https://doi.org/10.24191/jeesr.v27i1.017

New Approach of Microstrip Antenna Integrated with Parasitic Element for Dual Function Application

Hamizan Yon*, Nurul Huda Abd Rahman, Mohd Aziz Aris, Suhaila Subahir and Robi'atun Adayiah Awang

***Abstract*—Light Emitting Diode (LED) as parasitic element integrated with microstrip antenna in order to improve gain and enhanced antenna functionality has been studied in this research works. The antenna design has been simulated and developed to resonant at 2.45GHz due to rapid development in this frequency for Wi-Fi application. Simulation works have been done using Computer Simulation Technology (CST) to design the antenna. The FR-4 substrate with permittivity, εr = 4.3 and thickness, h = 1.6mm has been used and the surface mount device (SMD) LED is used to completed the simulation process. The stacked antenna consists of three layers substrate where the LEDs as parasitic are located on the top layer with the parallel connection. The radiating patch has been designed located on the second substrate. Meanwhile, ground plane and feed line are located on the bottom substrate. Simulated and measured results was compared to identify the feasibility of proposed integrated antenna. The simulation results have shown that the antenna works well with the integrated LED giving 4.22dBi gain, -25.16dB return loss and 100MHz bandwidth while 3.35dBi gain, -17.79dB return loss and 90MHz bandwidth design without LED placement. The antenna was measured using Vector network analyzer (VNA) and Anechoic chamber. The result of simulation and measurement shows that antenna potentially provides a new opportunity to introduce multi functionality device**

***Index Terms*—CST, FR4, , LED, Rectangular Microstrip Patch Antenna, VNA and Wi-Fi**

I. Introduction

Development of integrated antenna in order to works with multi-function characteristic had been widely studied nowadays [1], [2]. Currently, plasma antenna [3], [4] is one of the antennas that have dual function development in wireless communication technology especially an indoor Wi-Fi communication as an antenna and at the same time as illumination sources. However, plasma antenna technology has limitation due to expensive and difficulties to manufacture [5]. Meanwhile, plasma requires energy to be ionized and the gas is more complex and expensive. The volume of mercury in plasma also can harm the safety and not support green technology. Developing antenna with same capabilities and low cost and at the same time support, green technology is much more needed.

LED is known as the semiconductor device that can emit light. It has many advantages compared with other traditional light sources, such as long life expectancy, high-efficiency light sources, low maintenance, low power consumption and generally very robust and environmentally friendly [6], [7]. The structure of LED itself is in principle, can be integrated with other product to create a new multifunctional product. In the communication field, the integration LED with the antenna has a potential of dual functionality device, as transmission and reception medium for the wireless network and simultaneously as a light source [5], [8]–[10]. However, the feasibility of this integrated design is still continuously investigated due to the copper conductor on the LED that can affect the performance of the antenna.

Designing antenna integrated with LED using the series LED connection has been studied [5], [8]–[10]. However, using the series connection for LED power line will require high voltage input to turning ON the LED. In this paper, the integration of antenna with the parallel LED connection is studied. The stacked configuration has been reported, has been developed to overcome shifting resonant frequency problem. The simulation has been studied in [11] to design different types of LED circuit connectivity. In this design, the antenna has been designed to resonant at 2.45GHz for Wi-Fi application and the LED works as a parasitic element to improve antenna performance and as illumination sources. The implementation of LED at the top layer of design, for enhancing the performance in term of gain and return loss and at the same time locating the LED structure on the top the antenna structure will sustain the resonant frequency.

II. Theory and Design Analysis

The antenna with LED as parasitic elements in parallel connection is designed as shown in Fig. 1. The antenna is designed on FR4 substrate because of its advantages [12]–[14]. In this research works, FR-4 substrate with permittivity of 4.3 and thickness 1.6mm has been used. LEDs are soldered on the

This manuscript is submitted on 18th June 2025, revised on 19th June 2025 and accepted on 20th June 2025, and published on 31st October 2025. Hamizan Yon*, Nurul Huda Abd Rahman, Mohd Aziz Aris, Suhaila Subahir, and Robi'atun Adayiah Awang are from Faculty of Electrical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia.

*Corresponding author
Email address: hamizan2816@uitm.edu.my

top substrate with the size of substrate fixed at 50mm x 50mm, while patch radiator located on the second substrate. Meanwhile, ground plane and feed line are located on the bottom substrate as shown in Fig. 2.

