INTL JOURNAL OF ELECTRONICS AND TELECOMMUNICATIONS, 2017, VOL. 63, NO. 4, PP.405-408
Manuscript received November 21, 2016; revised September, 2017. DOI: 10.1515/eletel-2017-0056

A Dual-Band Single-Feed Switched Beam Antenna for WLAN

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***Abstract*—This article presents the dual-band of a single patch antenna that can operate at a frequency of 2.47 to 5.04 GHz, which is available in WLANs (IEEE 802.11). The beam pattern of the antenna can be switched by changing the position of shorted-circuit points at each edge of the antenna. The advantage of the proposed antenna is that it is a simple structure which is small in size, weighs little and has an easily adjustable beam. In addition, the antenna is tested under real circumstances using the existing WLAN infrastructure. The results confirm that the signal strength can be improved when the proposed switched beam antenna is utilized.**

***Keywords*—dual-band, single-feed, switched-beam antenna, shorted circuit, signal strength**

I. INTRODUCTION

NOWADAYS, wireless communication technologies are a part of daily life. The demand for wireless communication has rapidly increased. Therefore, the wireless system needs a higher frequency spectrum to manage this tremendous demand. However, the available frequency spectrum is currently limited. One technique that can increase the wireless system capacity without changing the frequency spectrum is a smart antenna technique [1]. The smart antennas are constituted by multiple element antennas accompanied by suitable signal processing units, either at the transmitter or receiver side of a communication link. The term beamforming means pointing the antenna beam towards a desired user and nulls or low side lobes towards interfering sources. According to this, the smart antennas are capable of considerably improving the quality of signal transmission in a multi user environment.

Wireless Local Area Network (WLAN) is one of a category of wireless communications that is used extensively. The IEEE 802.11b/g standards use the 2.4 frequency band while the IEEE 802.11a standard uses the 5 GHz frequency band. IEEE 802.11n standard uses a dual frequency band (2.4 GHz and 5 GHz). To support all IEEE 802.11 standards and increase the capacity of the systems, many types of switched beam antenna are proposed. The antenna that is a simple structure, small in size and suitable for mobile terminals is the most interesting.

There are some examples from literature concerning a dual band switched beam antenna using a single element. The work presented in [2] has shown that an antenna can operate at 2.45 GHz and 5.8 GHz. The beam pattern can switch in two directions by changing the position of the feeding point, likewise in the work of [3], in which the antenna operated at 2.4 GHz and 5.2 GHz. Also the works presented in [4-6] have proposed a dual band, low-profile, switched beam square loop antenna with capacitively coupled feeds, a dual-band low-profile capacitively coupled beam-steerable square-loop antenna and a low-profile switched-beam dual-band capacitively coupled square loop antenna. The antennas were developed to operate at 3.1 GHz and 3.8 GHz frequency bands for the work of [4] 3.8 GHz and 4.7 GHz frequency bands for the work of [5] and 4.1 GHz and 5.2 GHz frequency bands for the work of [6]. The antennas can steer beams in four different quadrants using four vertical feeding probes by four rectangular feeding patches. However, beams can also be switched by changing the feeding point. This is not considered practical as the feeding network is relatively complicated. The works of [7-8] have revealed a low profile antenna which is capable of beam switching in two directions and eight directions, respectively. They antenna is a simple structure using a single-layer printed circuit board. Beams can be switched by a shorted circuit at each edge of the antenna. Nevertheless, they can operate only on the single frequency band. Therefore, this article proposes a dual-band switched beam antenna with the antenna designed to support WLAN frequency bands. Moreover, it’s a low profile structure, only using a single feed. It is a simple beam, switchable by a shorted circuit at each edge of the patch antenna.

The rest of this article is as follows. After a brief introduction, configuration of the proposed antenna is discussed in section II. The simulation and experimental results are revealed and analyzed in section III. Next, the measured results obtained from testing the fabricated antenna under real circumstances, having a WLAN operation are shown in section IV. Finally, section V concludes the article.

