TELKOMNIKA, Vol.17, No.6, December 2019, pp.3066~3072
ISSN: 1693-6930, accredited First Grade by Kemenristekdikti, Decree No: 21/E/KPT/2018
DOI: 10.12928/TELKOMNIKA.v17i6.12679

A design of radial line slot array antennas using the specification of panel antennas

Teddy Purnamirza*[1], Muhammad Ralibi[2], Imran M. Bin Ibrahim[3], Rika Susanti[4], Halim Mudia[5], Depriwana Rahmi[6], Sutoyo[7], Mulyono[8]
[1,2,4,6,7,8]Department of Electrical Engineering, Faculty of Science and Technology,
UIN Sultan Syarif Kasim Riau, Indonesia
[3]Faculty of Electronic and Computer Engineering, Universiti Teknikal Malaysia Malaka, Malaysia
[5]Department of Mathematic Education, Faculty of Teaching and Education,
UIN Sultan Syarif Kasim, Riau, Indonesia
*Corresponding author, email: tptambusai@uin-suska.ac.id

Abstract

RLSA antennas were suggested by several researches as Wi-Fi antennas in addition to panel antennas. Therefore, this paper researched the possibility of this suggestion. We used the size of an available in market 16 dBi panel antenna (225 mm^2) as the size for our developed RLSA antenna. Based on this size, we developed 60 RLSA models using extreme beamsquint technique and simulated them. We then chose a best model with a best performance. The best model was then fabricated and measured. The simulation and measurement results show that the developed RLSA antenna has better performance compared to the 16 dBi panel antenna in term of gain (0.25 dB higher) and bandwidth (570 MHz wider). The RLSA antenna also tested as antenna for a Wi-Fi device and it showed good performance.

Keywords: *extreme beamsquint technique, panel antennas, RLSA antennas*

1. Introduction

RLSA antennas basically were developed for satellite communications [1-4]. Thereafter, RLSA antennas were developed for other applications such as Wi-Fi [5-10]. However, since Wi-Fi devices use small antennas, then RLSA antennas should also developed in small form. The small RLSA antennas have much less number of slots compared to the normal RLSA which is developed for satellite communications. The effect of small number of slots is the capability of slots to radiate power into space is linearly reduced, so that increasing reflected power at the perimeter of RLSA antennas, thus lead to the increase of reflection coefficients.

Several papers tried to overcome the problem of this high reflection coefficient. Hirokawa and Akiyama used the technique of matching slot pair aiming to waste the remaining power at perimeter antennas [11]. Zagriatski used long slots in order to reduce the remaining power [12]. Based on author's observation, the technique uses in these papers are not efficient since the power is wasted so that the power does not contribute to antenas gain. In last decade, there is no innovations in developing techniques to overcome the problem of high reflection coefficient in small RLSA antennas. The researches were only about the theory and the design of RLSA antenna using conventional techniques [13-20]

Purnamirza introduced a technique to reduce the reflection coefficient by using two material of cavity, which are polypropylene and FR4. This technique successfully reduces the reflection coefficient without wasting remaining power [21]. Purnamirza also introduced a technique to reduce reflection coefficient by designing RLSA antennas using high beamsquint values. This technique also successfully minimizes the reflection coefficient [22]. Due to this success, Purnamirza recommended their technique to be implemented in designing small RLSA antennas [23-25].

Based on this recommendation, we tried to design a small RLSA antenna for Wi-Fi devices at frequency of 5.8 GHz. In order to show the competitively of the RLSA antenna, we design the RLSA antennas with a same size with an antenna usually used as Wi-Fi antenna and widely available in market, which is a 16 dBi panel antenna. In order to test the RLSA antenna in real condition, we developed a test bed system by setting the RLSA antenna as an antenna

Received March 19, 2019; Revised July 2, 2019; Accepted July 18, 2019

for a Wi-Fi device. We observed and compared the performance of RLSA antenna and the 16 dBi panel antenna in order to show whether the RLSA antenna can compete the panel antenna, and become one option antenna for Wi-Fi devices.