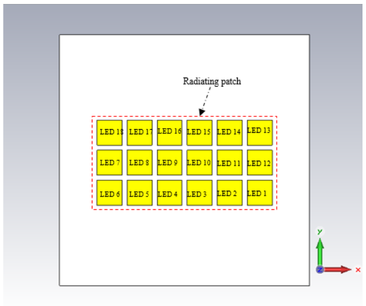


Fig. 1. LED as parasitic on the top antenna structure.

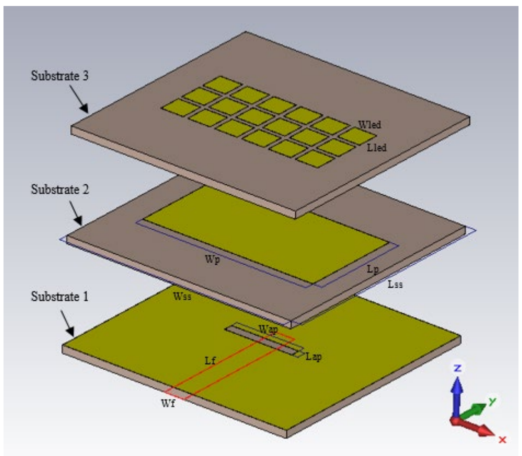


Fig. 2. Exploded view antenna design with ground layer on the bottom substrate 1, substrate 2 with patch structure and on the top layer substrate 3 LED with parallel connection has been design.

The size of patch radiator is determined from numerical analysis using equation [15]–[17] .

TABLE I. PROPOSED ANTENNA PARAMETERS

Parameter	Value (mm)
Width of Substrated,W	50
Width of LED,W1	5
Width of patch,Wp	38
Width of feedline,Wf	4.23
Width of aperture slot,Ws	15
Length of substrated, L	50
Length of LED, L1	5
Length of patch, Lp	22.28
Length of feedline, Lf	30
Length of aperture slot, Ls	2

In this design, the advantages of designing LEDs connection using a parallel configuration is proposedly to reduce the power usage for turning ON the LEDs. The SMD 5050 LED have been chose in this design which is the white LED due to its advantages [5], [7]. Fig. 3 shown LED structure that has been used in this design. 18 LEDs have been located on the top antenna structure in order to developed antenna with multiple application. Optimization of the LED location has been studied using computer simulation software (CST).

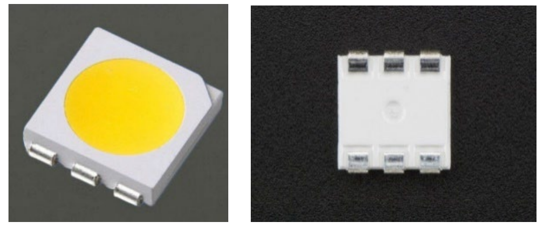


Fig. 3. SMD5050 LED.

Fig. 4 shows a process flow in designing the antenna Design. Enhancement from [5], [11] this intergrated antenna comes with new LED circuit configuration has been designing with parallel connection. The antenna that performed well during the modeling process was selected for fabrication and measurement. Standard measuring antenna procedures were used to measure the prototype antenna design, and the results were recorded for comparison.

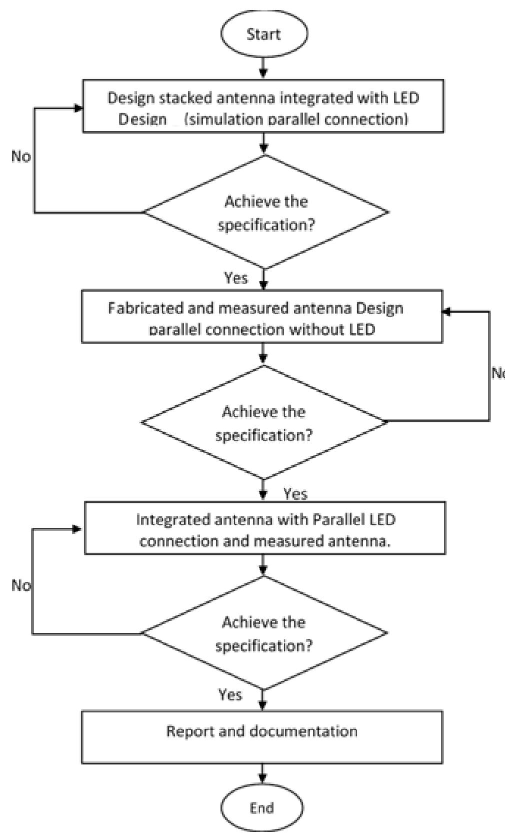


Fig. 4. Flowchat of the antenna development integrated with LED parallel connection.