II. CONFIGURATION OF THE ANTENNA

In this article, the advantages of the antenna from the work presented in [2] are adopted due to its simplicity and its ability to operate on a dual band. However, beam switching is simplified using only a single feeding point. From the work of [2] the square patch of each frequency is sized by

$$\lambda_d = \frac{\lambda}{\sqrt{\varepsilon_r}} \tag{1}$$

where ε_r is the dielectric constant of substrate. Therefore, there are two patches which operate two frequencies on a single antenna. Two microstrip transmission lines are shorted between these two patches, the length and width of lines are *a* and *b*, respectively. According to this, the size and structure of

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This work was supported by the Faculty of Engineering, Srinakharinwirot University, Thailand [364/2015, 2015].

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the proposed antenna in this article is also based on the work of [2]. However, the size of patches, *a* and *b* are varied due to changing the position of the feeding point and the thickness of the substrate. Then antenna configuration of the completed design is shown in Fig. 1 in which a patch, working at 5 GHz, has a width of 30.32 mm, a patch working at 2.45 GHz which has a width of 89.02 mm, *a* of 2.59 mm, *b* of 8.45 mm and a substrate thickness of 1.6 mm. To switch beam pattern, each edge of the antenna has a shorted circuit, three shorted positions of each edge are 30 mm apart. In Fig. 1, right edge and left edge of the patch are shorted circuit to beam steerable.

In the next Section, the results in term of S_{11} and radiation patterns of dual-frequency are revealed. The results from the experimental data are compared with the ones obtained from simulation.

III. THE SIMULATION AND EXPERIMENTAL RESULTS

The designed antenna is simulated using CST Microwave Studio at 2.45 GHz and 5 GHz, the structure is shown in Fig. 2. S_{11}, from simulation, is shown in Fig. 3 with the lowest value at 2.47 GHz and 5.04 GHz are 27.98 dB and 24.88 dB, respectively. As we can see, the center frequencies are slightly shifted. Next, the radiation pattern can be separated into two cases providing two different directions. First, the beam pattern can be switched by a shorted circuit on the left and right edges of the antenna, namely case A. The other is case B which is a shorted circuit on the top and bottom edges of the antenna. The radiation patterns at 2.47 GHz and 5.04 GHz of case A are shown in Fig. 4 (a). Also, the radiation patterns at 2.47 GHz and 5.04 GHz of case B are shown in Fig. 4 (b). As we can see, when the edges, which has a low current distribution of the antenna, are a shorted circuit, the beam pattern is switched in different directions of shorted-positions. In addition, radiation patterns of case A and case B are similar. This is due to the configuration of the antenna being symmetrical. However, the main beam directions are different because of the different positions of the shorted circuit. Therefore, beam pattern of the proposed antenna can be switched in two different directions, the directions of case A are 90° and 270° while the directions of case B are 0° and

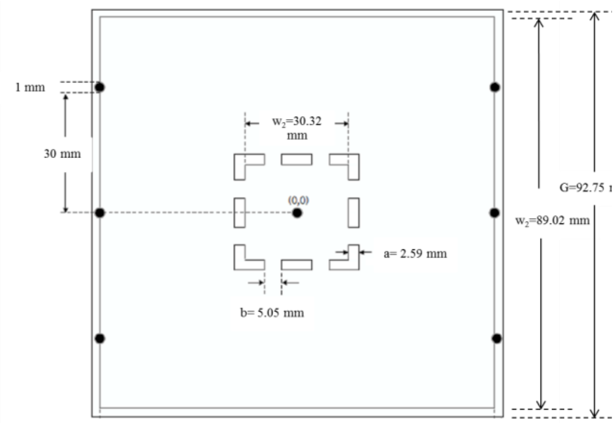


Fig. 1. The antenna configuration.