2. Research Steps

a. Determine the RLSA antenna specifications: We determined the antenna specification by choosing one commonly Wi-Fi antenna out of several antennas available in market. In this research we chose the specification of 16 dBi panel antenna, which is listed in Table 1.
b. Determine the antenna material: In this research, as shown by Figure 1 (a), we chose a material of copper as the radiating element and background of the antenna. We also chose polypropylenes as the dielectric material for the antenna. The material of copper and polypropylenes were chosen based on the successfully of their using in previous researches [21-26]. The values of all the material of antenna are listed in Table 2.
c. Determine the antenna size: The size of 16 dBi panel antenna is 190 mm x 190 mm = 36100 mm2. Using this size of 36100 mm2, the diameter of RLSA antenna can be calculated using simple circle equation, which is √(36100/phi) = 107 mm, as shown by Figure 1 (b).

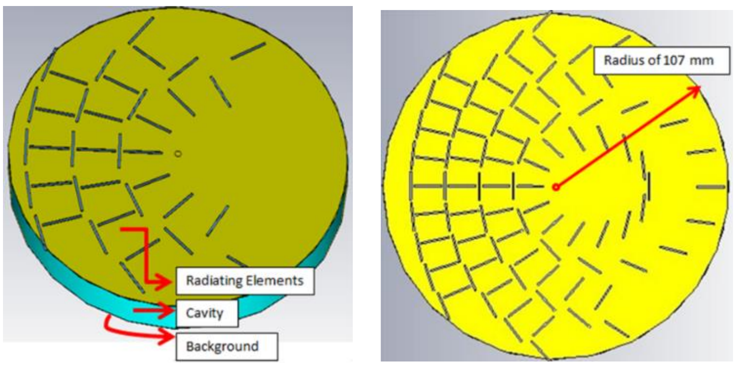
Table 2. Design Parameters of RLSA Antenna [21-26]

Specifications Parameters	Symbols	Values
Cavity Thickness	d_1	8 mm
The thickness of radiating element and background	d	0.001 mm
The permittivity of cavity	ε_{r1}	2.33
Beamsquint angle	Φ	from 60^0 to 89^0
Wavelength	λ_g	33.88 mm
Slot Length	L	0.5 λg
Slot width	w	1 mm
Radius of antenna	R	107 mm
Number of slot pair in first ring	n	from 10 to 14
Frequency centre	f	5.8 GHz

d. Design the antenna: Using the radius of 107 mm, we designed the antenna as shown by Figure 1.
e. Design the antenna feeder: We modified an ordinary SMA feeder by adding a header (as shown by Figure 2 (a)). This header functions to convert the TEM coaxial mode into TEM cavity mode, so that signals will spread radially within the cavity material, as shown by Figure 2 (b). The definition of feeder structure parameters is shown by Figure 2 (a). The material and the values of all feeder structure parameters are listed in Tables 3 and 4, respectively.

Table 1. Antenna Specifications

Specifications	Values
Gain	16 dBi
Bandwidth	125 MHz (5725–5850 MHz)
Beamwidth	25^0
Impedance	50 Ohm



(a) (b)

