

Analysis of Circular Microstrip Patch Antenna In C-Band Frequency for Communications

Putu Artawan¹, Putu Widiarini² and Yono Hadi Pramono³

¹Ganesha University of Education (UNDIKSHA), Singaraja, Bali, Indonesia.

² Ganesha University of Education (UNDIKSHA), Singaraja, Bali, Indonesia.

³Physics Department, Faculty of Natural Sciences, Institut Teknologi Sepuluh Nopember (ITS), Surabaya, Indonesia.

ABSTRACT

The design of a novel linearly polarized microstrip circular patch antenna in C-Band frequency is presented in this research. The circular patch with truncate square and feeding technique in stripline is adopted in this antenna design. The total size of antenna is 40mm x 40mm. This study has obtained design of novel linearly polarized microstrip circular patch antenna with more optimal characteristics parametric in its application in communications especially in C-Band frequency. The result indicate that the antenna characteristics parametric showed by Voltage Standing Wave Ratio ($VSWR \leq 2$) of the proposed antenna is 1.06, bandwidth is 740.0MHz (5.18GHz–5.92GHz), reflection coefficient is 0.03 and return loss is -30.69dB respectively. The antenna has achieved a stable radiation performance with a maximum gain of 7.46dB in C-Band operating frequency. Novel linearly polarized microstrip circular patch antenna with 50 Ohm impedance and easy integration are making this model suitable for C-Band frequency (4GHz-8GHz) satellite communication applications. Details of the proposed antenna design and results are presented and discussed.

Keywords: patch antenna, linearly polarized, antenna, communication.

1. INTRODUCTION

Various studies have been conducted on microstrip antenna type [1,2,8,10,11,12,13,14,16], among which is to perform a wide variety of designs and shapes microstrip antenna, by giving the slot [11,12] and patch microstrip antenna and adding to the number of the array [15,16]. Dual polarized microstrip patch antennas excite two orthogonal modes, which generate vertically polarized electric field and horizontally polarized electric field. Therefore, dual polarized antennas added information by providing two co-polarizations and two cross-polarizations. Microstrip patch antenna have good potential with the characteristics of a thin cross-section for making dual-polarized antennas due to their several attractive features including low profile, the mass that is light weight, low cost, easy to make, compatibility with Microwave Integrated Circuits (MICs) technology and can be made to multifrequency. Microstrip patch antennas have been widely used in high performance satellite. Several works have been reported to overcome drawbacks of the conventional microstrip antenna such as low efficiency and narrow bandwidth. The main problem designing the microstrip antenna is to widening bandwidth and optimizing the gain. In this research, the truncated in circular patch side is a one of the solution to reach wide in bandwidth and optimize in gain performance. Besides, to arranges the electricity field current distribution in vertical polarization. There are several solutions have been proposed to achieve the polarized antenna with wide bandwidth, and optimizing the gain. One of the most common solutions consists of using monopole feeding [11,12]. Other solutions using feedline coaxial waveguide in microstrip panel [14] have been reported. The various array technic in microstrip patch antenna [15,16,17,18,19] have been proposed to improve polarized antenna with wide bandwidth. Despite the excellent performances, these structures require in array structure which increase the complexity. In this work, a simple feeding structure and truncate circular patch antenna for vertical linear polarization is presented. One type of antenna that will be designed to have the characteristics in question are novel linear polarized microstrip circular patch antenna design [5]. In this study, linear polarized microstrip circular patch antenna design is propose to develop in C-Band frequency for many satellite communications transmissions, wi-fi devices which can be used in WLAN applications. The advantages of C-Band are weatherproof, high throughput

(easily support voice/data/imagery/HD video, excels with small antennas, low cost (extremely high MHz-Mbps efficiency), high link availability, and low probability of interference. The C-Band ranges from 4GHz to 8GHz and is used primarily for radar applications. C-Band used in radar applications including continuous-wave, pulsed, single-polarization, dual-polarization, synthetic aperture radar and phased arrays. C-Band radar frequency sub-bands are used in civil, military and government institutions for weather monitoring, air traffic control, maritime vessel traffic control, defense tracking and vehicle speed detection for law enforcement. The proposed novel linearly polarized microstrip circular patch antenna is afford to operate in [16] C-Band frequency in range 4GHz to 8GHz. The target of novel linearly polarized microstrip circular patch antenna is in 5.5 GHz center frequency, bandwidth more than 5.0%, return loss (S_{11} parameter) less than -10dB , Voltage Standing Wave Ratio (VSWR) less than 2, gain more than 5dB, and in linear polarization, respectively.

Table 1. Target of The Antenna Parameter.

PARAMETERS	SPECIFICATION
Center Frequency	5.5 GHz
Bandwidth	$>5.0\%$
S_{11} (Return Loss)	$< -10\text{dB}$
VSWR	< 2
Gain	$> 5\text{dB}$
Polarization	Linear (Vertical)

2. ANTENNA GEOMETRY AND DESIGN

The design procedure starts with the determination of sidelength of the patch using the classical equations [3,4,5]. The following figure is the geometry of the Novel Circular Microstrip Patch Antenna.