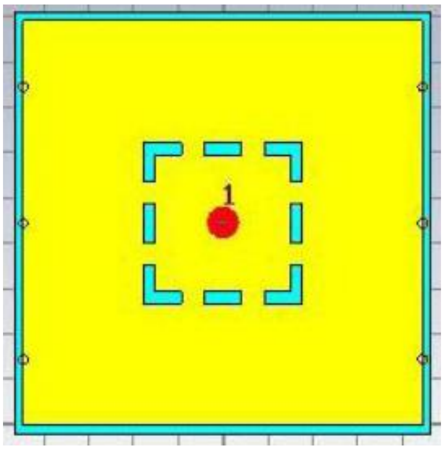


Fig. 2. The structure of antenna from simulation.

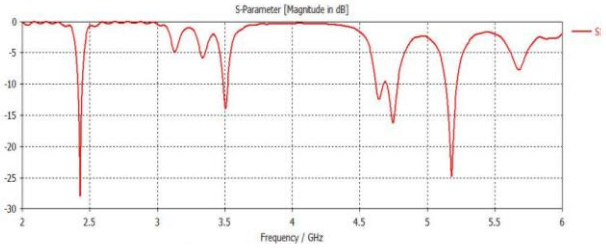
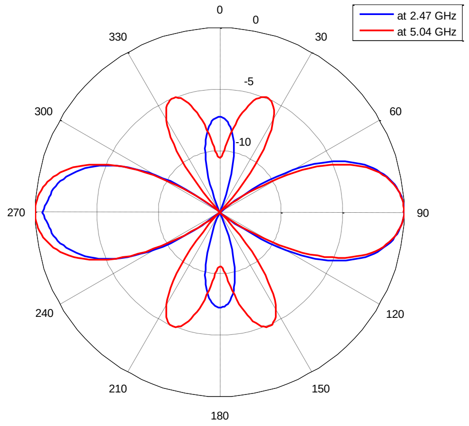
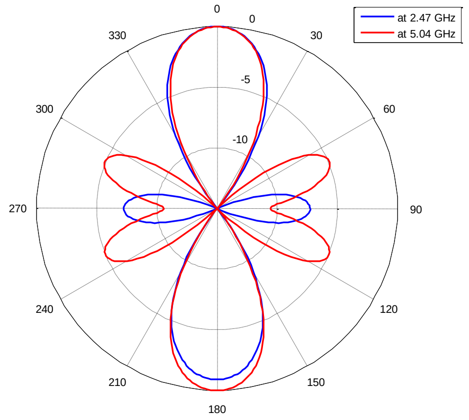


Fig. 3. S_{11} from simulation.



(a)



(b)

Fig. 4. The radiation patterns from simulation at 2.47 GHz and 5.04 GHz of (a) case A and (b) case B.

180°.

Next, the proposed antenna is constructed and tested to demonstrate its beam steering capability. The designed antenna is fabricated using a single-layer printed circuit board, using FR4-substrate with a dielectric constant of 4.5 as the structure of case A shows in Fig. 5. The SMA connector is attached from one side through another side at the patch center. S_{11} and radiation patterns are measured using a network analyzer. S_{11} from measurement is shown in Fig.6. It is 13.025 dB and 20.868 dB at 2.47 GHz and 5.05 GHz, respectively. The radiation patterns at 2.47 GHz and 5.04 GHz in case A are shown in Fig. 7(a). Also, the radiation patterns at 2.47 GHz and 5.04 GHz in case B are shown in Fig. 7 (b). As we can see, the simulation results have a good agreement with the ones from the measurement. Moreover, S_{11} is moderately comparable and beam directions are also relatively similar. The average measured gains for the two cases are 2.6 dBi and 7.5 dBi for frequencies of 2.47 GHz and 5.04 GHz, respectively. However, the sidelobes of 5.04 GHz are slightly different. This may be caused by a manufacturing error. However, the proposed antenna is able to confirm its beam switching capability.

The next section focuses on confirming the performance of the proposed switched beam antenna. The antenna is tested under real circumstances in transmitting real WLANs signals comparing that with the use of omnidirectional antenna and the antenna which is embedded in a computer notebook.

