Progress In Electromagnetics Research Letters, Vol. 23, 1–7, 2011

CYLINDRICAL-RECTANGULAR MICROSTRIP ARRAY WITH HIGH-GAIN OPERATION FOR IEEE 802.11J MIMO APPLICATIONS

J. H. Lu

Department of Electronic Communication Engineering
National Kaohsiung Marine University
Kaohsiung 811, Taiwan, R.O.C.

G. L. Huang

Wistron NeWeb Corporation (WNC), Taiwan, R.O.C.

Abstract—This article proposes a novel 4-sector cylindrical-rectangular microstrip array with high-gain operation and multi-beam radiation for IEEE 802.11j MIMO WLAN system. With the use of 1×2 array, the impedance bandwidth for the operating band of 5 GHz can reach about 2.5% (125 MHz), which is enough for IEEE 802.11j specifications. Peak antenna gains across the operating band are close to 11.0 dBi with the gain variations of 0.3 dBi.

1. INTRODUCTION

Due to rapid developments in WLAN communication technology and limited bandwidth of 2.4 GHz band for multi-application systems such as IEEE 802.11b/g, Bluetooth and Zigbee systems, high-gain operation with multi-beam radiation characteristics in the 5 GHz band is becoming demanding in IEEE 802.11j multi-input/multi-output (MIMO) applications to achieve long-distance communication. Several high-gained antenna designs had been presented by using the array antenna with antenna height increased [1], parasitic elements [2], dielectric substrate with high permittivity [3, 4] and PBG structure [5, 6]. However, the cylindrical-rectangular microstrip array with multi-beam radiation for MIMO WLAN (IEEE 802.11j) applications is very scant in the open literature. Therefore, in this

Received 15 March 2011, Accepted 11 April 2011, Scheduled 11 April 2011
Corresponding author: Jui-Han Lu (jhlu@mail.nkmu.edu.tw).

article, we propose a novel 4-sector 1×2 cylindrical-rectangular microstrip array anti-symmetrically fed by the microstrip line of $100\,\Omega$ with 180 degree phase difference for multi-beam radiation patterns, which each array sector covers the half-power beamwidth (HPBW) of 90 degrees, respectively, to obtain omnidirectional radiation patterns in the azimuthal plane. And, by adding the switching IC at the input point of this proposed cylindrical-rectangular microstrip array, a smart antenna array can be obtained for multi-input/multi-output (MIMO) applications. Owing to anti-symmetrical feed structure with 180 degree phase difference, the antenna gain of 11 dBi across the operating band can be easily achieved. It is found that, by properly adjusting the spacing between two cylindrical-rectangular microstrip antennas close to 58.9 mm, which is about $0.98\lambda_0$ with respect to the operating frequency of 5 GHz, the obtained impedance bandwidth (VSWR $\leqq 1.5$) is 125 MHz, which is enough for the requirements of IEEE 802.11j MIMO WLAN communication. Details of the proposed array designs are described, and experimental results for the obtained high-gain performance with multi-beam radiation patterns are presented and discussed.

2. ANTENNA DESIGN

To meet high-gain operation requirement for IEEE 802.11j WLAN long-distance communication system, a novel 4-sector cylindrical-rectangular microstrip array has been proposed and shown in Figure 1(a). The geometry of one antenna element of the proposed 4-sector cylindrical-rectangular microstrip array is illustrated in Figure 1(b). Dual cylindrical-rectangular microstrip antennas with the length and width of $L_1 \times W_1$ and $L_2 \times W_2$, respectively, are anti-symmetrically fed by the microstrip line with the width of W_f, which is simpler than the feeding structure of the presented antenna arrays [7–9]. This proposed cylindrical-rectangular microstrip array is etched on the air substrate of thickness 3 mm for the cylinder with the inner radius of 24.5 mm and height of 110 mm. The proposed microstrip array is composed of two cylindrical-rectangular antennas with less dimension difference to obtain two resonant modes close to 5 GHz. The microstrip lines are designed to be of $100\,\Omega$ for feeding at the center edge of the cylindrical-rectangular microstrip antenna to obtain optimal impedance matching to $50\,\Omega$ in the feed point with the spacing of h above the lower cylindrical-rectangular microstrip antenna. For omnidirectional radiation patterns in the azimuthal plane, each array sector shown in Figure 1(b) is designed to cover the half-power beamwidth (HPBW) of 90 degrees for the omni-directional pattern in the azimuthal plane.