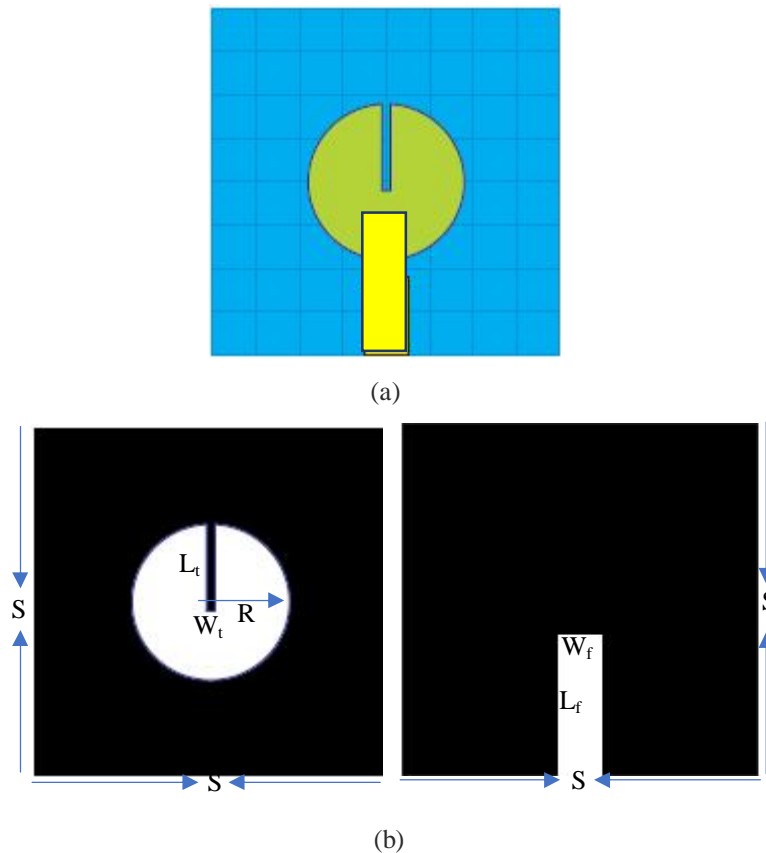


Figure 1. Geometry of proposed antenna.

The parameters of Novel Circular Microstrip Patch Antenna Design consist of the following table:

Table 2. Dimension Parameter of the Novel Circular Microstrip Patch Antenna Design.

Parameters	Dimension (mm)
S	40
t	0.035
R	9.35
h	1.6
Lt	10
Wt	1
Lf	16
Wf	4.9

Considering the requirements of design such as bandwidth and dielectric constant, the antenna is initially designed to operate in C-Band and consequently optimized to obtain the most efficient size of the patch using microstrip calculator method. The whole radiating element of the proposed linear polarized circular patch microstrip antenna is centered on the top of a 40x40 mm ground plane. The circular patch has a radius of 9.35mm and is directly printed on a microwave substrate (NPC-220AH) of thickness 1.6mm and relative permittivity 2.17 to reduce the cost. The spacing between line truncate slot is 1mm with 10mm length. The probe of feeds with 4.9mm in width and 16mm in length feeding away from the patch center. The feed arrangement excites 0° and 90° linearly polarized waves. The above specific shape patch for the slots and square shaped patch configuration allow us to obtain a satisfactory 50Ω impedance matching across the frequency band of interest.

3. RESULTS AND DISCUSSION

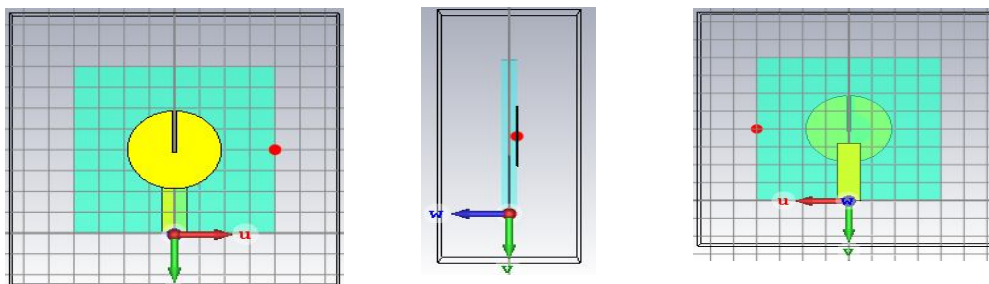
Selection method of fabrication [1,2,7,8,12,13] was essential to be conducted to obtain the results of truly optimal. The results reflect the optimal parameters generated as characteristic of the designed antenna. Fabrication is carried out using Nippon Pillar substrate (NPC-220AH) material with UV Photoresist Laminate technique. The result of antenna fabrication shown in Figure 2.



(a) In front of View. (b) Side View. (c) Back View.

Figure 2. The fabricated prototype Novel Circular Microstrip Patch Antenna.

The performance of the proposed antenna has been analyzed and optimized by using CST software. The result of simulation is presented in Figure 3.