IV. THE PERFORMANCE FROM FABRICATED ANTENNA

The fabricated antenna is tested under real circumstances in existing WLAN operations at the 1st level of the Department of Electrical Engineering, Srinakharinwirot University. The layouts of testing at this department are shown in Fig. 8 and Fig. 9 for frequencies of 2.47 GHz and 5.04 GHz, respectively. Please note that the access point which operates at 5 GHz is limited. Therefore, positions of testing for both frequencies are different. The signal strength recorded in the computer notebook is shown in Fig. 10. The measured signal strength at 2.47 GHz is shown in Table I. There are 15 points of measurement (1-15) which were chosen as being measuring locations as is shown in Fig. 8. The comparison between using the proposed antenna, omnidirectional antenna and embedded antenna is revealed. The value in bold represents the maximum signal strength in each case. As we can see, the signal strength with the proposed antenna is generally stronger than with other antennas. A few positions have lower signal strength by employing an omnidirectional antenna because of the position of the access point being located between main beams in the two cases. However, utilization of the proposed antenna in most positions provide a higher signal strength than the others. In addition, the signal strength of each channel that operates in Thailand is measured. Also, the comparison of three antenna types is shown in Table II. As we can see, signal strength is always higher than the others when the proposed antenna is utilized. Moreover, the signal power at 2.47 GHz and the signal power of each channel that operates in Thailand

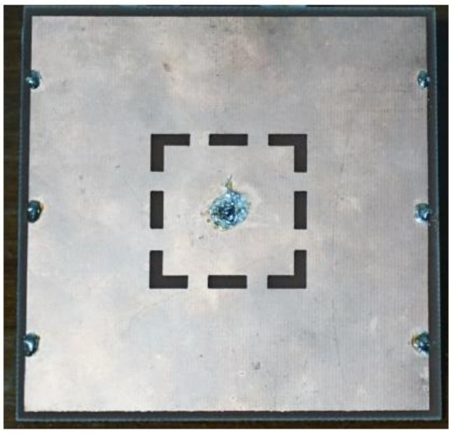
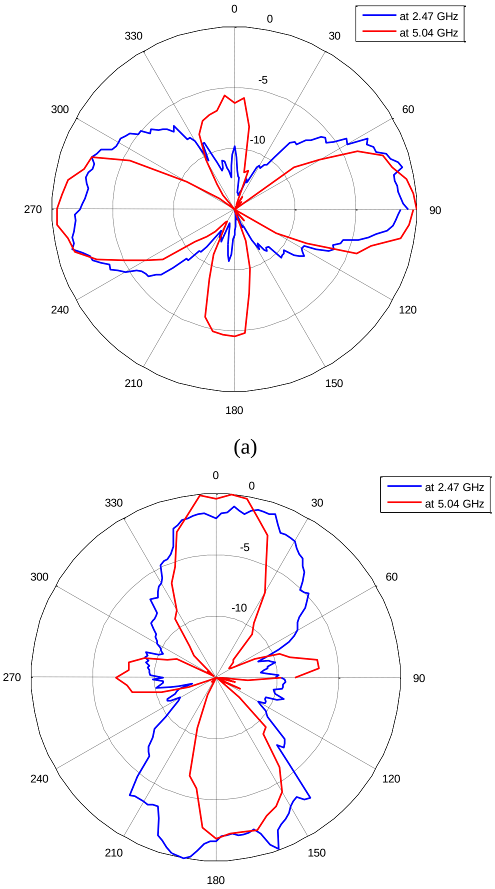


Fig. 5. The fabricated antenna.

Fig. 6. S_{11} of fabricated antenna.



(a)

(b)

Fig. 7. The radiation patterns from experimental at 2.47 GHz and 5.04 GHz of (a) case A and (b) case B.