Figure 1. (a) Antenna structure [23-26] and (b) design slots

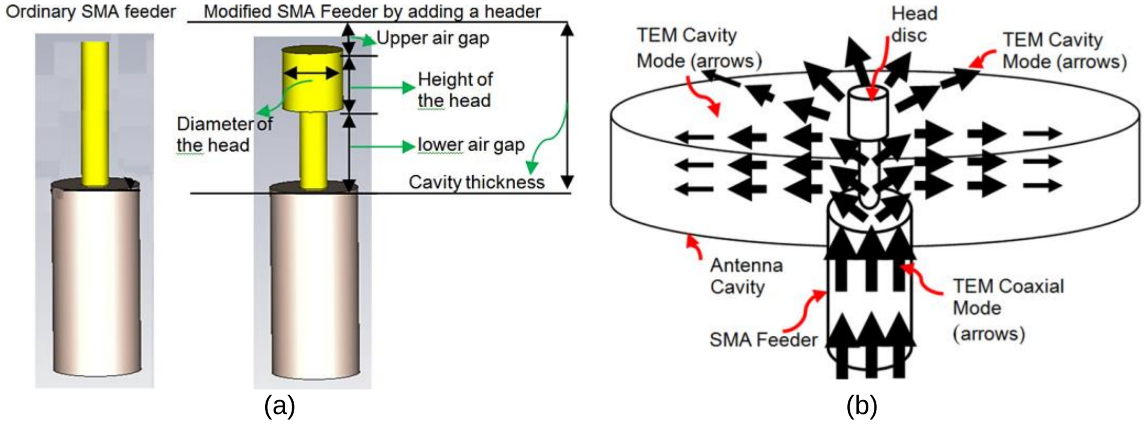


Figure 2. (a) Definition of feeder structure parameters, and
(b) Signal propagation within antenna cavity [21]

Table 3. Materials of RLSA Antenna [21-26]

Specifications Parameters	Material
Radiating element	Copper
Background	Copper
Cavity	Polypropylenes
Head of Feeder	Copper

Table 4. Design Parameters of Feeder [21-26]

Specifications Parameters	Symbols	Values
The height of disc	h	3 mm
The radius of disc	r_a	1.4 mm
The lower air gap	b_1	4 mm
The upper air gap	b_2	1 mm

f. Drawing the antenna: Since the structure of RLSA antenna is complex with hundreds of slots, so it is time consuming to draw this antenna manually in microwave simulation software. Hence in order to speed the drawing process, we develop a VBA (Visual Basic Applications) program. This program is embedded within the microwave simulation software. This program is able to draw an RLSA antenna within seconds while it takes days with manual drawing. Using this program we drew 150 models of RLSA antenna which vary in values of beamsquint (Φ) and the number of slots in first ring (n).
g. Simulate the antenna. We simulated the 150 antenna models and we took the simulation results of several performance parameters such as gain, bandwidth, S11 response, beamwidth, efficiency and radiation pattern. A best antenna in term of performance was chosen to be fabricated. The parameters of this antenna are n = 14 and $\Phi = 60^0$. The best model is shown by Figure 1 (b).
h. Fabricate the best antenna model and the feeder. The best antenna model and header chosen in previous step were fabricated as shown in Figure 3.

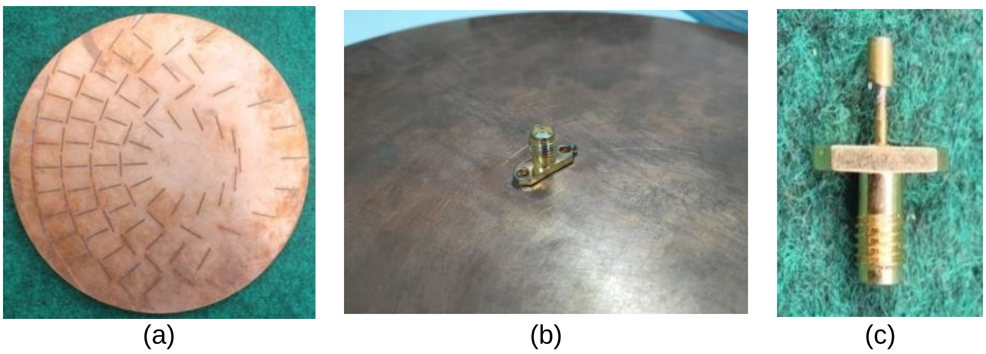
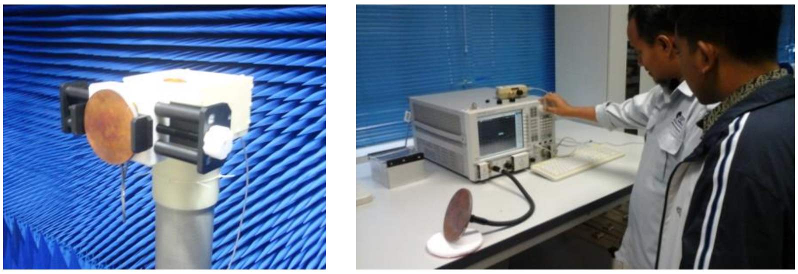