(a) Top View. (b) Side View. (c) Bottom View.

Figure 3. Simulation result of Novel Circular Microstrip Patch Antenna.

Measuring antenna had been done at Laboratory. In Figure 4 has been shown the measuring process.



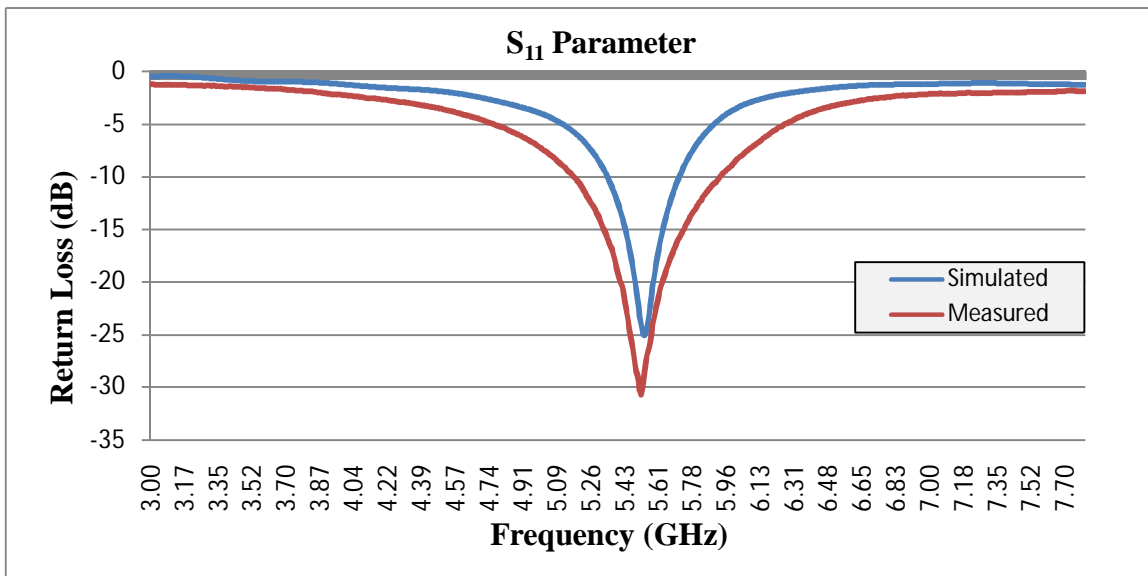
(a) Using Network Analyzer.

(b) In Chamber.

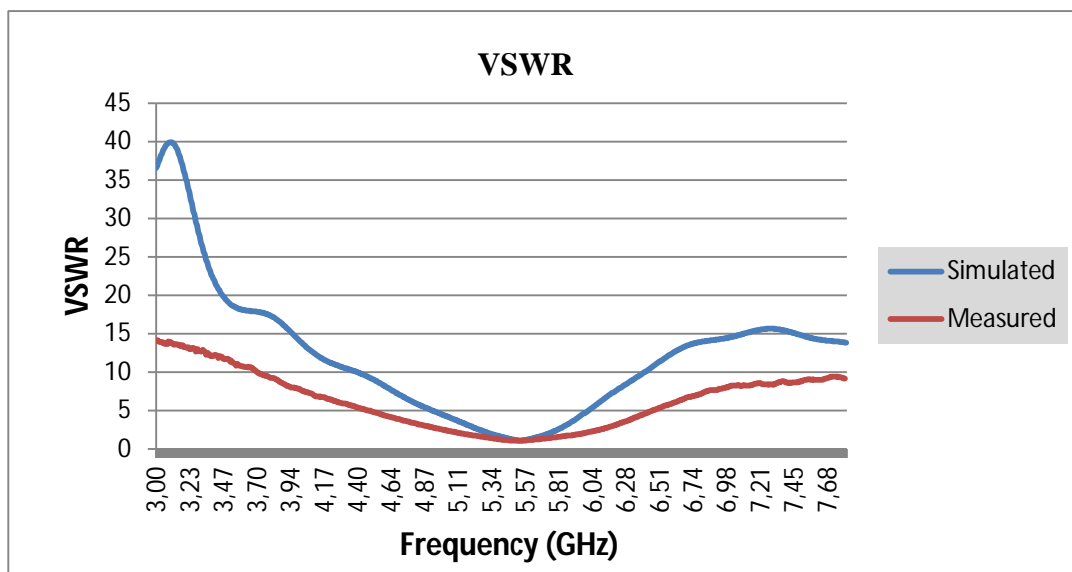
Figure 4. Measuring Process at Laboratory.

