

SECTOR ANTENNA DESIGN FOR WLAN APPLICATIONS

Kanthorn Keeratipianlerd*, Peerapong Uthansakul, Pongnarin Sriploy, and Monthippa Uthansakul

Received: May 16, 2018; Revised: September 21, 2018; Accepted: September 24, 2018

Abstract

This paper presents a simulation and performance of a sector antenna for WLANs. The designed antenna operating in the 2.4 GHz band provides 90 degrees coverage with 4 sectors. The antenna is designed on a FR-4 substrate with a dielectric constant of 4.4 and thickness of 1.6 mm. Simulation results of the antenna such as return loss, radiation pattern, and gain are compared with the experimental results.

Keywords: Sector antenna, WLANs, microstrip patch antennas

Introduction

In the current decade, wireless and mobile communication has been developing at a rapid pace because the demand for high-speed data transmission increases continuously. For wireless and mobile communication, there are many standards such as for a cellular network, satellite communication, and wireless local area networks (WLANs). The popular communication network is the WLAN which is a wireless computer network that links 2 or more devices using wireless communication within both private

and public areas such as the home, office, and university. The WLAN has many standards based on IEEE 802.11 which is operated in the frequency range from 2.4 to 2.5 GHz. The WLAN has many advantages; it can support a large number of devices, it is easy to set up a network especially when compared to laying cables for wired networks, it can provide an appropriate range of coverage which is about 100 meters, and it can provide high-speed data transmission at about 54-300 Mbps (Au, 2016). However, the

School of Telecommunication Engineering, Institute of Engineering, Suranaree University of Technology, Nakhon Ratchasima, 30000, Thailand. E-mail: M5840717@g.sut.ac.th, uthansakul@sut.ac.th, pongnarin.s@nrru.ac.th, mtp@sut.ac.th

** Corresponding author*

coverage area and data rate of the WLAN are limited in some environments which have many obstacles (Blaunstein and Christodoulou, 2007). Moreover, the 1 major problem of the WLAN is the hidden node. The hidden node problem occurs when 2 nodes (the 1st and 2nd nodes) in the WLAN are communicating with each other, and other nodes (e.g., the 3rd node) cannot send data to those 2 nodes. So, the 3rd node is considered as a hidden node (Kim and Choi, 2013). Thus, the transmitted information from the 3rd node is lost. Then, the system's average throughput is low. In view of these problems, a sector antenna design for the WLAN is proposed in this paper in order to allow simultaneous cross-communication between 4 nodes.

From the literature, Korakis *et al.* (2008) have revealed that the use of a 4 or 8-sector antenna can tackle the problem of hidden nodes and also increase the system's gain and coverage area. However, the realization of the sector antenna was not demonstrated in their paper. Recently, many researchers have proposed microstrip antennas which are suitable for indoor communication and are light in weight and have a low cost. Table 1 summarizes the contents of the literature (Lai *et al.*, 2008; Haraz and Sebak, 2011; Kaswiati and Suryana, 2012; Chan-arpas *et al.*, 2014; Patron *et al.*, 2014; Yassin *et al.*, 2014; Mahlaoui *et al.*, 2015; Wnuk and Nowosielski, 2016). According to Table 1, those proposed antennas cannot be applied for a 4-sector node as their beamwidth is not 90 degrees and their front-to-back ratio is too high, which can introduce interference among 4- beams when they are operating simultaneously. Therefore, we have designed a

sector antenna for WLANs which has 90 degrees in half-power beamwidth and also provides a 20-dB front-to-back ratio (Keeratipianlerd *et al.*, 2017). Thus, the antenna can be perfectly applied for a 4-sector node and also handle the issue of self-interference between beams. In this paper, we develop the 4- sector antenna that provides full 360 degrees coverage and a low back lobe. The designed antenna provides a sector antenna which has 90 degrees beamwidth and less interference. The experimental results show that the designed antenna operates at 2.4 GHz for WLANs. Moreover, the designed antenna uses a single layer FR4 and provides - 45 dB self-interference between the beams.