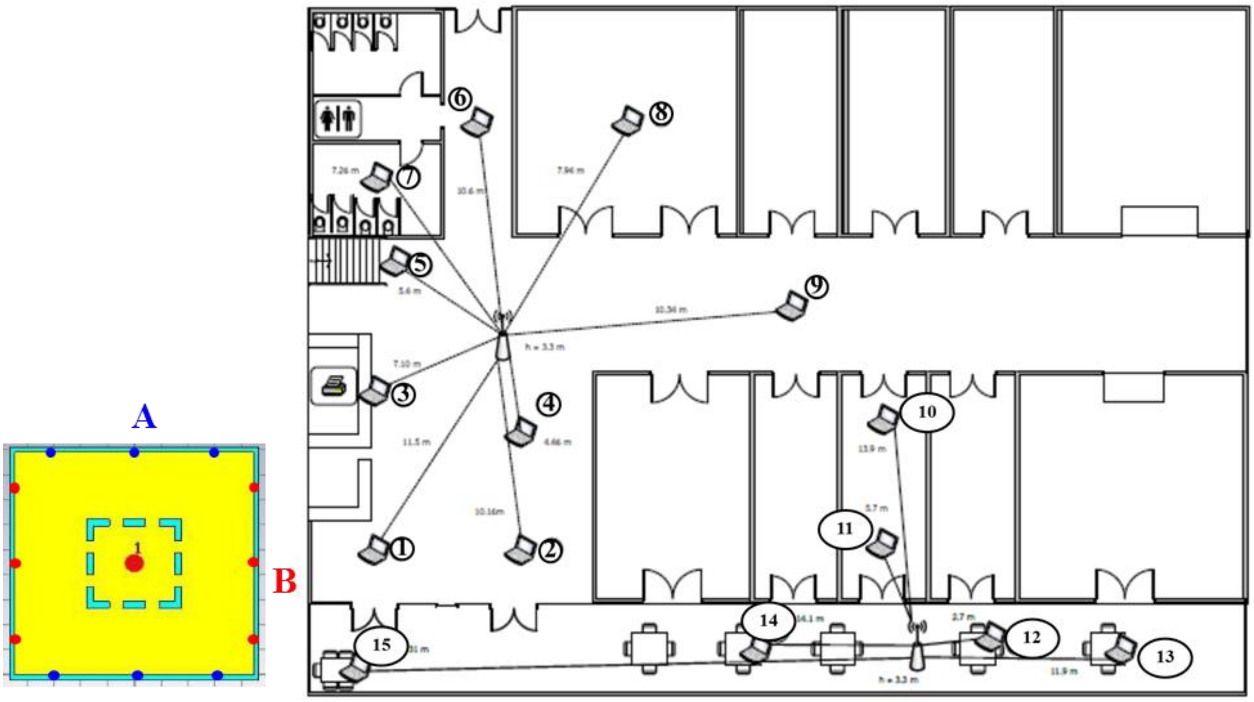


Fig. 8. The layout of testing at the department of electrical for frequencies of 2.47 GHz.