Comparing Simulation and Measurement Result:

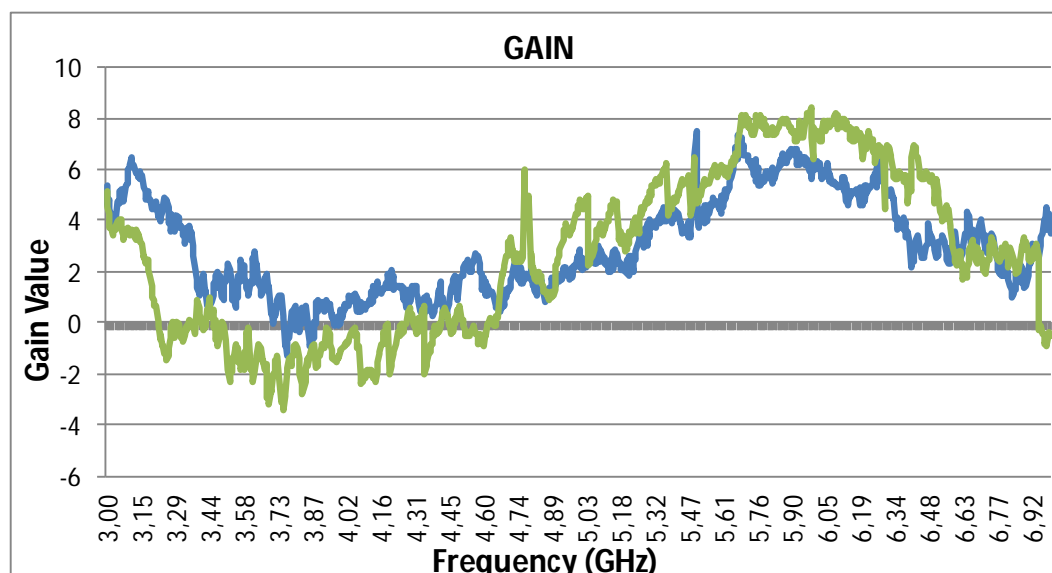
Novel Circular Microstrip Patch Antenna work in 5.53GHz frequency center in bandwidth range approximately 402.0MHz (5.32GHz–5.72GHz). The simulation result shown the antenna works well within the design frequency range. This indicate that the Novel Circular Microstrip Patch Antenna giving the good effect in bandwidth and antenna performance that can be applied in satellite communication especially in C-Band frequency. The simulation shown in S_{11} parameter is reflection coefficient 0.05, Voltage Standing Wave Ratio (VSWR) 1.11, return loss -25.09dB and 7.38dB in gain. The measurements shown in 5.51GHz frequency center in bandwidth range approximately 740.0MHz (5.18GHz–5.92GHz), S_{11} parameter is reflection coefficient 0.03, Voltage Standing Wave Ratio (VSWR) 1.06, return loss -30.69dB and 7.16dB in gain. The simulated and measured return loss (S_{11} parameter), VSWR and gain of the proposed antenna is shown in Figure 5.



(a) S_{11} Parameter.



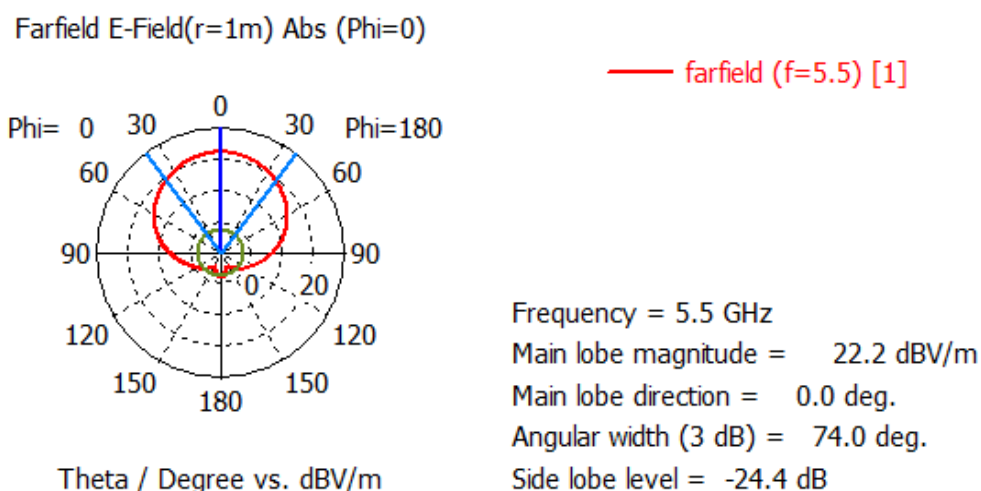
(b) VSWR.



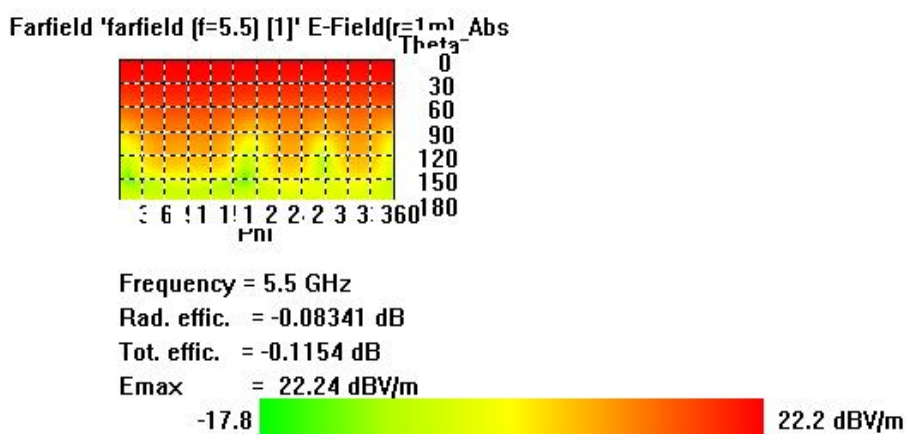
(c) Gain

Figure 5. The result of Novel Circular Microstrip Patch Antenna.