Antenna Design

From the beginning, we needed to design an antenna that operates at 2.4 GHz for the WLAN system. A microstrip antenna has a small size and easy fabrication process. This paper starts with a circular microstrip antenna on FR4 having a dielectric constant of 4.4 and substrate thickness of 1.6 mm. We designed the circular microstrip antenna from Equations (1) and (2) (Constantine, 2005).

$$a = \frac{F}{\left\{1 + \frac{2h}{\pi \epsilon_r F} \left[\ln \left(\frac{\pi F}{2h} \right) + 1.7726 \right] \right\}^{\frac{1}{2}}} \quad (1)$$

$$F = \frac{8.791 \times 10^9}{f_r \sqrt{\epsilon_r}} \quad (2)$$

where a is the radius of the circle (cm), f_r is the resonant frequency, ϵ_r is the dielectric

Table 1. Summary of the contents of the literature

Literature	Antenna Type	Operating Frequency (GHz)	HPBW	Front to back ratio
Kaswiati and Suryana, 2012	Microstrip - Planar	1.8 and 2.1-2.5	80-degree	-
Haraz and Sebak, 2011	Microstrip - Planar	1.8, 2.5 and 3.5	-	-
Patron <i>et al.</i> , 2014	Microstrip - Planar	2.4	60-degree	-
Wnuk and Nowosielski, 2016	Microstrip – Dipole	2.4, 5.8	85-degree	-
Chan-arpas <i>et al.</i> , 2014	Microstrip	1.575 and 2.45	-	-
Mahlaoui <i>et al.</i> , 2015	Microstrip	2.46 and 5.34	-	-
Yassin <i>et al.</i> , 2014	Microstrip	3.5 and 5.2	89.4-degree	-
Lai <i>et al.</i> , 2008	Microstrip - Planar	2.4-2.5	124.5-degree	-

constant, and h is the thickness of the substrate. Then, (1) and (2) provide a radius of 1.69 cm and the designed antenna, as shown in Figure 1. The concept of Keeratipianlerd *et al.* (2017) was to make the main beam narrower and to raise the front-to-back ratio. Keeratipianlerd *et al.*, (2017) revealed the designed antenna while changing the shape of the substrate that affects the resonance frequency, beamwidth, and front-to-back ratio. The results showed that changing the flare angle affects the resonant frequency and changing the size of the bottom side affects the half-power beamwidth and front-to-back ratio. Moreover, this antenna was proposed for a 4-sector node in WLANs which provides a half-power beamwidth of 90 degrees and front-to-back ratio of 20 dB.

Therefore, the initial antenna can be designed from the antenna, as shown in Figure 2. Then, we arranged 4 antennas on the same substrate, as shown in Figure 3. The 1st gap's

position starts from the minimum size of the gap between the antennas. As can be seen, we varied the size of the gap that affects the received power at the 1st antenna when the 2nd, 3rd, and 4th antennas were acting as a transmitter. Moreover, when the size of the gap was adjusted to 9.71 cm, the average received power was -52 dB. If we vary the size of the gap to be bigger than 9.71 cm, the received power will change slightly. Figure 4 shows the received power when we varied the size of the gap. In addition, Figure 5 defines the meaning of the width (W) and height (H). Figures 6 and 7 show the change of the resonant frequency and beamwidth, respectively. We can see that changing the W affects the resonant frequency and the changing the H affects the beamwidth. However, the designed antenna covers the 2.4 GHz band (2.4 -2.484 GHz), half-power beamwidth of 90 degrees, and has low interference from the side antenna.

