Progress In Electromagnetics Research Letters, Vol. 55, 39–43, 2015

Three Optimized Omnidirectional Microstrip Antennas (OMA) for WLAN Applications

Seyed Hassan Esmaeli[1], Mohammad Khalaj Amirhosseini[1], and Seyed Hassan Sedighy[2, *]

Abstract—In this paper, three omnidirectional microstrip array antennas are optimized, fabricated and measured. The proposed planar antennas are composed from series of microstrip line sections with inverted top and bottom conductors at each section. The antenna design parameters are optimized to design three different antennas: wide bandwidth, high-gain and dual-band antennas. In the wideband antenna, a good impedance matching is obtained for relative bandwidth of 31% that covers the frequency range of WLAN. The dual-band omnidirectional antenna operates at 2.45 GHz and 5.25 GHz with gains of 6.69 dBi and 7.71 dBi, respectively. Also, the optimized high-gain antenna achieves 9.3 dBi gain. The three optimized antennas are fabricated and tested. The measurement results show a very good agreement with the simulation ones. The optimization results verify the ability and capability of the antenna to achieve the desired specifications.

1. INTRODUCTION

Many wireless application channels using 802.11b (2.45 GHz), 802.11a (5.2 GHz) and WiMAX protocols. These systems need antennas with omnidirectional radiation pattern in the azimuth plane and narrow beam width radiation pattern in the elevation plane for large service area coverage. The microstrip antennas are good candidates for these applications due to their small size, easy installation and low cost. For WLAN applications and WiMAX systems, several design methods for omnidirectional antennas have been developed in [1–5]. The collinear dipole array (COA) is a well-known high-gain dipole antenna introduced in [6] based on Franklin idea. This antenna includes U-shaped wire sections to keep the current feeding of the longitudinal radiating wire antenna in-phase. The omnidirectional coaxial collinear (COCO) antennas are composed of series half wavelength coaxial cable sections where their inner and outer cable conductors are transposed at each section [7]. Based on the COCO antenna concept, a planar omnidirectional microstrip antenna (OMA) has been proposed in [8–10]. Also, a number of design approaches have been proposed in the literatures for multi-band or wide-band omnidirectional antennas. A dual-band OMA has been proposed in [11]. In this antenna, the higher frequency radiation with low-pass filtering attribute is placed near the antenna feed and a relatively lower frequency radiating array at the end which increases the antenna dimension significantly. In [12], an omnidirectional broad-bandwidth microstrip array antenna has been proposed for WiMAX applications suitable for WLAN operation at 5.2 GHz (5.150–5.350 GHz) and 5.8 GHz (5.725–5.875 GHz) bands comprising two back-to-back folded dipoles printed on a dielectric substrate. In [13], a novel shunt-fed triband printed two-element collinear dipole array antenna has been presented for required bands of GSM850 (824–894 MHz), DCS (1710–1880 MHz), and PCS (1850–1990 MHz). Moreover, some efforts have been made in the literatures to design a circular polarization and dual-polarization omnidirectional antenna. In [14] a compact omnidirectional antenna with circular polarization has been presented for

Received 11 June 2015, Accepted 3 August 2015, Scheduled 17 August 2015
* Corresponding author: Seyed Hassan Sedighy (sedighy@iust.ac.ir).
[1] School of Electrical Engineering, Iran University of Science and Technology, Tehran, Iran. [2] School of New Technologies, Iran University of Science and Technology, Tehran, Iran.

2.4 GHz WLAN. Also, a high-isolation dual-polarization microstrip patch antenna with omnidirectional radiation patterns has been proposed in [15].

In this paper, three different optimized omnidirectional antennas based on OMA concept are proposed and fabricated which can be used in 802.11b and/or 802.11a wireless applications. The wideband operation, high gain and dual-band operation are the goals of these three optimized antennas. The optimization results verify the capability of the OMA to achieve the desired specification. The designed antennas are successfully fabricated, and the experimental results are presented and show good agreement with the simulation ones.