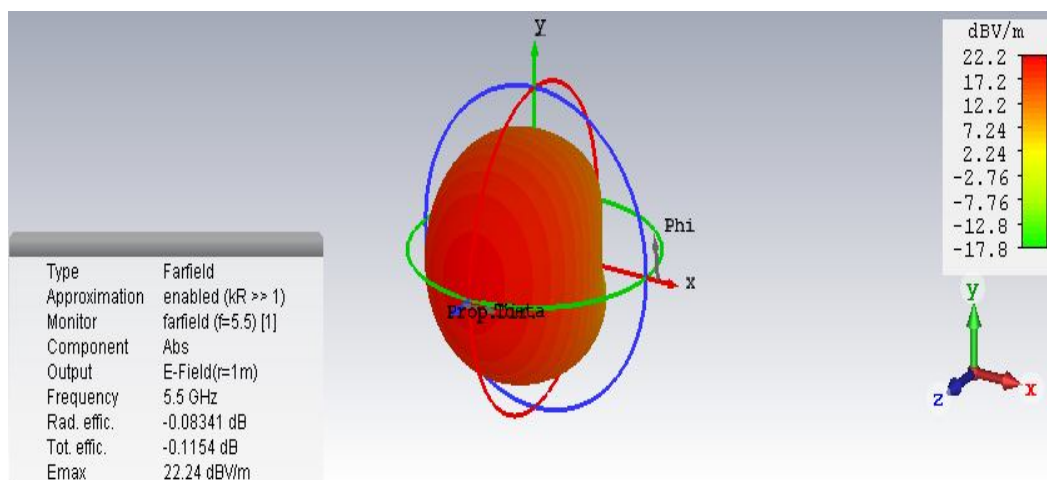
From the (S_{11} parameter) return loss plot, it can be observed that the antenna has a -10dB bandwidth 7.23% (5.72GHz–5.32GHz) which is in the C-Band region. It resonates at 402.0MHz. From the VSWR graph (1.11 VSWR) its shown that the antenna is able to transmit the electromagnetic field. And from the gain plot (7.46dB) thats indicate the antenna has a good power to transmit the signal power. Figure 6 shown the polarization for vertical linear polarization of the proposed antenna at resonance frequency of 5.53GHz.



(a) 1D Polarization Pattern.

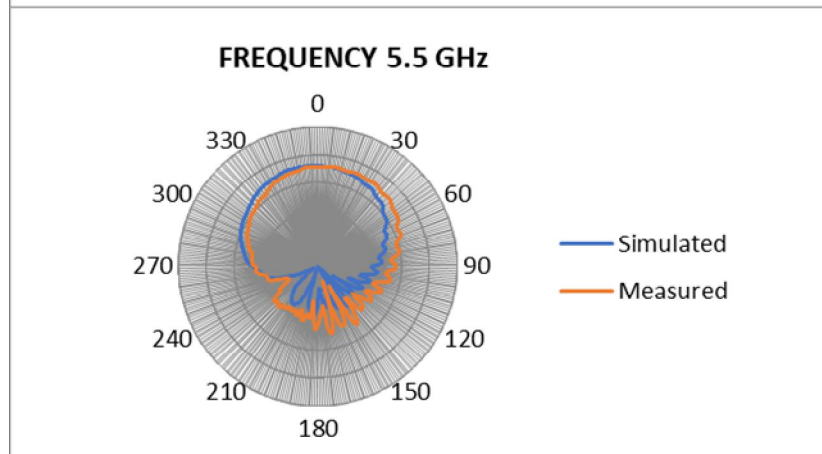
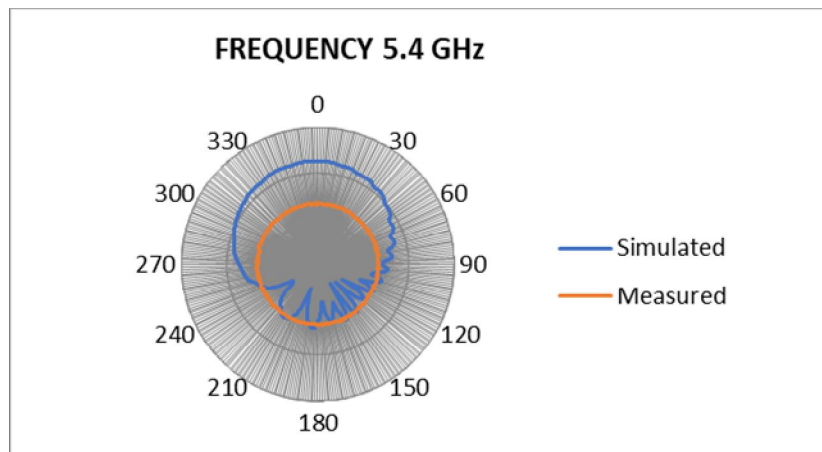
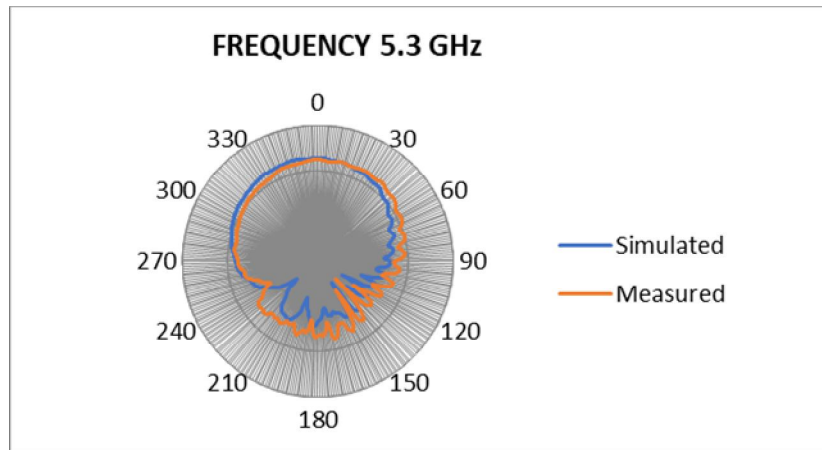