Figure 3. Fabricated model (a) radiating element (b) background (c) feeder

i. Measure the fabricated prototype. We measured several performance parameters including gain, radiation pattern, beamwidth, bandwidth and S11. The measurement was conducted using an anechoic chamber and a network analyzer as shown by Figure 4.



(a) (b)

Figure 4. Measurements (a) in anechoic chamber (b) by a network analyzer

j. Analysis and compare the simulation and measurement result. In order to verify the validity of our design, we compared between the simulation result and the measurement result. If they have good agreement, then meaning the design is the correct ones.
k. Test the prototype. We set a test bed in order to show the ability of the prototype in working in a real communication systems.

3. Results and Analysis

Figure 5 shows the S11 response of the antenna both in simulation and measurement. It is observed that the antenna has a bandwidth of about 720 MHz at the center of 5.8 GHz. We can draw conclusion that the bandwidth is more than enough for Wi-Fi communications which is only 150 MHz. The interesting result is the bandwidth is also much wider compared to the bandwidth of the 16 dBi panel antenna which is only 125 MHz. Figure 6 shows the radiation pattern of the antenna both in simulation and measurement. It is observed that the antenna has beamwidth of about 28^0 and point to about 52^0 from boresight direction. We also got the antenna gain of 16.25 dBi which is 0.25 dB higher than the panel antenna gain (16 dBi).

From Figures 5 and 6, we can observe that the simulation result matches the measurement result, thus verifying the validity of our design. Slight differences between the simulation and measurement result are due to the shift of cavity, radiating element and background elements from the correct positions during the fabrication process. The differences are also due to the inaccuracies during the installation of header at the correct position in SMA Feeder. Based on above analysis, we summarized the specifications of RLSA antenna and the panel antenna as shown by Table 5. From this table, we can conclude that the RLSA antenna has better performance compared to panel antenna in term of gain and bandwidth. Especially in term of bandwidth, the RLSA antenna has much wider bandwidth compared to the panel antenna.