2. OMA DESIGN AND CONFIGURATION

The OMA is composed of series half guided wavelength microstrip sections where the ground and signal layers are transposed at each junction. Since each microstrip section has an effective length about half guided wavelengths, the whole microstrip array appears to be fed in-phase. In other words, this transposition causes the current distribution to be in phase, and the antenna can be considered as an array with in-phase elements while is simply fed from one point. Therefore, this array antenna achieves a high-gain radiation pattern in the azimuth plane.

The configuration of a 4-segmented OMA is presented in Figure 1. The antenna consists of top and bottom traces printed on both sides of the substrate. The top trace begins with a narrow section and then alternates between wide and narrow sections so that the last upper section is wide. The bottom trace starts with a wide section and then alternates between narrow and wide complementing the top trace. The bottom trace is terminated with a short ended narrow section which is connected to the center of the last wide section on the top trace through a via. A key advantage of this antenna is the high-gain property of the series array antennas, whereas the simplicity of the single feeding point is maintained. The antenna is fed with a SMA connector at the beginning of the first section. The antenna section lengths (L_n) are about half of the guided wavelength at operating frequency. Although the antenna section widths have no effect on the antenna operating frequency, with change of them, the current distributions are changed which results in antenna input impedance variation. The width of narrow line sections is chosen such that they form a 50 Ω microstrip line with their opposite side wide section viewed as a ground plane. The wide sections are as wide as at least five times of narrow sections. Here, the RT/duriod5880 with $\varepsilon_r = 2.2$ and thickness of 0.381 mm is chosen as the substrate for all three antennas.

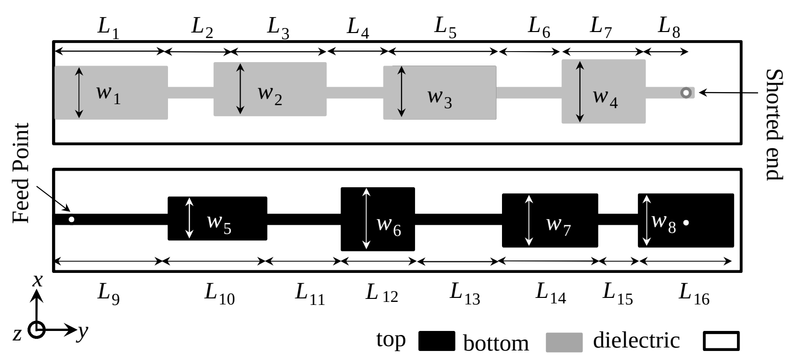

Figure 1. OMA configuration.

3. WIDEBAND OMA

Since The antenna section lengths are about half of guided wavelength at operating frequency, these antennas are inherently narrow band. To enhance the antenna bandwidth, the section lengths can be chosen differently, such that each section works at one portion of the bandwidth. But it causes some significant effects on the current distribution, and the antenna input impedance and gain, consequently. To deal with this problem, other antenna dimensions can be optimized such that the antenna works in the whole bandwidth properly.

Now, the 4-segment antenna dimensions shown in Figure 1 are optimized to enhance the antenna bandwidth. The antenna center frequency is chosen as 2.45 GHz which has guided wavelength of $\lambda_g = 89.48$ mm. The lengths and widths of radiating sections and space between two adjacent ones of them are optimized to achieve a wideband OMA. The short-ended via located at the end of the antenna has 0.5 mm radius, and the width of narrow sections is considered as 1.2 mm which is 50 Ω microstrip line on the chosen substrate. Also, the substrate extends out 2.0 mm from each side. The optimized antenna widths, $w_1 \sim w_8$, are $0.275\lambda_g$, $0276\lambda_g$, $0.247\lambda_g$, $0.272\lambda_g$, $0.134\lambda_g$, $0.189\lambda_g$, $0.255\lambda_g$ and $0.269\lambda_g$, respectively. Also, the antenna sections lengths, $L_1 \sim L_{16}$, are $0.572\lambda_g$, $0.449\lambda_g$, $0.599\lambda_g$, $0.386\lambda_g$, $0.519\lambda_g$, $0.623\lambda_g$, $0.318\lambda_g$, $0.300\lambda_g$, $0.66\lambda_g$, $0.35\lambda_g$, $0.721\lambda_g$, $0.27\lambda_g$, $0.573\lambda_g$, $0.49\lambda_g$, $0.478\lambda_g$ and $0.667\lambda_g$, respectively. The antenna is fed with an SMA connector at 6.1 mm after the beginning of the first line. The simulated and measured radiation patterns of the optimized wideband antenna at 2.25 GHz, 2.45 GHz and 2.65 GHz as well as $|S_{11}|$ are shown in Figure 2. The matching band is from 2.20 GHz to 2.98 GHz which gives us 30% bandwidth. Also, the maximum antenna gain at the center frequency is 7.34 dBi. From these results, one can see that in the xz-plane, the radiation pattern is omnidirectional in the whole operation bandwidth.

