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Submission date: 16-Jan-2021 02:06PM (UTC+0700)

Submission ID: 1488534913

File name: enna_with_the_Specifications_of_16_dBi_Outdoor_patch_Antenna.pdf (650.23K)

Word count: 2472

Character count: 13151

TELKOMNIKA, Vol.16, No.1, February 2018, pp. 46~52
ISSN: 1693-6930, accredited **A** by DIKTI, Decree No: 58/DIKTI/Kep/2013
DOI: 10.12928/TELKOMNIKA.v16i1.6727

A Radial Line Slot Array (RLSA) Antenna with the Specifications of 16 dBi Outdoor patch Antenna

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Abstract

It is recommended by several researches that RLSA antennas have possibility as an option for Wi-Fi devices antennas. Therefore, to dig deeper this possibility, we designed a RLSA antenna that mimics the specification of an antenna usually found in market, that is 16 dBi outdoor patch antenna. We carried out a parameterization to get a best RLSA antenna model. The model was then fabricated and measured. The measurement results are quite agrees with the simulation results. We found that with the same size of 0.05 m2, our RLSA antennas has better performance in term of gain (2 dB higher), S_{11} (7 dB lower), and beamwidth (90^0 wider) compared to the patch antenna. A significant result is that RLSA antenna has much wider bandwidth (815 MHz wider) compared to the patch antenna. A test to our RLSA antenna as an antenna for Wi-Fi devices shows that it works properly.

Keywords: *RLSA, Antenna for Wi-Fi, patch antenna, Extreme Beamsquint*

1. Introduction

Efforts to bring small RLSA antennas as the antenna for small devices have been doing since the beginning of 1990 [1-2]. However, due to the small size, small RLSA antennas have not enough slots to radiate power within antenna cavities, resulting high power at the perimeter of antennas, thus causing high reflection from the antenna perimeter into the antenna feeders [3]. This problem of high reflection coefficient has been a main obstacle for the development of small RLSA antenna for decades.

Many researches tried to overcome this problem by their own technique, such as utilizing fews of long slots [4-7], using large RLSA antenna [8-10], using the loss material of FR4 [11-12], using the combination of FR4 and polypropelene as cavity material of RLSA antenna [13], and using extreme beamsquint technique [3]. The other latest research tried to optimize the RLSA antenna design using several syntesis theory [14-17].

Based on author's observation, the using of extreme beamsquint technique is the best technique since it can obtain small RLSA antenna with high gain and good reflection coefficient response [14]. This is achieved by concentrating the antenna slots in certain area of radiating antenna. This causes most of the signal within the cavity flows into concentrated slots, and then radiated. Because most of the signal is able to be radiated, so that remain power at the antenna perimeter can be reduced significantly, thus minimize the reflection coefficients.

Based on this result [14], this research investigated the capability of RLSA antenna as antenna for Wi-Fi devices. Therefore, in this paper, we designed an RLSA antenna that mimic the specification of 16 dBi outdoor patch antenna, which is one of antenna that usually available in markets.

2. Research Method

The steps to get the result of this research are as follow:

Received October 10, 2017; Revised November 24, 2017; Accepted January 3, 2018

a. Assign the antenna specifications: Since this research tries to investigate the capability of RLSA antennas as an antenna for Wi-Fi devices, hence We chose the specification of one popular Wi-Fi antenna that available in markets, as a specification for the RLSA antenna. The chosen antenna is a 16 dBi outdoor patch antenna. The spesification of the 16 dBi outdoor patch antenna is listed in Table 1.

Table 1. Antenna Specifications

Specifications	Values
Bandwidth	125 MHz
Gain	15 dB1
Beamwidth	16^0
Impedansi	50 Ohm
S_{11}	-7 dB

b. Calculate the antenna size: The size of 16 dBi outdoor patch antenna is 0.263 m x 0.192 m = 0.05 m^2. This size of 0.05 m^2 was used as the size for our design RLSA antenna. Based on this size of 0.05 m^2, we get the radius of the RLSA antenna of 127 mm.

c. Design the antenna structure: We designed the antenna structure using the radius of RLSA antenna of 127 mm and the structured developed in previous research [3, 13]. Normally, the structure of RLSA antennas consist of three layer, which are radiating element, cavity, and background element, as shown by Figure 1(a). Figure 1(b) shows the result of our design. The design parameter of the antenna structure and its material are shown in Table 2 and Table 3, respectively.