III. SIMULATION RESULTS

The proposed antenna is simulated using CST simulation software and the simulation of the antenna has been compared with antenna design with and without LED. At the first stages, simulation works was developed to studied and determine (a) suitable LED location in order to sustain the resonant frequency. With this requirement, parametric studies using simulator was done as shows in Fig. 5.

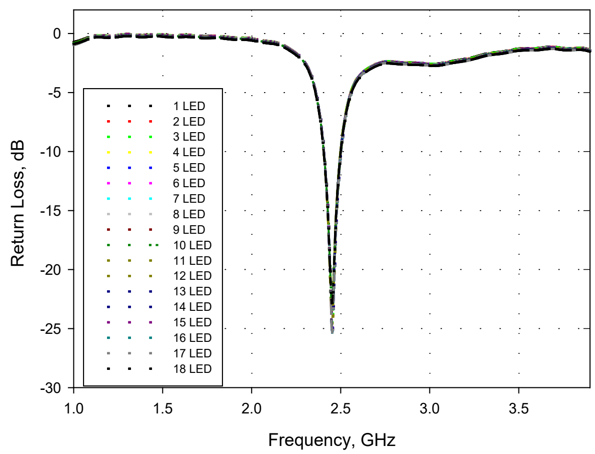
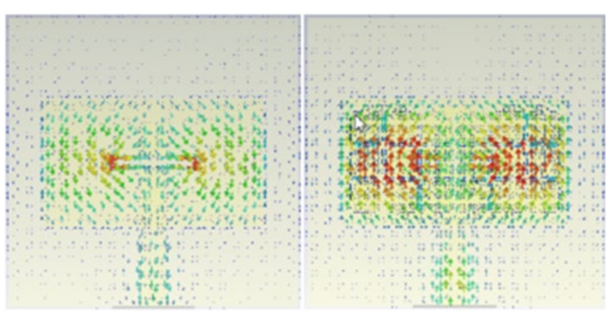


Fig. 5. Parametric study increasing number of LEDs.

As shown in Fig. 5, it is prove that by placing LEDs on the top antennas structure will sustain the resonant frequency. The antenna has achieved consistent frequency reading values starting with LED 1 until LED 18. From the figure it shows that the values of return loss was -25.16dB at 2.45GHz.

Meanwhile, further investigation on antenna structure was done as show in Fig. 6. The figure shows a surface current of antenna design with 18 number of parallel LED connection on the top structure. The antenna results show a good agreement between with and without LED.

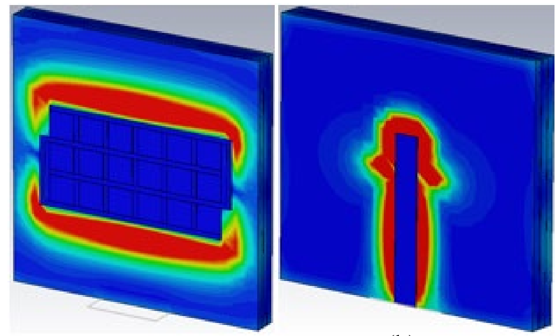


(a) (b)

Fig. 6. Simulation surface current (a) without and (b) with LED.

Fig. 6 (a) shows surface current distribution without LED and (b) with LED. From the figure, it is clear shows that the surface current for an antenna with LED is more as compared to without LED structure. The result shows that by locating LED on that area has improved slightly antenna performance. This improvement is believed due to the increment volume of copper structure on the top antenna structure has more effected to the current from the feeding line source.

Meanwhile, Fig. 7 showing the E-field distribution for antenna design. The figure is shown (a) top layer with 18 numbers of LEDs and (b) antenna feed line. From the figure shows, several of the electric waves will radiate away, and other of the power will be reflected back to the radiating patch towards LED structure in the z-axis.