(b) 2D Polarization Pattern



(c) 3D Polarization Pattern

Figure 6. The Polarization of the Circular Microstrip Patch Antenna.



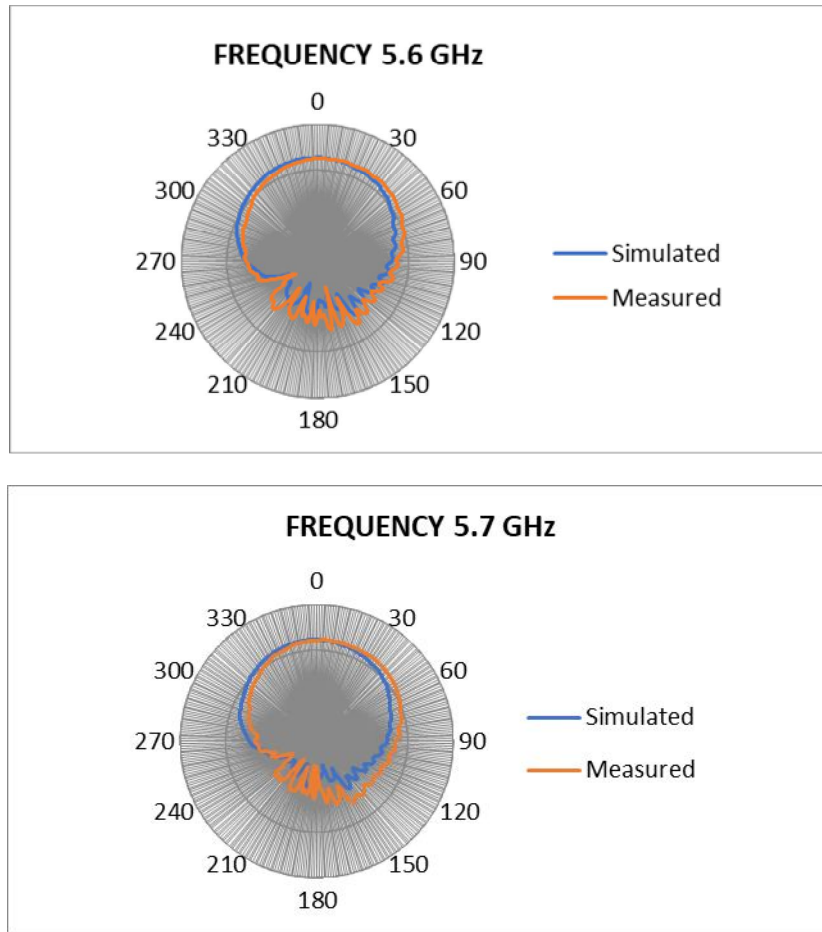


Figure 7. The Polarization of the Circular Microstrip Patch Antenna in (5.3,5.4,5.5,5.6,5.7)GHz Frequency.

The polarization in Novel Circular Microstrip Patch Antenna is linear vertical polarization. A directivity of 7.38dBi is obtained in simulation. This results is compatible for antenna in C-Band frequency. The Circular Microstrip Patch Antenna was tested using Network Analyzer type The Agilent 8510 Vector Network Analyzer. The measured S_{11} indicate that the Circular Microstrip Patch Antenna compatible in communications application especially in C-Band frequency. Summarizing the comparison between simulated and measured is shown in following table.