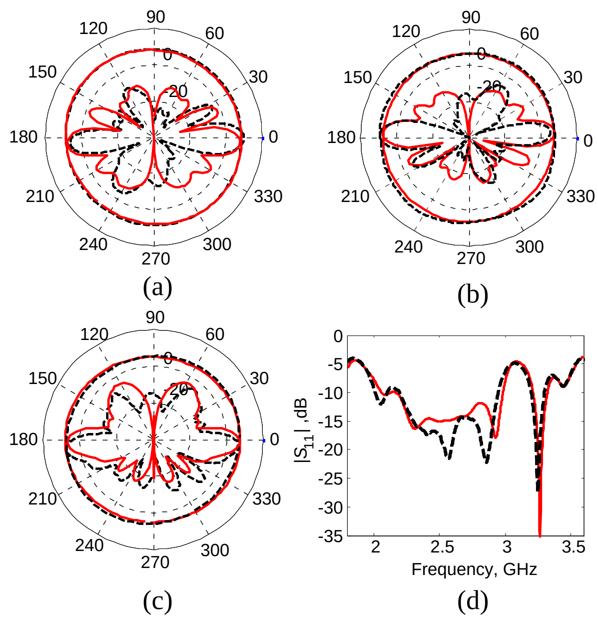

Figure 2. Simulated (solid) and measured (dashed) radiation pattern of the wideband OMA. (a) 2.25 GHz. (b) 2.45 GHz. (c) 2.65 GHz. (d) $|S_{11}|$ (inner: xy-plane; outer: xz-plane).

4. HIGH GAIN OMA

To increase the OMA gain, the current distribution must be uniform and in-phase in all sections, while the discontinuity and mutual coupling between the sections affect the current distributions. Therefore, we cannot have the maximum gain with the isometric sections. In other words, the antenna dimension should be optimized to achieve an in-phase current distribution as much as possible with considering all mutual effects and discontinuities. Here, we optimize the lengths, widths and distances of radiating sections at 2.45 GHz. The optimized antenna widths, $w_1 \sim w_8$, are $0.238\lambda_g$, $0.279\lambda_g$, $0.279\lambda_g$, $0.254\lambda_g$, $0.241\lambda_g$, $0.234\lambda_g$, $0.268\lambda_g$ and $0.275\lambda_g$, respectively. Also, the optimized antenna section lengths, $L_1 \sim L_{16}$, are $0.720\lambda_g$, $0.581\lambda_g$, $0.38\lambda_g$, $0.639\lambda_g$, $0.4\lambda_g$, $0.616\lambda_g$, $0.308\lambda_g$, $0.264\lambda_g$, $0.805\lambda_g$, $0.399\lambda_g$, $0.548\lambda_g$, $0.528\lambda_g$, $0.526\lambda_g$, $0.475\lambda_g$, $0.512\lambda_g$ and $0.739\lambda_g$, respectively. Moreover, the antenna is fed with a SMA connector at 4.3 mm after the beginning of the first line. Figure 3 depicts the simulated and measured results of the high-gain antenna. This antenna is narrow band but its gain is high as 9.25 dBi in the xy-plane.