(a) (b)

Fig. 7. Simulated current distribution (a) top layer with LED and (b) Feed line.

Fig. 8 shown antenna return loss result for both condition, with and without LED structure. The figure is shown good in the result where there is no shifting frequency when the LED is located on the top antenna structure. Furthermore, the return loss, S_{11} for an antenna with LED is higher as compared with without LED. The technique that place LED on the top antenna structure as the parasitic element, will improve the antenna performance without altering the antenna resonant frequency, therefore LED can work equally well on other antenna stack design. The radiation pattern of the antenna is shown in Fig. 8 respectively.

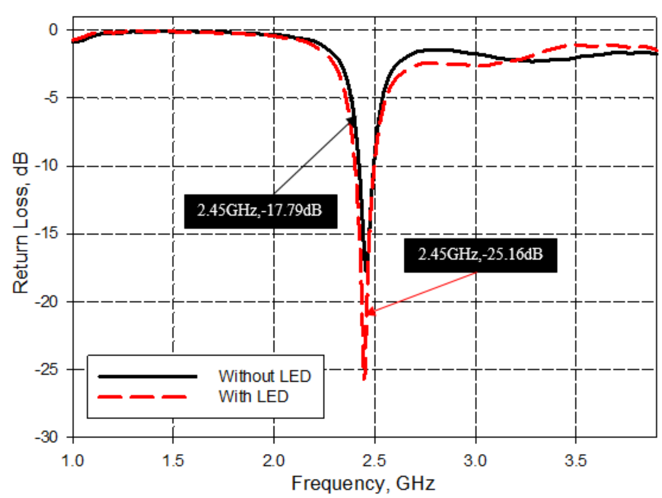


Fig. 8. Simulated result return loss, S11 without and with LED.

From the Fig. 9, it is shown that locating the LED has improved in the antenna gain. Although the figure is shown radiation pattern with a back loop, the front loop is more dominant compared with back loop. The antenna gain has been increased from 3.35dBi without LED to 4.22dBi in the design with LED structure.

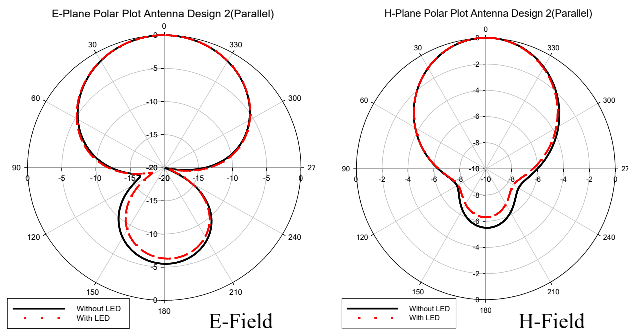


Fig. 9. Polar Plot E-plane and H-plane with and without LED parallel connection.

Meanwhile, Fig. 10 shows the antenna gain comparison in 2-D view and Table II shows the antenna simulation result between without and with LED.

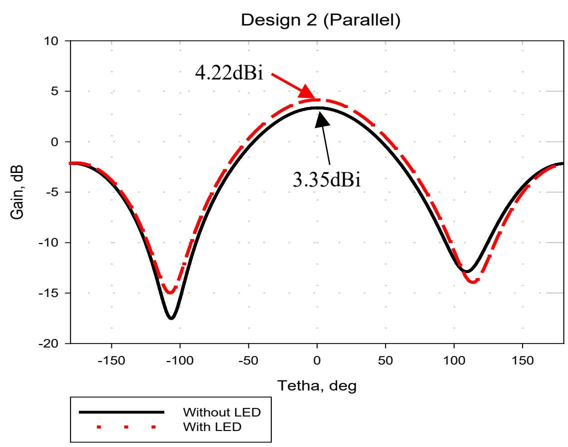


Fig. 10. Simulated gain comparison between with and without LED.