Table 3. Summarizing table of simulated and measured results of proposed antenna.

Parameters	f_c (GHz)	BW (%)	RL (dB)	VSWR	Γ	Gain (dB)
Simulated	5.53	7.23	-25.09	1.11	0.05	6.43
Measured	5.51	13.43	-30.69	1.06	0.03	7.46

A satisfy Circular Microstripline Array Antenna must have more than 5dB gain in working frequency. The simulation results of the Circular Microstripline Array Antenna obtained of 7.46dB gain and the measurement results of the Circular Microstripline Array Antenna obtained of 7.16dB gain.

The current distribution on the patch at resonance frequency of 5.5GHz is depicted in Figure 8.

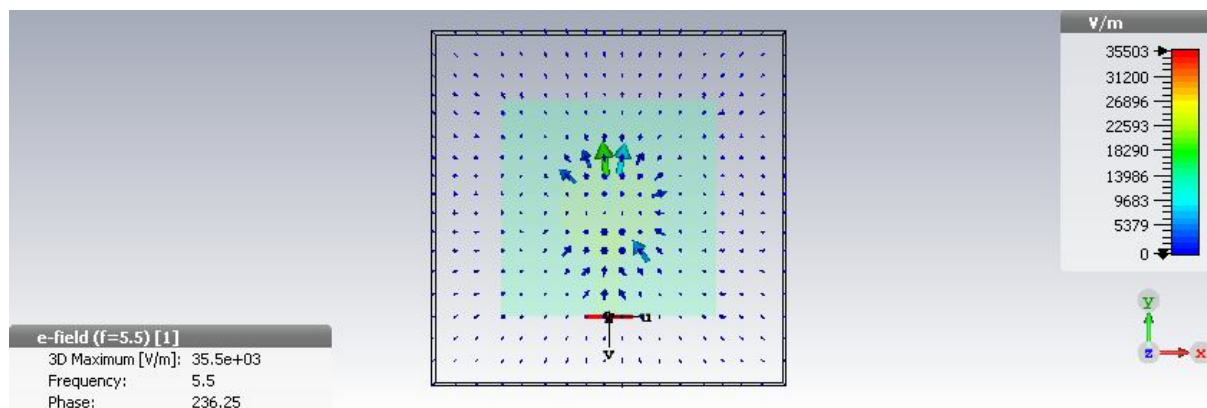


Figure 8. Current distribution of proposed antenna at 5.5GHz frequency.

Arrow sign indicates the direction of current. It can be seen that the current distribution flows at the edge of the patch intensively.

In general, the proposed antenna is designed to operate at C-Band and it can be observed from return loss and gain in antenna design that this antenna is suitable for being used in satellite communication. It can also be observed that an impedance bandwidth of 402.0MHz (7.23%) is obtained due to proper matching. It can be easily observed from the radiation pattern that the designed antenna produces linear vertical polarization radiation pattern. There are some significant advantages if a patch antenna has a stable and symmetrical in radiation pattern. One of the major advantages is that during construction of an antenna, the radiation pattern would be more stable across the operating bandwidth. From the current distribution display, it is observed that at resonant frequency of 5.5GHz, the electric current strongly flows at the edge of the patch especially near the circular of the patch. This indicates that the circular patch dominate the antenna performance. The current distribution flow is restricted due to the circular patch which leads the reduction of cross-polarization level. However, the current distribution at different part of the patch is almost uniform.

4. CONCLUSIONS

Linearly polarized microstrip patch antenna with truncate square in circular patch and feeding stripline has been demonstrated in this study. The circular patch with truncate square and feeding technique makes it possible to have a bandwidth of 13.43% and linear polarization at C-Band. It covers the frequency ranges from 5.18GHz–5.92GHz in 5.51GHz center frequency. This antenna can be easily fabricated on substrate material due to its small size and thickness. The results of characteristic antenna parameter in this paper indicate that the novel circular microstrip patch antenna with linear polarization can be used in C-Band frequency application and capable supporting satellite communication system.

ACKNOWLEDGMENT

The authors would like to thank the Indonesian Ministry of Research, Technology and Higher Education through LPDP and PKPI (Sandwich-like) scholarships, Center for Environmental Remote Sensing (CEReS), Josaphat Tetuko Sri Sumantyo (JMRSU Chiba University), Promotor Yono Hadi Pramono and Mashuri (Physics Department, ITS Surabaya). And, my department Ganesha University of Education (UNDIKSHA).

References

- [1] Artawan. *Fabrikasi dan Karakterisasi Antena Mikrostrip Tapered Patch Untuk Aplikasi Antena Panel Pada Frekuensi 2,4GHz*. Tesis Magister, Jurusan Fisika, Fakultas Matematika dan Ilmu Pengetahuan Alam, Institut Teknologi Sepuluh Nopember (ITS), Surabaya, 2011.
- [2] Artawan, Hadi Pramono, Yono. *Perancangan Antena Panel Mikrostrip Horn Array 2x2 Untuk Komunikasi Wi-Fi Pada Frekuensi 2,4GHz*. Prosiding Simposium Fisika Nasional (SFN), ITS, Surabaya, 2010.
- [3] Balanis, C.A. *Antena Theory Analysis and Design*. Second Edition, John Wiley and Sons, New York, 1997.
- [4] Edward, Terry. *Foundation For Microstrip Circuit Design*. Knaresborough England, 1991.
- [5] Shafai. *Microstrip Antena Design Handbook*. Profesor University Of Manitoba, Wimmipeg, Canada, 2001.