Table 2. Design Parameters of RLSA Antenna [3, 13]

Specifications Parameters	Symbols	Values
Centre frequency	f	5.8 GHz
Beamsquint angle	Φ	Vary from 60^0 to 90^0
Wavelength	λ_g	33.88 mm
Slot Length	l	0.5 λ_g
Slot width	w	1 mm
Radius of antenna	r	127 mm
Number of slot pair in first ring	n	Vary from 10 to 16
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

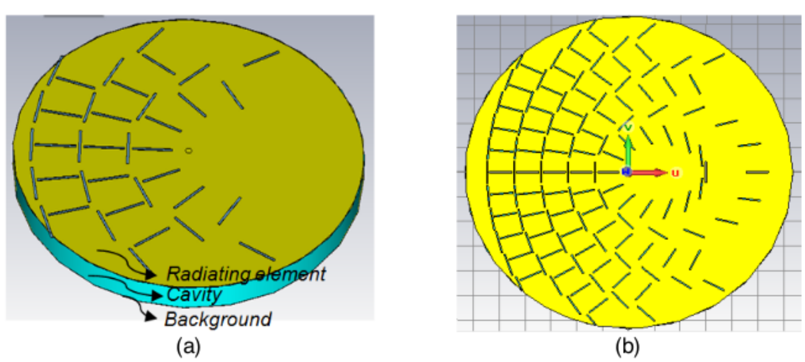

Figure 1. (a) General Structure of RLSA antennas (b) Design result (radiating element)

Since drawing the antenna slots manually is difficult and take a long time, so We developed a computer program based on VBA (Visual Basic Application) language. This program functions to calculate the position and slope angle of slots and to draw the slots and the antenna structures. Hence, using this program we are able to do simulation and parameterization accurately and rapidly

Table 3. Materials of RLSA Antenna [3, 13]

Specifications Parameters	Material
Radiating element	*copper*
Background	*Copper*
Cavity	*Polypropelene*
Head of Feeder	*Copper*

d. Design the antenna feeder: The antenna feeder is an SMA feeder that is usually found in market. This SMA Feeder was modified by adding a copper head, as shown in Figure 2. The head functions to transform TEM coaxial mode signal within coaxial cable into TEM cavity mode signal within the cavity structure, so that the signal from the feeder will propagate in radial directions within the cavity of the antenna, as shown by Figure 2(a). Table 4 show design parameters of the feeder and Figure 2(b) shows the meaning of the design parameters.

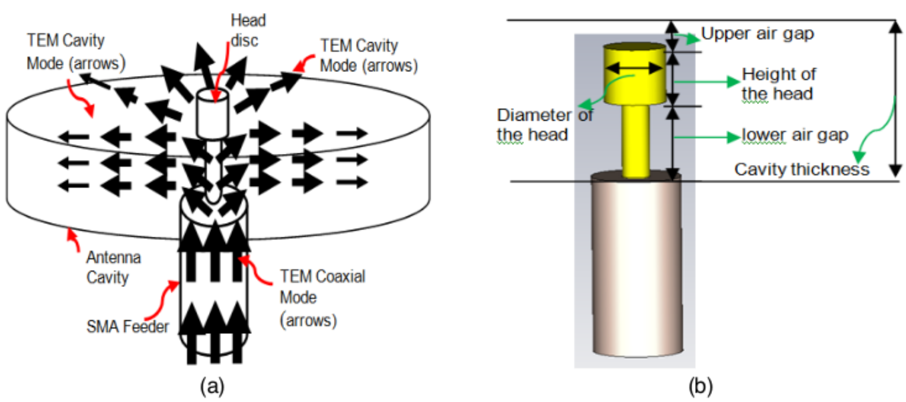

Figure 2. (a) Signal Flow of RLSA antennas (b) Feeder

Table 4. Design Parameters of Feeder

Specifications Parameters	Symbols	Values
The height of disc	*h*	3 mm
The radius of disc	*ra*	1.4 mm
The low er air gap	*b1*	4 mm
The upper air gap	*b2*	1 mm

e. Conduct parameterizations: The design antenna resulted from step (d) was then simulated to get the characteristic of the antenna in term of gain, radiation pattern, beamwidth, bandwidth, and coefficient reflection. In order to get a best antenna model, We carried out parameterizations by tuning several antenna parameters such as the number of slots in first ring (n varies from 10 to 16) and the beamsquint (Φ varies from 60^0 to 90^0). From this parameterizations, We resulted a best antenna model, which the parameters are n = 14 and $\Phi = 63^0$.

f. Fabricate the best antenna model and the feeder: In order to verify the simulation result conducted in the previous step, We fabricated the best antenna model resulted in previous step. The prototype of the antenna model and the feeder is shown in Figure 3.