TABLE II . SIMULATION RESULTS

Parameter	Without LED	With LED
Resonant Frequency (GHz)	2.45	2.45
Reflection coefficient, (dB)	-17.79	-25.16
Gain (dBi)	3.35	4.22
Bandwidth (MHz)	75	95.4
Efficiency (%)	64	75

IV. MEASUREMENT RESULTS

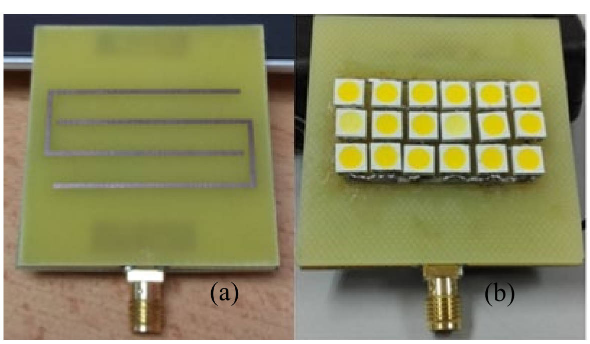


Fig. 11. Prototype antenna design (a) without and (b) with LED.

In this section, the optimized antenna design structure has been fabricated as shows in Fig. 11 and measured the return loss has been carried out using VNA Keysight. The return loss of the integrated antenna comparison between simulation and measurement result was compared in Fig. 12 for without LED and with LED in Fig. 13, respectively. However, in measurement result, the resonant frequency is shifted to the higher frequency from the simulation result about 2% to 2.50GHz. This situation is believed due to improper handling of the fabrication process. On the other hand, return loss value with LED structure is much better as compared to the antenna without LED structure. The corresponding operating bandwidths were 132 MHz without LED and 152MHz on with LED.

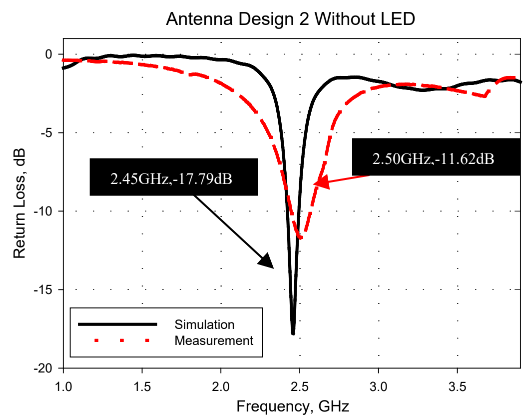


Fig. 12. Return loss result without LED antenna.

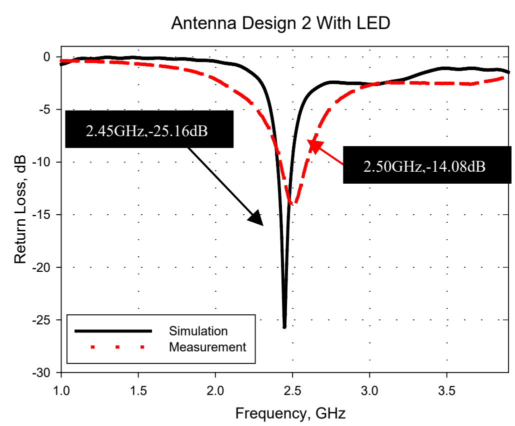


Fig. 13. Return loss result with LED antenna.

Meanwhile Fig. 14, shows a well matched result at the input of antenna where the antenna has been resonant at the same frequency of 2.50GHz, the S_{11} OFF LED is -14.08dB and -16.90dB for ON LED. The corresponding operation bandwidth is 205MHz when LED is ON state and 171MHz at OFF LED state. The result shows the antenna resonant frequency unchanged when turning ON and OFF the LEDs. Meanwhile, the bandwidth is slightly improved when LED is in ON stage, it may be caused due to the current distribution from the LEDs terminal as a parasitic element. Furthermore, the reflection coefficient has been increased slightly in ON LEDs condition.