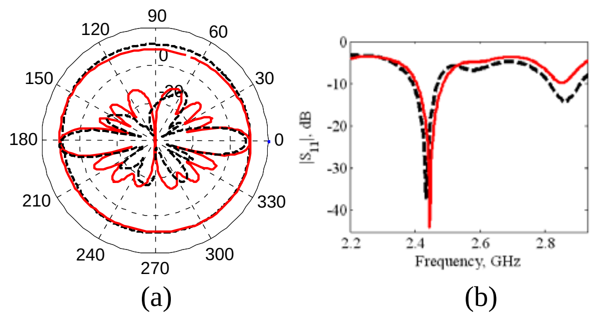

Figure 3. Simulated (solid) and measured (dashed) radiation pattern of the high gain OMA. (a) Radiation pattern at 2.45 GHz (inner: xy plane; outer: xz-plane). (b) $|S_{11}|$.

5. DUAL BAND OMA

In dual-band operation, the antenna should radiate properly in both the frequencies. One solution, which was considered in [11], is the design of an OMA antenna in each band and feeding them in series, which increases the whole antenna dimension. Another way is the optimization of antenna sections to radiate properly in both the frequencies.

Here we aim to design a dual-band antenna at 2.45 GHz and 5.20 GHz. The antenna is fed with a SMA connector at 3.7 mm after the beginning of the first line. The optimized antenna widths, $w_1 \sim w_8$, are $0.129\lambda_g$, $0.130\lambda_g$, $0.145\lambda_g$, $0.078\lambda_g$, $0.147\lambda_g$, $0.141\lambda_g$, $0.141\lambda_g$ and $0.082\lambda_g$, respectively. Here, λ_g is considered at 2.45 GHz. Also, the optimized antenna section lengths, $L_1 \sim L_{16}$, are $0.333\lambda_g$, $0.655\lambda_g$, $0.267\lambda_g$, $0.292\lambda_g$, $0.393\lambda_g$, $0.376\lambda_g$, $0.442\lambda_g$, $0.25\lambda_g$, $0.379\lambda_g$, $0.308\lambda_g$, $0.619\lambda_g$, $0.401\lambda_g$, $0.398\lambda_g$,

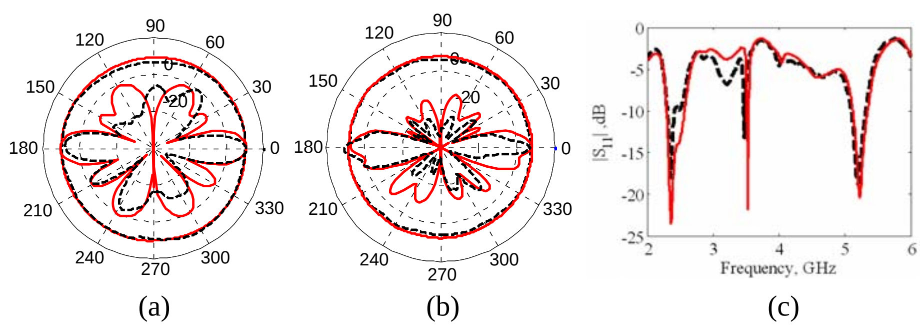

Figure 4. Simulated (solid) and measured (dashed) radiation pattern of the dual band OMA. (a) Radiation pattern at 2.45 GHz. (b) Radiation pattern at 5.2 GHz (inner: xy plane; outer: xz-plane). (c) $|S_{11}|$.

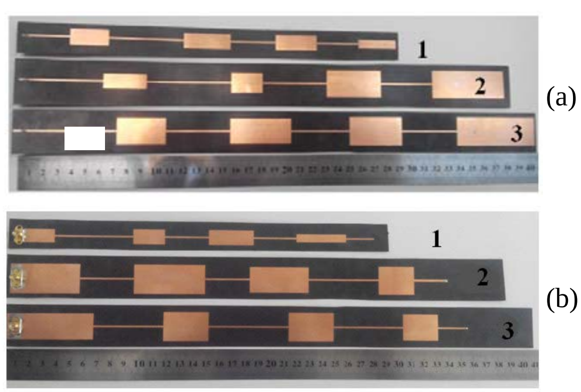

Figure 5. Photograph of the fabricated antennas. (a) Top view. (b) Bottom view (1: dual band, 2: wideband, 3: high gain).

$0.781\lambda_g$, $0.815\lambda_g$ and $0.734\lambda_g$, respectively. Figure 4 depicts the simulated and measured results of the dual-band antenna. This antenna has two narrow band radiation frequencies with gains 6.69 dBi and 7.71 dBi. Finally, the three fabricated antennas are shown in Figure 5.