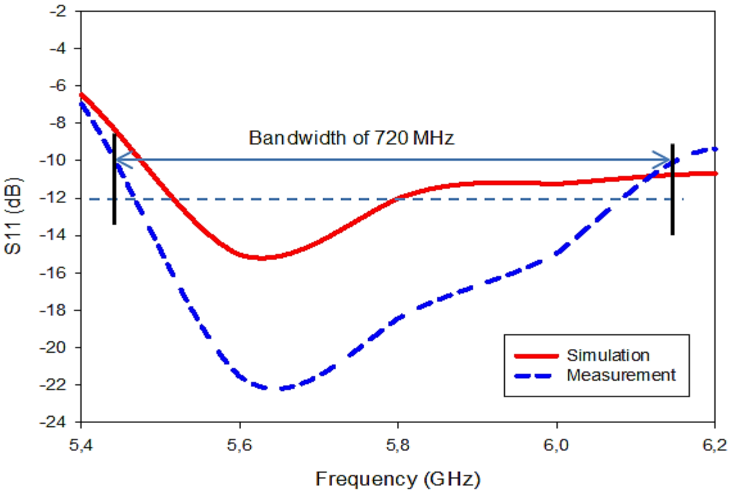


Figure 5. Reflection coefficient

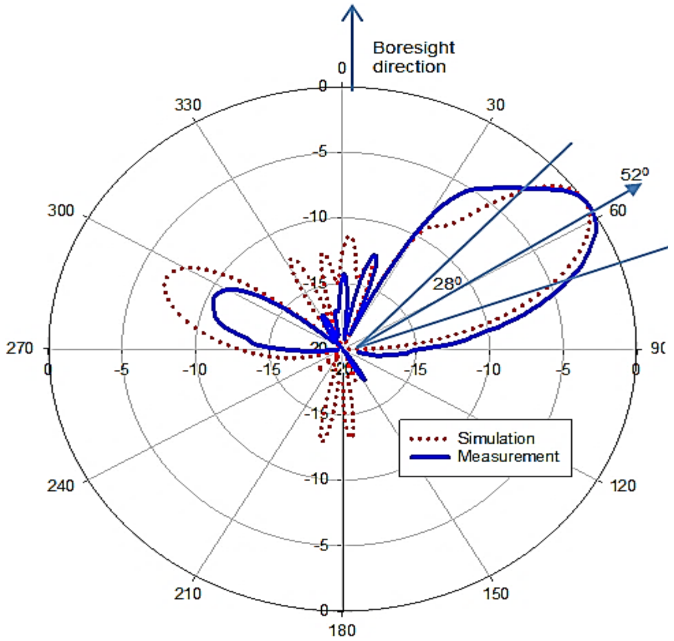


Figure 6. Radiation pattern

Table 5. The Specifications of Panel and RLSA Antenna

Specifications	Panel Antenna	RLSA antenna
Gain	16 dBi	16.25 dBi
Bandwidth	125 MHz (5725-5850 MHz)	720 MHz (5432 -6150 MHz)
Beamwidth	25^0	28^0
Impedance	50 Ohm	50 Ohm

We tested the RLSA antenna as the antenna for Wi-Fi Devices. We set up a test bed as shown in Figure 7. The test bed consists of two transceivers. The first transceiver shown in Figure 7 (a) consists of a laptop and a Wi-Fi access point connected using an Unshielded Twisted Pair (UTP) cable. In the second transceiver shown in Figure 7 (b), we connected the RLSA antenna to a Wi-Fi access point using a pigtail cable RG-147 SMA male to RP-SMA male. The access point is connected to a laptop using a UTP cable. We carried out a Wi-Fi communication (data, picture, audio and video streaming) between the two transceivers in several conditions, those are for outdoor, indoor and different weather. The test result showed that the communication link could be established well, thus verifying the good performance of the RLSA antenna in actual implementation.

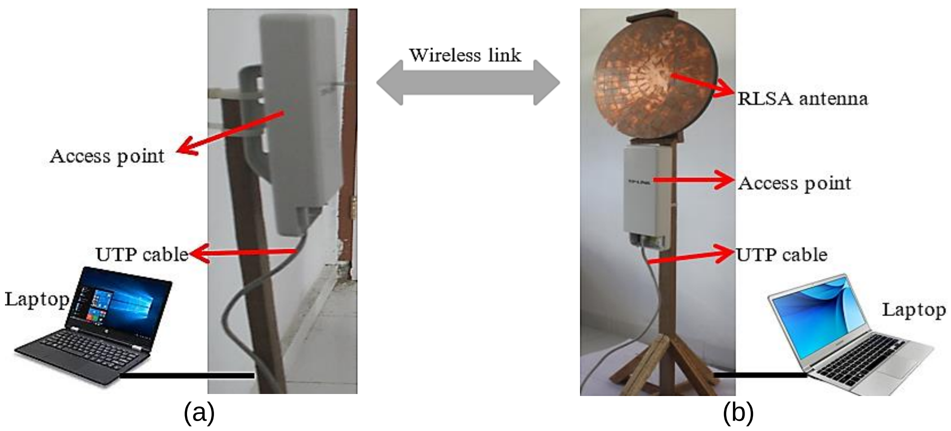


Figure 7. Test bed systems: (a) first and (b) second transceiver

4. Conclusions

We have designed, simulated, fabricated, and measured the RLSA antenna based on the specification of a panel antenna that available in markets. The simulation and measurement result shows that with same size, the RLSA antenna has better performance compared to the panel antenna, especially in term of bandwidth. We also have tested the RLSA antenna as an antenna for Wi-Fi devices. The test shows that the RLSA antenna performed a good performance.