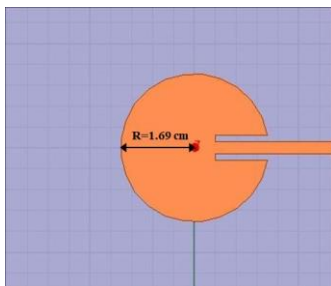


Figure 1. Circular microstrip patch antenna

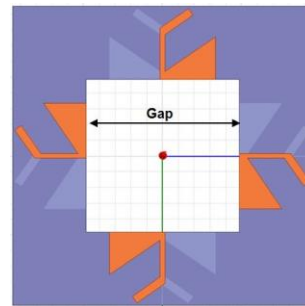


Figure 3. Antenna design when varying the size of the gap

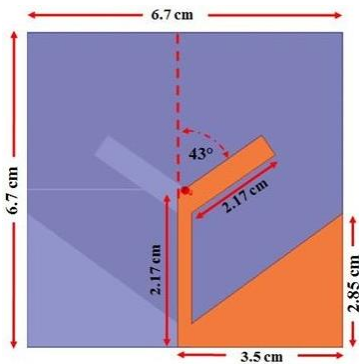


Figure 2. The initial antenna

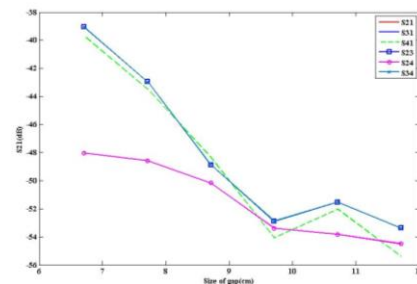


Figure 4. The received power at 1st antenna when 2nd, 3rd, and 4th were acting as a transmitter

Figures 8 and 9 show the final designed antenna and the details of the antenna, respectively. This antenna can be fabricated on 2-sided FR4 with a dielectric constant of 4.4 and substrate thickness of 1.6 mm. Furthermore, the overall size of the antenna is 19.6×19.6 cm². The antenna testing will be presented in the next section including the simulation and experimental results in terms of the return loss,

interference from the side antenna, and radiation pattern.

Results and Discussion

Figure 10 shows a photograph of the designed antenna. In this paper, the factors indicating the radiation performance are the return loss,

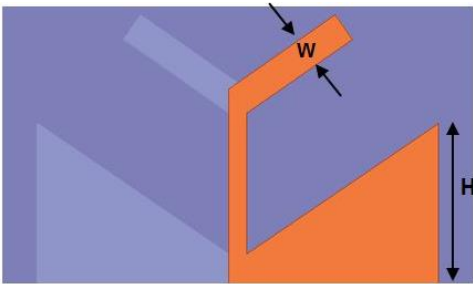


Figure 5. The meaning of W and H

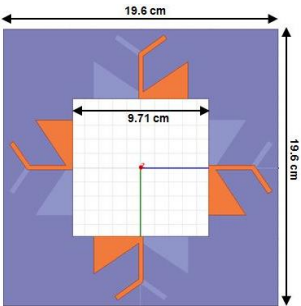


Figure 8. Final designed antenna

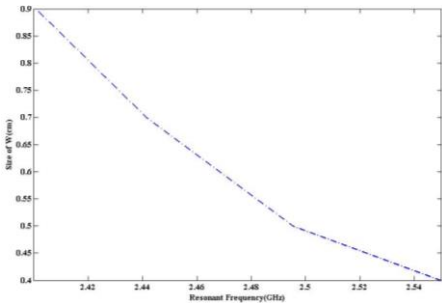


Figure 6. Resonant frequency VS Size of W

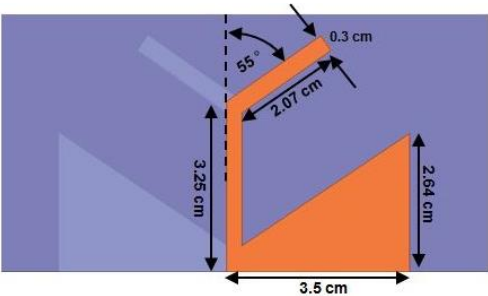


Figure 9. Final designed antenna detail

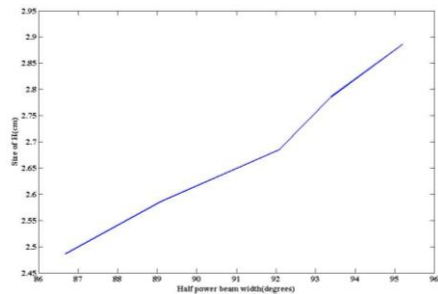


Figure 7. Half power beamwidth vs. Size of H



Figure 10. Photograph of antenna

interference from the side antenna, and radiation patterns. Figure 11 shows the simulated and measured S11 for the designed antenna, as shown in Figure 10. As can be seen, the simulated and measured S11 at 2.45 GHz is -39.96 dB and -33.76 dB, respectively. In addition, the simulated and measured S11 below -10 dB can cover the frequencies from 2.05 to 2.74 GHz and from 2.12 to 2.68 GHz, respectively. Moreover, the designed antenna covers the 2.4 GHz band (2.4-2.484 GHz). According to the simulation and measurement results, the S11 is in good agreement.