3. RESULTS AND DISCUSSIONS

The electromagnetic simulator HFSS based on the finite element method [10] has been applied for the proposed cylindrical-rectangular microstrip array design to demonstrate the above deduction and guarantee the correctness of simulated results. Figure 2 shows the related simulated and experimental results of VSWR for the proposed array design of Figure 1(b) with various antenna lengths. The related results are listed in Table 1 as comparison. Results show the satisfactory agreement for the proposed array design operating at 5 GHz band. It is found that, by properly adjusting the spacing between two cylindrical-rectangular microstrip antennas close to 58.9 mm, which is about $0.98\lambda_0$ with respect to the operating frequency of 5 GHz, the obtained impedance bandwidth (VSWR $\leqq$ 1.5) is 125 MHz (2.5%). This proposed cylindrical-rectangular microstrip array can provide much greater impedance bandwidth to meet the IEEE 802.11j specifications of MIMO WLAN communication system.

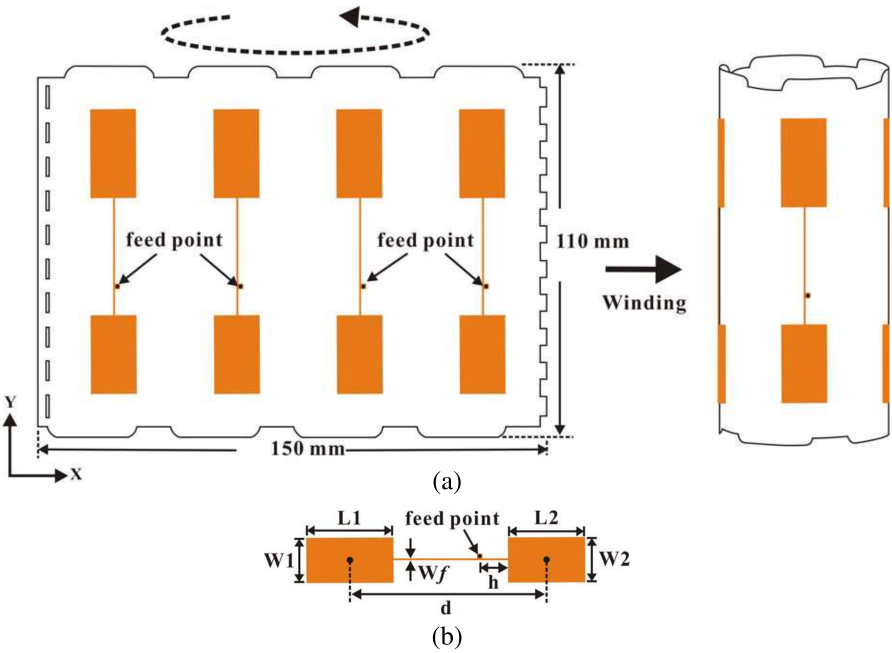

Figure 1. (a) Geometry of the proposed 4-sector cylindrical-rectangular microstrip array for IEEE 802.11j MIMO WLAN system. (b) One antenna element of the proposed 4-sector cylindrical-rectangular microstrip array.

The radiation measurement of the proposed cylindrical-rectangular microstrip array is carried out in anechoic chamber by introducing NSI 800F far-field system. The two-dimensional (2-D) radiation patterns at the operating mode of the proposed array are measured and plotted in Figure 3. In the E-plane (elevation plane), it is also found that the sidelobe radiation is generated due to the 1×2 array effect. And, the related half-power beamwidths (HPBW) are measured to be 25 and 90 degrees, respectively, in the E- and H-plane to obtain omnidirectional radiation patterns. Figure 4 shows the measured peak gain of one antenna element of the proposed microstrip array. The maximum measured peak antenna gains across the operating band are close to 11.0 dBi with the gain variations of 0.3 dBi.