Acknowledgements

Firstly, we would like to thank to Lembaga Penelitian dan Pengabdian Masyarakat (LPPM) Universitas Islam Negeri Sultan Syarif Kasim, Indonesia, for partially funding this research. Secondly, Appreciation also goes to Advance Microwave Laboratory, Faculty of Electronic and Computer Engineering, Universiti Teknikal Malaysia Malaka for their assistances in conducting antenna measurements. Thirdly, we also thank to Computer Simulation Technology Malaysia Sdn. Bhd, for giving a temporary license to use CST STUDIO SUITE™ Software for one month as simulation software in our research.

References

[1] Ando M, et al. Linearly polarized radial line slot antenna. *IEEE Transactions on Antennas and Propagation*. 1988; 36(12): 1675-1680.
[2] Takahashi M, et al. A slot design for uniform aperture field distribution in single-layered radial line slot antennas. *IEEE Transactions on Antennas and Propagation*. 1991; 39(7): 954-959.
[3] Davis PW. Experimental investigations into a linearly polarized radial slot antenna for DBS TV in Australia. *IEEE Transactions on Antennas and Propagation*. 1997; 45(7): 1123-1129.
[4] Takada J, et al. A reflection cancelling slot set in a linearly polarized radial line slot antenna. *IEEE Transactions on Antennas and Propagation*. 1992; 40: 433-438.
[5] Tharek AR, Farah Ayu IK. *Theoretical investigations of linearly polarized radial line slot array (RLSA) antenna for wireless LAN indoor application at 5.5 GHz*. Proceedings of the Mediterranean Electrotechnical Conference–MELECON. 2002: 364-367.
[6] Imran MI, Tharek AR. *Radial line slot antenna development for outdoor point to point application at 5.8GHz band*. 2004 RF and Microwave Conference, RFM 2004- Proceedings. 2004: 103-105.
[7] Imran MI, et al. *An optimization of beam squinted radial line slot array antenna design at 5.8 GHz*. 2008 IEEE International RF and Microwave Conference, RFM 2008. Sabah. 2008: 139-142.
[8] Imran MI, et al. *Beam squinted Radial Line Slot Array Antenna (RLSA) design for point-to-point WLAN application*. 2007 Asia-Pacific Conference on Applied Electromagnetics Proceedings, APACE2007. 2007: 1-4.
[9] Islam MRU, Rahman TA. Novel and simple design of multi layer Radial Line Slot Array (RLSA) antenna using FR-4 Substrate. 2008 Asia-Pacific Symposium on Electromagnetic Compatibility and 19th International Zurich Symposium on Electromagnetic Compatibility, APEMC 2008. 2008: 843-846.
[10] Islam MRU, et al. *Simple integrated system for wireless backhaul networks*. Proceedings of the International Conference on Computer and Communication Engineering 2008, ICCCE08: Global Links for Human Development. 2008: 341-345.
[11] Hirokawa J, et al. *Matching slot pair for a circularly-polarised slotted waveguide array*. IEE Proceedings H: Microwaves, Antennas and Propagation. 1990; 137(6): 367-371.
[12] Zagriatski S, Bialkowski ME. *Circularly polarised radial line slot array antenna for wireless lan access point*. 15th International Conference on Microwaves, Radar and Wireless Communications, MIKON–2004. 2004: 649-652.
[13] Ibrahim IM, Rahman TA, Iliya SZ, Sabran MI. Aperture slot size effect to wide band open air gap radial-line slot array performance. *Microwave and Optical Technology Letters*. 2014; 56(12): 2974-2978.
[14] Ibrahim IM, Rahman TA, Sabran MI, Jamlos MF. *Comparison of polypropylene and FR4 dielectric cavity for RLSA Antenna design at 5.8GHz*. IEEE TENSYMP 2014 - 2014 IEEE Region 10 Symposium. 2014: 232-234.
[15] Ibrahim IM, Rahman TA, Sabran MI, Jamlos MF. *Bandwidth enhancement through slot design on RLSA performance*. IEEE TENSYMP 2014 - 2014 IEEE Region 10 Symposium. 2014: 228-231.
[16] Sierra-Castañer M, Domínguez AT, Gea MB, Rajo-Iglesias E, Vazquez-Roy JL. *Monopulse RLSA antenna at 24 GHz based on a gap-waveguide cavity feed*. 2017 European Radar Conference (EURAD). 2017: 386–389.