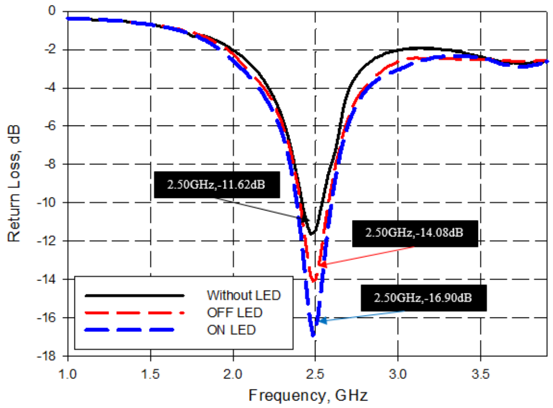


Fig. 14. Measurement return loss antenna ON/OFF condition

The radiation pattern ware measured in an indoor anechoic chamber using the Far-field measurement at operating frequency 2.45 GHz for antenna design. Fig. 15 shows the setup for antenna measurement in order to measure radiation pattern. The setup consists of horn antenna (700MHz to 6GHz) as the transmitter antenna directly connected with Keysight VNA analyzer that has capabilities to measure up to 40GHz. Meanwhile, the antennas is connected to the computer that has been installed with software to read and plotting antenna measured data. The Anechoic chamber was placed radio frequency(RF) absorber in order to minimize reflection signal that can affect the measured result. From the simulation current surface result that has been simulated in Fig. 6, the designing antenna exhibits the dominant wave distribution at E-Plane with a simulated radiation pattern shows that it radiates at 0º angle. Thus, by considering the mentioned factors, the radiation pattern measurement has been held in E-Plane condition. However, the measurement in H-Field also has been done to ensure antenna radiation pattern same as a simulated result.

The normalized E and H-Plane radiation pattern measurement for antenna design are depicted in Fig. 15 for antenna without LED and Fig. 16 for an antenna with LED. From the figure, the far-field radiation pattern, gain and antenna efficiency has been measured in the fully equipped anechoic chamber at operating frequency of 2.45GHz. The measurement of the antenna between without LED and with LED has been measured successfully using anechoic chamber at Antenna Research laboratory.

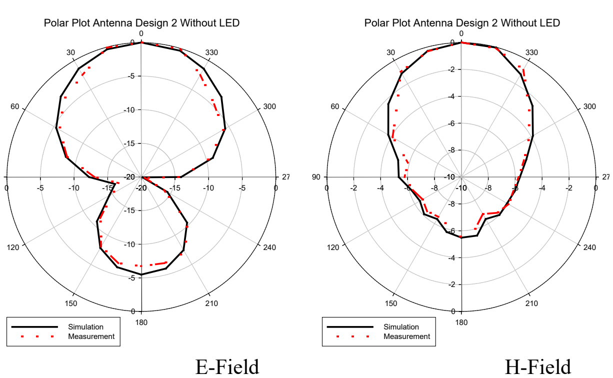


Fig. 15. Radiation pattern without LED

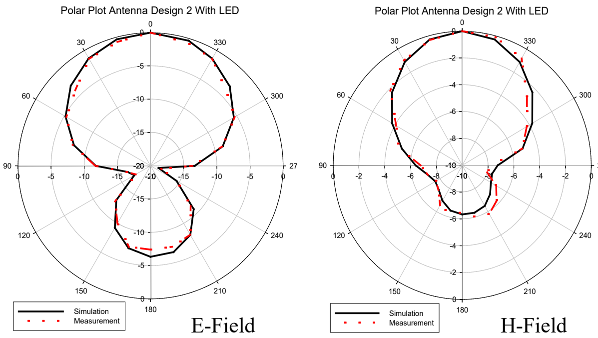


Fig. 16. Radiation pattern with LED

Fig. 15 and Fig. 16 shown two cutting planes of the purposed antenna design radiation pattern with E and H-Plane in order to describe the antenna far-field performance. Form both figure, the measurement pattern agree closely with the simulated result. The measured radiation pattern at the selected frequency is close to the directional radiation pattern.

The measurement result of the prototype antenna design without LED was 3.70dBi in gain at a 2.5GHz operating frequency and with an antenna efficiency of 65.05%. Meanwhile, the antenna gain for an antenna with LED structure slightly increase to 3.92dBi on the same operating frequency with the efficiency of 68.05%. The gains and the antenna efficiency are expectedly dropped from the simulation results due to losses that occurred from the fabricated antenna process and the stacked alignment itself. Meanwhile, Fig. 16 shown antenna radiation pattern in E and H-Plane for measurement result of the purposed antenna in ON and OFF LED.