Table 1. Performance for the proposed high-gain cylindrical-rectangular array with various antenna lengths; $L_2 = 23.0\,\text{mm}$, $W_1 = W_2 = 13.2\,\text{mm}$, $W_f = 0.33\,\text{mm}$, $d = 58.9\,\text{mm}$, $h = 8.7\,\text{mm}$.

	L_1 (mm)	f (MHz)	BW (MHz, %)
Antenna 1 (simulated)	25.8	4945	130, 2.6
Antenna 1 (measured)	25.8	4950	125, 2.5
Antenna 2 (measured)	25.4	4995	135, 2.7
Antenna 3 (measured)	25.0	5070	160, 3.2

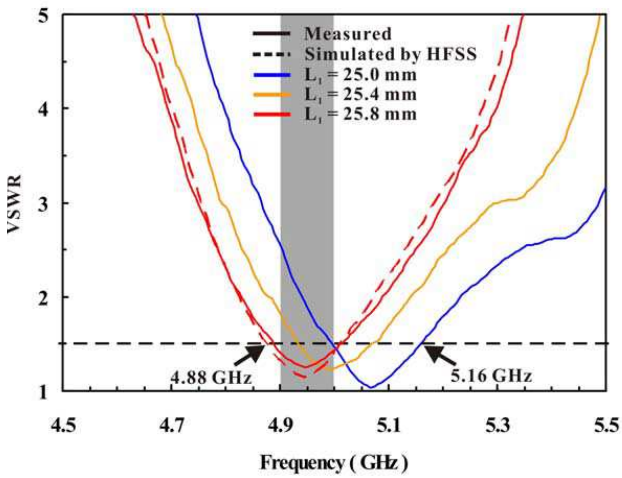

Figure 2. Simulated and measured VSWR against frequency for one antenna element of the 4-sector cylindrical-rectangular microstrip array; related parameters shown in Table 1.

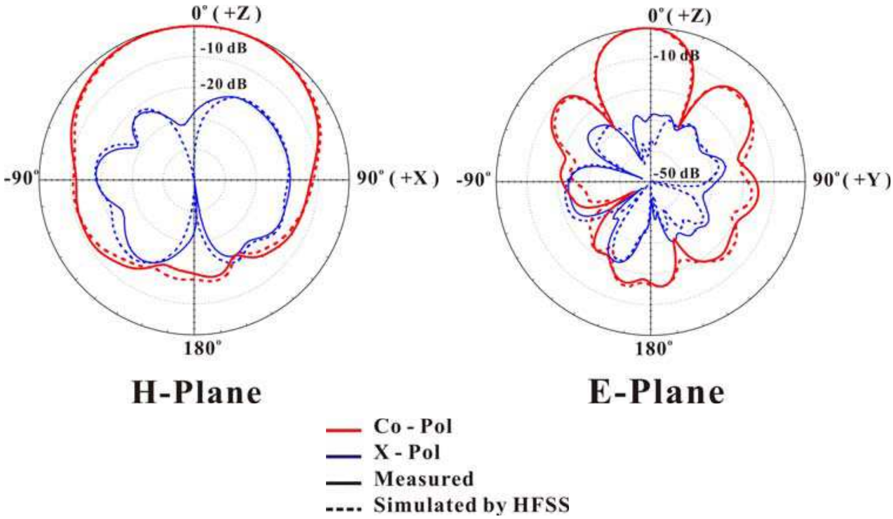

Figure 3. *E*-plane (*y*-*z* plane) and *H*-plane (*x*-*z* plane) radiation patterns for one antenna element of the proposed cylindrical-rectangular microstrip array given in Figure 2 at 4.95 GHz.