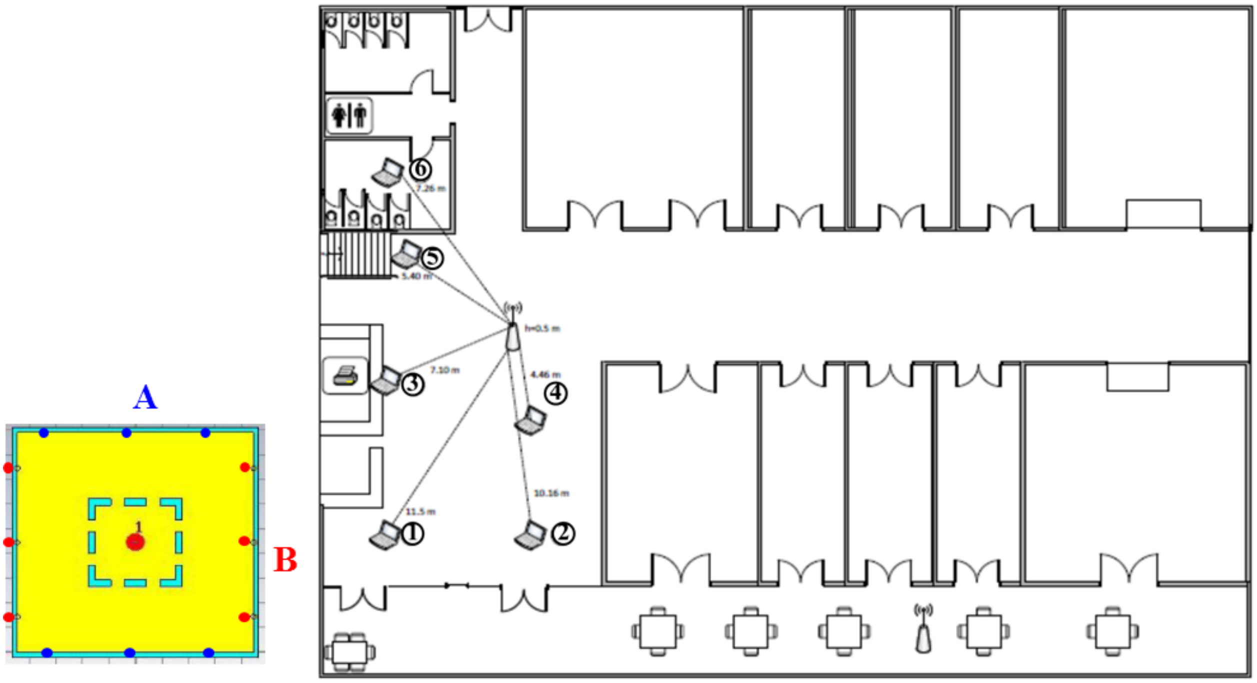


Fig. 9. The layout of testing at the department of electrical for frequencies of 5.04 GHz.

are measured using spectrum analyzer to confirm the performance of the proposed switched beam antenna as shown in Fig. 11. In the measurement setup, case A means that main beam of the proposed antenna is directed to the transmitted antenna which is connected with signal generator. Also, side lobe of the proposed antenna is directed to the transmitted antenna that prefers to case B. The comparison between using the proposed antenna and omnidirectional antenna are shown in Table III. The results can confirm that the proposed antenna provides a higher signal strength than the omnidirectional antenna when main beam is directed to the transmitter. Moreover, signal strength at 5.04 GHz is also measured and compared with the one obtained from an omnidirectional antenna. The results from laptop are shown in Table IV. There are 6 points of measuring (1-6) which are chosen as being measuring locations, as is shown in Fig. 9. Signal strength, which is measured with each channel, are compared and shown in Table V. Please note that the signal strength when

Fig. 10. Measurement setup under existing WLAN infrastructure.

TABLE I
THE MEASURED SIGNAL STRENGTH AT 2.47 GHZ

Position	Signal Strength			
	embedded antenna	omni-directional antenna	The proposed antenna	
			case A	case B
1	**-73**	**-65**	**-61**	-63
2	**-76**	**-61**	-63	**-59**
3	**-71**	**-63**	**-62**	-65
4	**-64**	**-57**	-58	**-55**
5	**-74**	**-67**	**-69**	**-69**
6	**-70**	**-54**	-57	**-53**
7	**-88**	**-67**	**-69**	**-69**
8	**-80**	**-75**	**-73**	-75
9	**-78**	**-61**	**-61**	-63
10	**-73**	**-63**	-65	**-62**
11	**-72**	**-53**	-55	**-52**
12	**-55**	**-47**	**-47**	-51
13	**-49**	**-39**	**-37**	-39
14	**-63**	**-49**	**-49**	-52
15	**-69**	**-65**	**-64**	-66

Fig. 11. Measurement of signal power using spectrum analyzer.

employing an embedded antenna on a computer notebook cannot be compared due to the embedded antenna only being able to operate on a single band at 2.45 GHz. As we can see, the proposed antenna always provides a higher signal strength compared with the one obtained from an omnidirectional antenna. Also, the results form spectrum analyzer at 5.04 GHz and each channel that operates in Thailand are shown in Table VI. As we can see, the proposed antenna provides a higher signal strength than the other. Therefore, we can confirm that the proposed switched beam antenna improves the performance of the systems in dual frequency bands.