Figure 12 shows S21 at 2.4 GHz where S21 is the received power at the 1st antenna. We can see that the average of S21 is -52 dB for the simulation and -46 dB for the measurement. Figures 13 and 14 present both the simulated and measured radiation pattern for 4 antennas at 2.4 GHz for the E-plane and H-plane, respectively. The simulated and measured gain of the antenna is 4.67 dB and 4.45 dB, respectively.

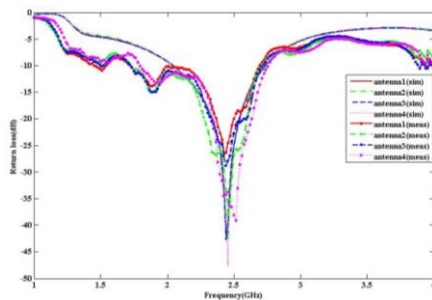


Figure 11. S11 of designed antenna from simulation and measurement

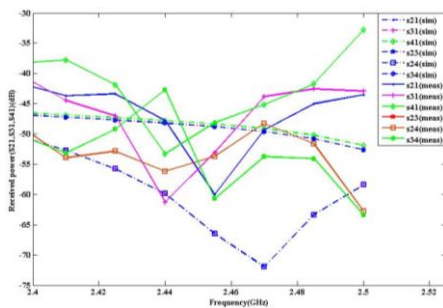


Figure 12. Received power at 1st antenna from simulation and measurement

Moreover, Figure 15 shows the sector antenna that provides full 360 degrees coverage up to 3 dB for the simulation and up to 4 dB for the

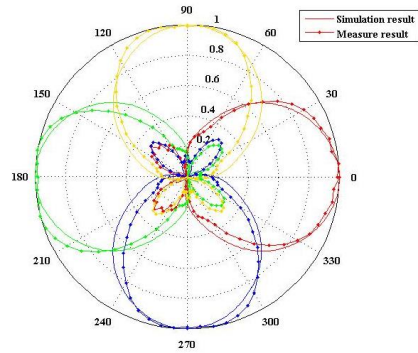


Figure 13. Radiation pattern (E-plane) from simulation and measurement

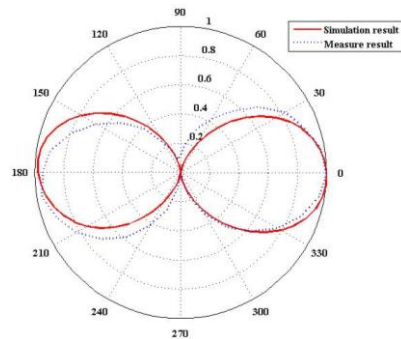


Figure 14. Radiation pattern (H-plane) from simulation and measurement

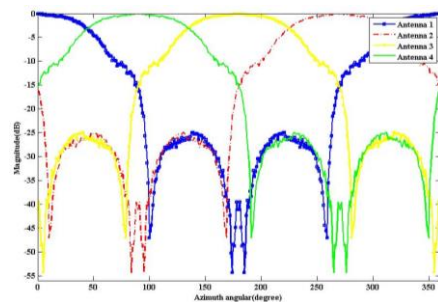


Figure 15. Combined antenna pattern of 4 sector antennas

measurement. We can observe that they are in good agreement as we can have a low back lobe.

In this paper, the obtained results are the return loss, interference from the side antenna, and radiation pattern. The obtained results of the designed antenna are in good agreement. In addition, this designed antenna has full 360 degrees coverage and low self-interference for the side antenna.