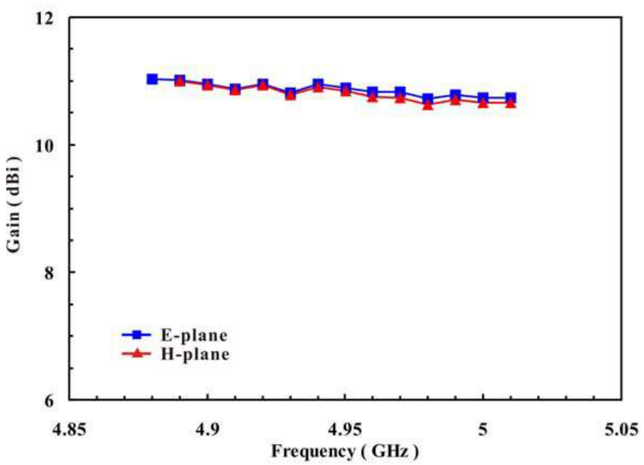

Figure 4. Measured peak gain across the operating frequency for one antenna element of the proposed cylindrical-rectangular microstrip array.

4. CONCLUSION

A novel 4-sector cylindrical-rectangular microstrip array with the antenna gain of 11 dBi for IEEE 802.11j MIMO WLAN long-distance communication system has been proposed and experimentally studied. With the use of 1×2 array, the impedance bandwidths for the operating band of 5 GHz can reach about 2.5% (125 MHz), which is enough for IEEE 802.11j specifications. The measured peak antenna gains across the operating band are close to 11.0 dBi with the gain variations of 0.3 dBi.

ACKNOWLEDGMENT

This paper was supported by the National Science Council (NSC), Taiwan, R.O.C., under Grant NSC97-2221-E-022-005-MY3 and NSC96-2622-E-022-003-CC3.

REFERENCES

1. Hong, C. S., "Small annular slot antenna with capacitor loading," *IET Electron. Lett.*, Vol. 36, 75–83, February 2003.
2. Lee, R. Q. and K. F. Lee, "Gain enhancement of microstrip antenna with overlaying parasitic directors," *IET Electron. Lett.*, Vol. 24, 656–658, May 1988.
3. Huang, C. Y., J. Y. Wu, C. F. Yang, and K. L. Wong, "Gain enhancement compact broadband microstrip antenna," *IET Electron. Lett.*, Vol. 34, 138–139, January 1988.
4. Gauthier, G. P., A. Courtay, and G. M. Rebeiz, "Microstrip antennas on synthesized low dielectric-constant substrates," *IEEE Trans. Antennas Propagat.*, Vol. 45, 1310–1314, August 1997.
5. Coccioli, R., W. R. Deal, and T. Itoh, "Radiation characteristics of a patch antenna on a thin PBG substrate," *IEEE AP-S Int. Symp. Dig.*, Vol. 2, 21–26, 1998.
6. Kuo, J. S. and G. B. Hsieh, "Gain enhancement of a circularly polarized equilateral-triangular microstrip antenna with a slotted ground plane," *IEEE Trans. Antennas Propagat.*, Vol. 51, 1652, July 2003.
7. Yin, Y. Z., N. Zhao, Z. Huili, and Y. M. Guo, "High performance planar antenna array for broadband WLAN applications," *IEEE Int. Symp. on Microwave, Antenna, Propagat. and EMC Technol. for Wireless Communications*, Vol. 1, 220–223, 2005.

8. Wong, K. L., F. R. Hsiao, and T. W. Chiou, "Omnidirectional planar dipole array antenna," *IEEE Trans. Antennas Propagat.*, Vol. 52, 624–628, February 2004.
9. Lin, C. C., C. M. Su, F. R. Hsiao, and K. L. Wong, "Printed folded dipole array antenna with directional radiation for 2.4/5 GHz WLAN operation," *IET Electron. Lett.*, Vol. 39, 1698–1699, November 2003.
10. Ansoft Corporation HFSS, http://www.ansoft.com/products/hf/hfss.