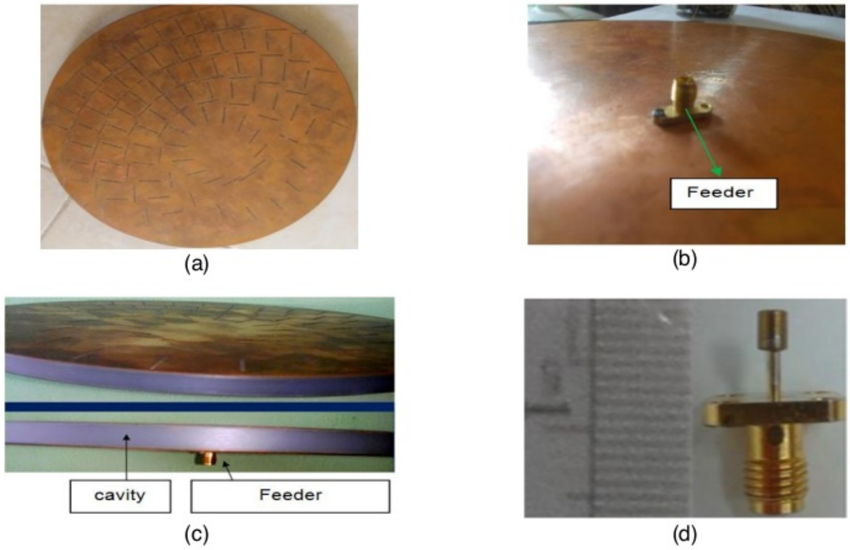

Figure 3. (a) Front View of the Prototype; (b) Back View of the Prototype; (c) Side View of the Prototype; (d) Structure of Feeder

3. Results and Analysis

The prototype of RLSA antenna resulted in previous section, was measured in a Anachaoic Chamber to measure the antenna radiation pattern and the gain, and also using Network Analyzer to measure the reflection coefficient. The activities of measurement is shown by Figure 4.

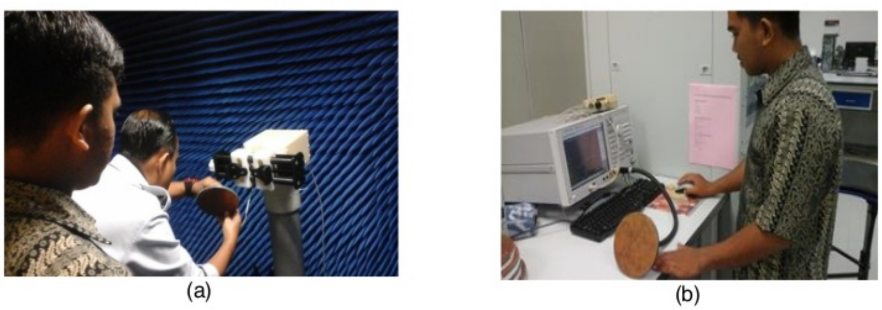

Figure 4. Measurement activities (a) using Chamber (b) using Network Analyzer

Figure 5 shows the measured and the simulated S11 of the prototype antenna. From this figure, it can be observed that the prototype antenna has bandwidth of about 1 GHz at the centre frequency of around 5.8 GHz. This bandwidth is more than enough for Wi-Fi signal which typically needs bandwidth of only around 150 MHz. The significant result found in this research is that the RLSA antenna has much wider bandwidth (850 MHz wider) compared to the 16 dBi outdoor patch antenna. Also at the centre frequency of 5.8 GHz, We can get reflection coeffient of about -14 dB which is 7 dB lower than the reflection coeffient of 16 dBi outdoor patch antenna.