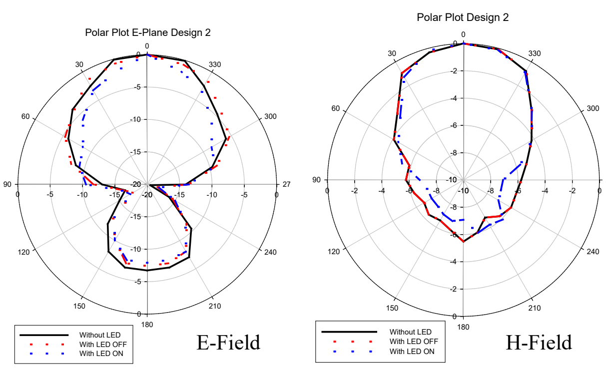


Fig. 17. Radiation pattern ON and OFF LED

Fig. 17 shown antenna performance OFF and ON LED. The figure is shown when antenna ON LED, the gain antenna measured has been slightly increased to 4.19dBi with an antenna efficiency of 70.48%. The antenna gain with LED in ON condition is higher compare with OFF LEDs. The summaries measured value for antenna design is shown in Table III. Meanwhile, Fig. 18 shown the antenna in 3-D view (a) without LED (b) with LED OFF and (c) with LED ON, respectively.

TABLE III. FINAL ANTENNA MEASUREMENT RESULTS

Results	Unit	Without LED	LED OFF	LED ON
Frequency	GHz	2.50	2.50	2.50
Reflection coefficient	dB	-11.62	-14.08	-16.90
Gain	dBi	3.70	3.92	4.19
Bandwidth	MHz	123	171	205
Efficiency	%	65.05	68.05	70.48

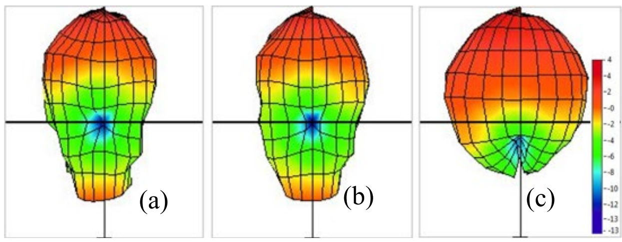


Fig. 18. 3D view (a) without (b) LED OFF and (c) LED ON

V. CONCLUSION

The rectangular stack microstrip patch antenna integrated with LED has been designed and investigated. From this research works, it can be concluded that the designed antenna contributes to dual-function in a device. It can function as an antenna at Wi-Fi application and the same time it gives illumination to the user with improved the overall performance of the antenna with and without LED. The measurement proves that LED can assume as a parasitic element to the antenna and well matched to the patch to improve the gain of the antenna. The final measurements indicate that the antenna operates effectively, it achieving a gain of 4.19 dBi, bandwidth of 205MHz, and an efficiency of 70.48% when the LED is turned ON. The use of the integrated LED in the design supports the green environment and will contribute better in terms of energy consumption. However, future works will be considered to improve this antenna to have better performance for both conditions in terms of gain.

ACKNOWLEDGMENT

The authors would like to thank Universiti Teknologi MARA for sponsoring the work. Express gratitude to the members of the Antenna Research Centre (ARC), College of Engineering, School of Electrical Engineering, Universiti Teknologi MARA for supporting the research work

REFERENCES

[1] B. Fu, H. Cheng, S. Pan, W. Shen, and G. Li, "A Multi-band and Multi-functional Conformal Array Antenna," *Proc. IEEE Radar Conf.*, vol. 2021-December, pp. 2723–2727, 2021, doi: 10.1109/Radar53847.2021.10028621.

[2] H. Liao, X. Luan, and J. Fan, "Multi-function Antenna Based on CRLH- TL for Navigation and Mobile Communication Applications," *2022 Int. Conf. Microw. Millim. Wave Technol. ICMMT 2022 - Proc.*, no. 1, pp. 1–3, 2022, doi: 10.1109/ICMMT55580.2022.10023312.

[3] M. Jha, N. Panghal, R. Kumar, and S. K. Pathak, "Reconfigurable Plasma Antenna Array for Beamsteering Application at S-band," *2022 IEEE Microwaves, Antennas, Propag. Conf. MAPCON 2022*, pp. 1403–1406, 2022, doi: 10.1109/MAPCON56011.2022.10047047.

[4] H. Ja'afar, M. T. B. Ali, A. N. B. Dagang, H. M. Zali, and N. A. Halili, "A Reconfigurable Monopole Antenna with Fluorescent Tubes Using Plasma Windowing Concepts for 4.9-GHz Application," *IEEE Trans. Plasma Sci.*, vol. 43, no. 3, pp. 815–820, 2015, doi: 10.1109/TPS.2015.2398878.