Conclusions

We have presented the simulation and measurement results for the sector antenna which can be fabricated on a single-layer FR4. The proposed antenna has a size of $19.6 \times 19.6 \text{ cm}^2$. The return loss of the designed antenna covers the 2.4 GHz -band (2.4-2.484 GHz). The results have presented the antenna that has full 360-degree coverage with 4 sector antennas and a low back lobe. The obtained results of the designed antenna are in good agreement between the simulation and measurement. In addition, the measured radiation patterns have a resemblance to the simulated patterns. The designed antenna has been proposed for a 4-sector node and the results show excellent suitability for WLANs.

Acknowledgment

This work was supported by Suranaree University of Technology, Thailand.

References

- Au, E. (2016). The latest progress on IEEE 802.11 mc and IEEE 802.11ai [Standards]. *IEEE Veh. Technol. Mag.*, 11(3):19-21.
- Blaunstein, N. and Christodoulou, C. (2006). *Radio Propagation and Adaptive Antennas for Wireless Communication Links: Terrestrial, Atmospheric and Ionospheric*. Wiley and Sons, Hoboken, NJ, USA, 614p.
- Chan-arpas, P., Denti, S., and Phongcharoenpanich, C. (2014). Dual-band dual-pattern truncated-corners microstrip antenna for GPS and WiFi applications. *Proceedings of the 20th Asia-Pacific Conference on Communication*; October 1-3, 2014; Pattaya, Thailand, p. 438-441.
- Constantine, A.B. (2005). *Antenna Theory: Analysis and Design*. Microstrip Antennas. 3rd ed. John Wiley & Sons, Hoboken, NJ, USA, 1136p.
- Haraz, O.M. and Sebak, A.R. (2011). Quadband planar PCB antenna for WLAN and mobile WiMAX applications. *Proceedings of the IEEE International Symposium on Antennas and Propagation*; July 3-8, 2011; Spokane, WA, USA, p. 416-418.
- Kaswiati, W. S. and Suryana, J. (2012). Design and realization of planar bow-tie dipole array antenna with dual-polarization at 2.4 GHz frequency for Wi-Fi access point application. *Proceedings of the 7th International Conference on Telecommunication Systems, Services, and Applications*; October 30-31, 2012; Bali, Indonesia, p. 218-222.
- Keeratipianlerd, K. Uthansakul, P., Uthansakul, M., and Sriployp, P. (2017). Unpublished data. Suranaree University of Technology, Nakhon Ratchasima, 30000, Thailand.
- Kim, M. and Choi, C.H. (2013). Hidden-node detection in IEEE 802.11n wireless LANs. *IEEE T. Veh. Technol.*, 62(6):2724-2734.
- Korakis, T., Jakllari, G., and Tassioulas, L. (2008). CDR-MAC: A protocol for full exploitation of directional antennas in ad hoc wireless networks. *IEEE T. Mobile Comput.*, 7(2):145-155.
- Lai, M.I., Wu, T.Y., Hsieh, J.C., Wang, C.H., and Jeng, S.K. (2008). Compact switched-beam antenna employing a four-element slot antenna array for digital home applications. *IEEE Transactions Antenn. Propag.*, 56(9):2929-2936.
- Mahlaoui, Z., Latif, A., Hussaini, A.S., Elfergani, I.T.E., Ali, A., Mirza, F., and Abd-Alhameed, R. A. (2015). Design of a Sierpinski patch antenna around 2.4 GHz/ 5GHz for WiFi (IEEE 802.11n) applications. *Proceedings of Internet Technologies and Applications (ITA)*; September 8- 11, 2015; Wrexham, UK, p. 472-474.
- Patron, D., Daryoush, A.S., and Dandekar, K. R. (2014). Optical control of reconfigurable antennas and application to a novel pattern-reconfigurable planar design. *J. Lightwave Technol.*, 32(20):3394-3402.
- Wnuk, M. and Nowosielski, L. (2016). Multisystem antenna for applications in WiFi networks. *Proceedings of the 10th European Conference on Antennas and Propagation*; April 10- 15, 2016; Davos, Switzerland, p. 1-3.
- Yassin, A.A., Saeed, R.A., and Mokhtar, R.A. (2014). Dual-band microstrip patch antenna design using C-slot for WiFi and WiMax Applications. *Proceedings of the International Conference on Computer and Communication Engineering*; September 23- 25, 2014; Kuala Lumpur, Malaysia, p. 228-231.