TABLE II
THE MEASURED SIGNAL STRENGTH OF EACH CHANNEL AT 2.47 GHZ

Channel (GHz)	Signal Strength			
	embedded antenna	omni-directional antenna	The proposed antenna	
			case A	case B
1 (2.401 - 2.423)	**-47**	**-29**	-29	**-27**
2 (2.406 - 2.428)	**-49**	**-33**	**-24**	-27
3 (2.411 - 2.433)	**-47**	**-35**	**-27**	**-27**
4 (2.416 - 2.438)	**-46**	**-31**	-29	**-26**
5 (2.421 - 2.443)	**-45**	**-33**	**-29**	-30
6 (2.426 - 2.448)	**-40**	**-33**	**-28**	-31
7 (2.431 - 2.453)	**-40**	**-33**	**-26**	-29
8 (2.436 - 2.458)	**-42**	**-35**	**-29**	**-29**
9 (2.441 - 2.463)	**-40**	**-33**	**-29**	**-29**
10 (2.446 - 2.468)	**-40**	**-31**	-31	**-30**
11 (2.451 - 2.473)	**-48**	**-33**	**-26**	-28

TABLE III
FREQUENCY SPECTRUM AT 2.47 GHZ AND EACH CHANNEL USING SPECTRUM ANALYZER

Frequency (GHz)	Signal Power (dBm)		
	omni-directional antenna	The proposed antenna	
		case A	case B
2.47	-55	-51	-53
1 (2.401 - 2.423)	-56	-54	-56
2 (2.406 - 2.428)	-57	-55	-56
3 (2.411 - 2.433)	-57	-54	-56
4 (2.416 - 2.438)	-53	-51	-53
5 (2.421 - 2.443)	-54	-51	-53
6 (2.426 - 2.448)	-53	-51	-52
7 (2.431 - 2.453)	-53	-52	-53
8 (2.436 - 2.458)	-55	-50	-52
9 (2.441 - 2.463)	-53	-49	-52
10 (2.446 - 2.468)	-55	-49	-52
11 (2.451 - 2.473)	-54	-51	-53

V. CONCLUSION

This article has proposed a dual-band switched beam antenna for WLAN users. This single patch can operate dual frequency bands, 2.47 GHz and 5.04 GHz, and is capable of beam switching for two different directions. Beam pattern can be switched by shorted-circuits at edges of the patch. Its beam-switching capability has been confirmed through simulation and measurement. Moreover, the antenna is tested under real circumstances having a WLAN operation to confirm the improvement in performance of both frequencies. The advantages of the proposed antenna are that it is a simple structure, easy to perform beam switching and it can operate dual-band on only a single patch.

TABLE IV
THE MEASURED SIGNAL STRENGTH AT 5.04 GHZ

Position	Signal Strength		
	omni-directional antenna	The proposed antenna	
		case A	case B
1	**-65**	**-60**	**-60**
2	**-65**	-60	**-58**
3	**-66**	**-60**	-62
4	**-61**	-53	**-49**
5	**-64**	**-52**	-54
6	**-84**	**-72**	-77

TABLE V
THE MEASURED SIGNAL STRENGTH OF EACH CHANNEL AT 5.04 GHZ

Channel (GHz)	Signal Strength		
	omni-directional antenna	The proposed antenna	
		case A	case B
149 (5.735 -5.755)	**-51**	**-45**	**-45**
153 (5.755 -5.775)	**-50**	-46	**-44**
157 (5.775 -5.795)	**-54**	**-45**	-47
161 (5.795 -5.815)	**-53**	**-45**	**-45**

TABLE VI
FREQUENCY SPECTRUM AT 5.04 GHZ AND EACH CHANNEL USING SPECTRUM ANALYZER

Frequency (GHz)	Signal Power (dBm)		
	omni-directional antenna	The proposed antenna	
		case A	case B
5.04	-52	-47	-49
149 (5.735 -5.755)	-50	-45	-47
153 (5.755 -5.775)	-53	-46	-49
157 (5.775 -5.795)	-53	-47	-49
161 (5.795 -5.815)	-52	-48	-50

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