix," *IEEE Trans. Antennas Propagat.*, vol. 23, pp. 392–397, May 1975.

[2] A. A. Agius, S. M. Leach, and S. R. Saunders, "Antenna design for ICO handheld terminal," in *Proc. 10th Int. Conf. Antennas and Propagation*, Edinburgh, U.K., Apr. 1997.

[3] K. C. D. Chew and S. R. Saunders, "Improvements relating to multifilar helix antenna," U.K. Patent Filing, Application no. 0 204 014.5, Feb. 2002.

[4] J. Rashed and C. T. Tai, "An new class of resonant antennas," *IEEE Trans. Antennas Propagat.*, vol. 39, pp. 1428–1430, Sept. 1991.

[5] H. Nakano, H. Tagami, A. Yoshizawa, and J. Yanauchi, "Shortening ratios of modified dipoles," *IEEE Trans. Antennas Propagat.*, vol. AP-32, pp. 385–386, Apr. 1984.

[6] E. Tsutomu, Yonehiko, S. Shinichi, and K. Takashi, "Resonant frequency and radiation efficiency of meander line antennas," *Electron. Commun. Jpn.*, vol. 83, pp. 52–58, 2000.