[5] suhaila subahir Hamizan yon, aziati husna awang, mohd tarmizi ali, "Development of stacked antenna integrated with ring configuration LED for wi-fi application," *Proceeding 2017 Asia Pasific Microw. Conf.*, pp. 5–8, 2017.

[6] N. O. Tippenhauer, D. Giustiniano, and S. Mangold, "Toys communicating with LEDs : Enabling Toy Cars Interaction," pp. 48–49, 2012.

[7] B. Weir, "High Brightness LED Driver Solutions for General Lighting World of Lighting," *Semicond.*, pp. 1–63, 2009.

[8] S.subahir, M.s.amari, M.t.ali, and S.n.kamarudin, "rectangular spiral microstrip patch antenna integrated with LED for wifi application," in *2nd international symposium on telecommunication technologies(ISTT)*, 2014, vol. 1, pp. 76–79.

[9] S. Subahir, M. K. Marzuki, M. T. Ali, A. H. Awang, U. Teknologi, and M. Uitm, "Integration Diamond Shape Antenna with SMD Light Emitting Diode," *IEEE Int. RF Microw. Conf.*, no. Rfm, pp. 14–16, 2015.

[10] S. Subahir, R. A. Ramli, M. T. Ali, M. N. M. Tan, and S. Alam, "Investigation on Integrated Archimedean Spiral Patch Antenna with Light Emitting Diode (LED)," *IEEE 6th Control Syst. Grad. Res. Colloq.*, pp. 169–173, 2015.

[11] H. Yon, A. H. Awang, M. T. Ali, S. Subahir, and S. N. Kamaruddin, "Comparative Analysis for Multilayer Stacked Substrates Microstrip Patch Antenna," *Asia-Pacific Conf. Appl. Electromagnatic*, pp. 34–37, 2016.

[12] A. Botau and C. Negrea, "Thermal behavior of FR4 and flexible substrates for high output IR LEDs application," *2022 IEEE 9th Electron. Syst. Technol. Conf. ESTC 2022 - Proc.*, pp. 528–532, 2022, doi: 10.1109/ESTC55720.2022.9939550.

[13] Y. Su, M. Pellaton, C. Affolderbach, G. Mileti, and A. K. Skrivervik, "Mode Suppression and Homogeneous Field Bandwidth Enhancement of a Tuning-Free Micro-Loop-Gap Resonator Using FR4 for Chip-Scale Rubidium Clock," *IEEE Trans. Microw. Theory Tech.*, vol. 72, no. 6, pp. 3711–3721, 2024, doi: 10.1109/TMTT.2023.3326482.

[14] R. Liu, K. Ma, N. Yan, Y. Wang, and Y. Wu, "An FR4-Based Miniaturized High-Efficiency Double-Sided SISL Longitudinal Slot Antenna Array for 5G Millimeter-Wave Applications," *IEEE Trans. Antennas Propag.*, vol. 72, no. 7, pp. 6099–6104, 2024, doi: 10.1109/TAP.2024.3400018.

[15] S. Younes and F. Jaouad, "Wearable Patch Antenna with Rectangular Slots and Defected Ground for Biomedical Applications," *Proc. IEEE InC4 2023 - 2023 IEEE Int. Conf. Contemp. Comput. Commun.*, vol. 1, pp. 1–6, 2023, doi: 10.1109/InC457730.2023.10263109.

[16] A. Rukmana, A. Hasyim, R. Fauziyah, A. M. Ridwan, T. Romdoni, and M. T. A. Hakim, "The Design of A Rectangular Patch Microstrip Antenna 2×2 Element on S-and Frequency for Beach Supervision Radar Applications," *Proceeding 2022 8th Int. Conf. Wirel. Telemat. ICWT 2022*, pp. 1–4, 2022, doi: 10.1109/ICWT55831.2022.9935500.

[17] A. Javali, "Design of Rectangular Microstrip Patch Antenna for Wi-Fi Application: Enhancement of Bandwidth and Gain," *Proc. - 2022 IEEE World Conf. Appl. Intell. Comput. AIC 2022*, no. 2, pp. 552–555, 2022, doi: 10.1109/AIC55036.2022.9848972.