6. CONCLUSION

Three planar Omnidirectional Microstrip Antennas (OMA) have been optimized and fabricated. The antenna design parameters, section widths, lengths and distances were optimized to achieve the desired properties. In the first case, the OMA was optimized to achieve a wideband antenna with 30% bandwidth around 2.45 GHz. The second antenna was optimized to achieve a high-gain antenna which resulted in 9.25 dBi gain at 2.45 GHz. In the third case, the antenna was optimized to achieve dual-band radiation at 2.45 GHz and 5.20 GHz. The three optimized antennas have been fabricated and tested. The measurement results were in good agreement with the simulation ones. The optimization results clarified the ability and capability of the antenna to achieve the desired specifications.

REFERENCES

1. Wu, Y.-J., B.-H. Sun, J.-F. Li, and Q.-Z. Liu, "Triple-band omni-directional antenna for wlan application," *Progress In Electromagnetics Research*, Vol. 76, 477–484, 2007.
2. Wang, B., F. Zhang, L. Jiang, Q. Li, and J. Ren, "A broadband omnidirectional antenna array for base station," *Progress In Electromagnetics Research C*, Vol. 54, 95–101, 2014.
3. Tze-Meng, O., T. K. Geok, and A. W. Reza, "A dual-band omni-directional microstrip antenna," *Progress In Electromagnetics Research*, Vol. 106, 363–376, 2010.
4. Si, L.-M. and X. Lv, "CPW-fed multi-band omni-directional planar microstrip antenna using composite metamaterial resonators for wireless communications," *Progress In Electromagnetics Research*, Vol. 83, 133–146, 2008.
5. Quan, X. L., R. L. Li, J. Y. Wang, and Y. H. Cui, "Development of a broadband horizontally polarized omnidirectional planar antenna and its array for base stations," *Progress In Electromagnetics Research*, Vol. 128, 441–456, 2012.
6. Solbach, K., "Microstrip-Franklin antenna," *IEEE Transactions on Antennas and Propagation*, Vol. 30, No. 4, 773–775, 1982.
7. Judasz, T. J., W. L. Ecklund, and B. B. Balsley, "The coaxial collinear antenna: Current distribution from the cylindrical antenna equation," *IEEE Transactions on Antennas and Propagation*, Vol. 35, No. 3, 327–331, Mar. 1987.
8. Bancroft, R. and B. Bateman, "An omnidirectional microstrip antenna," *IEEE Transactions on Antennas and Propagation*, Vol. 52, 3151–3153, Nov. 2004.
9. Bancroft, R. and B. Bateman, "An omnidirectional planar microstrip antenna with low sidelobes," *Microwave and Optical Technology Letters*, Vol. 42, 68–69, Jul. 2004.
10. Bancroft, R., "Design parameters of an omnidirectional planar microstrip antenna," *Microwave and Optical Technology Letters*, Vol. 47, No. 5, 414–418, Dec. 2005.
11. Wei, K. P., Z. J. Zhang, and Z. H. Feng, "Design of a dualband omnidirectional planar microstrip antenna array," *Progress In Electromagnetics Research*, Vol. 126, 101–120, 2012.
12. Li, J., "An omnidirectional microstrip antenna for WiMAX applications," *IEEE Antennas and Wireless Propagation Letters*, Vol. 10, No. 1, 67–169, 2011.
13. Wei, K., Z. Zhang, W. Chen, Z. Feng, and M. F. Iskander, "A triband shunt-fed omnidirectional planar dipole array," *IEEE Antennas and Wireless Propagation Letters*, Vol. 9, 850–853, 2010.
14. Yu, Y., Z. Shen, and S. He, "Compact omnidirectional antenna of circular polarization," *IEEE Antennas and Wireless Propagation Letters*, Vol. 11, 1466–1469, 2012.
15. Deng, C., P. Li, and W. Cao, "A high-isolation dual-polarization patch antenna with omnidirectional radiation patterns," *IEEE Antennas and Wireless Propagation Letters*, Vol. 11, 1273–1276, 2012.