[17] Xu X, Mori D, Mazzinghi A, Freni A, Hirokawa J, Ando M, Araki K. *A 60-GHz RLSA fed by butler matrix carrying three OAM modes*. IEEE International Symposium on Antennas and Propagation & USNC/URSI National Radio Science Meeting. 2017: 1445–1446.
[18] Mazzinghi A, Freni A. Simultaneous Generation of Pseudo-Bessel Vortex Modes with a RLSA. *IEEE Antennas and Wireless Propagation Letters*. 2017; 16: 1747–1750.
[19] Pavone SC, Mazzinghi A, Freni A, Albani M. *Wideband analysis of RLSA Bessel beam launchers based on standing and inward traveling wave aperture distributions for electromagnetic pulse generation*. 2017 11th European Conference on Antennas and Propagation (EUCAP). 2017: 3649–3652.
[20] Nguyen T, Hirokawa J, Ando M. *Design of non-uniform aperture illumination RLSA and its applications in mm-Wave*. 2015 International Symposium on Antennas and Propagation (ISAP). 2015; 219–220.
[21] Purnamirza T, Rahman TA. A Novel Technique in Simplifying the Fabrication Process and in Improving the Reflection Coefficient of the Linear Polarized Radial Line Slot Array (LP-RLSA) Antennas. *Journal on Electromagnetic Wave and Application*. 2012; 26(4): 535-548.
[22] Purnamirza T, Rahman TA, Jamaluddin MH. The extreme beamsquint technique to minimize the reflection coefficient of very small aperture radial line slot array antennas. *Journal of Electromagnetic Waves and Applications*. 2012; 26(17-18): 2267-2276.
[23] Purnamirza T, Hasbi S, Bin Ibrahim IM, Mulyono M, Amillia F, Rahmi D. A Radial Line Slot Array (RLSA) Antenna with the Specifications of 16 dBi Outdoor patch Antenna. *TELKOMNIKA Telecommunication Computing Electronics and Control*. 2018; 16(1): 46-62.
[24] Purnamirza T, Kristanto D, Ibrahim IM. A Design of Compact Radial Line Slot Array (RLSA) Antenna for Wi-Fi Market Needs. *Journal of Progress in Electromagnetics Research Letters (PIER-L)*. 2016; 64: 21-28.
[25] Purnamirza T, Prowadi P, Ibrahim IM. Small Radial Line Slot Array (RLSA) Antennas for Wi-Fi 5.8 GHz Devices. *International Journal on Communications Antenna and Propagation*. 2017; 7(5): 397-402.
[26] Purnamirza T, Budikesuma P, Bin Ibrahim IM, Rahmi D, Susanti R. A Small RLSA Antenna Utilizing the Specification of Back Fires 17 dBi LAN Antennas. *TELKOMNIKA Telecommunication Computing Electronics and Control*. 2018; 16(6): 2871-2878.