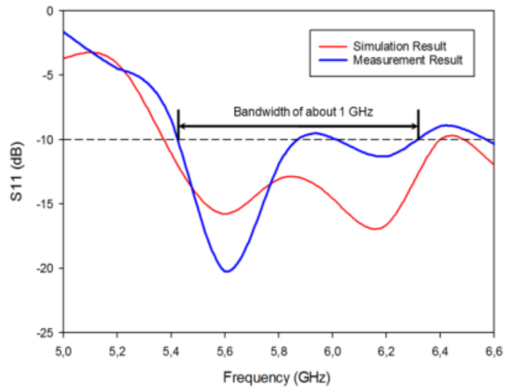

Figure 5. Simulated and Measured S_{11}

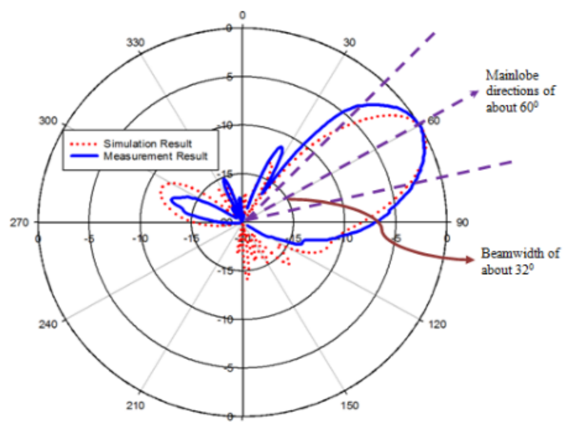

Figure 6. Simulated and Measured Radiation Pattern

Figure 6 Shows the radiation pattern of the RLSA antenna both for measurement result and simulation result. From this figure, we can observe that the antenna has a beamwidth of 320 which is about 180 wider than the beamwidth of the patch antenna. We also get the RLSA antenna has a gain of 17 dBi. This means that with the same size of RLSA antenna and patch antenna, the RLSA antenna has better perfoperformance compared to the patch antenna.

Table 4. Performance Parameters

Performance Parameters	Values
Bandwidth	1 GHz
Gain	17 dB
Beamwidth	32^0
Impedance	50 Ohm
S_{11}	-14 dB

From Figure 5 and Figure 6, We can notice that the simulation result is agree with the measurement result. The difference between them is due to the imperfections during the fabrication process of the antenna model. The imperfections are caused by: firstly, the radiating element, the cavity and the background are separated elements, so when they were combined during the fabrication process, there was a slight shift from the correct position. Secondly, the permittivity of the cavity is slightly increases due to the use of glue to stick the radiating element and the background to the cavity. Thirdly, there is an imperfection in soldering the head disc at the SMA feeder at the correct position

A testbed systems was developed in order to show the performance of the antenna in real situations, as shown in Figure 7. The testbed consists of two 5.8 GHz transceivers, the RLSA antenna connected to one of the transceivers, and a panel antenna connected to the other transceiver, and two computers connected to the two tranceivers.

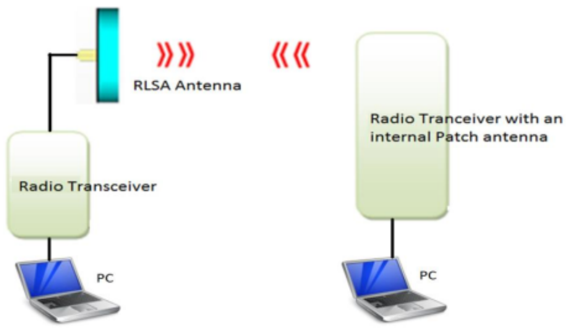

Figure 7. Testbed System

Using this testbed, We tested the performance of the RLSA antenna by setting up connection between the two computers. The test result showed that the connection could be established just like usual, then this verify the good performance of the RLSA antenna in real conditions.

4. Conclusion

An RLSA antenna with the specification of 16 dBi outdoor patch antenna was designed, simulated, fabricated, and measured. The simulation result just match the measurement result. The interesting result is that the RLSA antenna has better performance in term of gain, reflection coefficient and bandwidth, compared to the 16 dBi outdoor patch antenna. The test to the RLSA antenna as an antenna for a radio transceiver shows that the RLSA antenna can performs its function well.

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