- [6] Kraus, John, D. *Electromagnetics*. Third Edition, McGraw-Hill, New York, 1984.
- [7] Ohri, V, Amin, O, Gebremariam, H Dubois, B. *Microwave Microstrip Horn Antena Design and Test System*. San Jose State University, 2003.
- [8] Masduki, K. *Desain, Fabrikasi dan Karakterisasi Antena Mikrostrip Biquad dengan CPW (Coplanar Waveguide) pada Frekuensi Kerja 2,4GHz*. Program Magister Bidang Keahlian Optoelektronika Jurusan Fisika, FMIPA-ITS: Surabaya. 2009.
- [9] Hund, E. *Microwave Communications, Component and Circuit*. McGraw Hill, New York, 1989.
- [10] Hadi Pramono, Yono. *Karakterisasi Antena Mikrostrip Patch 3GHz Secara Simulasi FDTD (Finite Difference Time Domain) Dan Eksperimen*. Jurnal Fisika. Institut Teknologi Sepuluh Nopember. Surabaya, 2005.
- [11] Hadi Pramono, Yono. *Prototipe Antena Bi-Mikrostrip Tapered Patch dengan Dua Arah Pola Radiasi Dan Satu Feeding Monopole Beroperasi Pada Freq.2,4GHz*. Prosiding T.Informatika, UPN. Yogyakarta, 2009.
- [12] Hidayah, Ifa. *Desain dan Fabrikasi Antena Bi-Mikrostrip Tapered Patch dengan Dua Arah Radiasi dan Satu Feeding Monopole Untuk Komunikasi Wi-fi*. Tesis Magister. Institut Teknologi Sepuluh Nopember. Surabaya, 2009.
- [13] Naqiah, Hawaun. *Fabrikasi dan Karakterisasi Antena Mikrostrip Loopline untuk Komunikasi Wireless Local Area Network (WLAN)*. Program Magister Bidang Keahlian Optoelektronika Jurusan Fisika FMIPA-ITS: Surabaya, 2009.
- [4] Risfaula, Erna. *Antena Mikrostrip Panel Berisi 5 Larik Dipole dengan Feedline Koaksial Waveguide untuk Komunikasi 2,4GHz*. Program Keahlian Optoelektronika Jurusan Fisika FMIPA-ITS: Surabaya, 2011.
- [15] Haider Raad, "An UWB Antenna Array for Flexible IoT Wireless System," *Progress In Electromagnetics Research*, Vol. 162, 109-121, 2018.
- [16] Kumar Dwivedi M, Srivastava Pragati. "Microstrip Patch Array Antenna for X-Band Application". *Antenna Test and Measurement Society (ATMS India-16)*, 01-03 Feb, 2016.
- [17] Ranjani M.N, Sivakumar B. "Analysis of Linearly and Circularly Polarized Microstrip Patch Antenna Array". *International Journal Of Electrical, Electronics And Data Communication*, ISSN: 2320-2084, Volume-4, Issue-7, Jul.2016.
- [18] Reddy Vishnu Vardhana C, Rana Rahul. "Design Of Linearly Polarized Rectangular Microstrip Patch Antenna Using IE3D/PSO". *Thesis*. Bachelor Technology in Electronics and Communication Engineering. Department of Electronics and Communication Engineering. National Institute of Technology. Rourkela. 2009.
- [19] Madhav, B.T.P, Sai Gupta, G, Rahul, M, Lahari Krishna, Sameera, M. "Linearly Polarized Microstrip Planar Filtenna for X and Ku Band Communication System". *Indian Journal of Science and Technology*, Vol. 9 (38), DOI:10.17485/ijst/2016/v9i38/97115, October. 2016.

AUTHOR



Putu Artawan. Was born in Seririt, Bali, Indonesia on 20 December 1979. Following elementary school until senior high school in Seririt Bali. He was graduated (S.Pd) at IKIP Negeri Singaraja, Bali Indonesia in Physics Education programme on 2002. And, was graduated in Master Programme (M.Si) at ITS Surabaya, Indonesia in Optoelectronics field, Department of Physics, Faculty of Sciences on 2011. Now, he has been following Doctoral programme at Physics Departement, Faculty of Science ITS Surabaya, Indonesia in Antenna Design and its application in communications systems specifically. Author as a lecturer at Physics Education Departement, Faculty of Mathematics and Sciences, Ganesha University of Education Singaraja, Bali, Indonesia start from 2006. Besides teaching, he as a advicer science and physics olympiads actively, write some books such as Mathematical Physics, Basic Physics, Magnetic Electricity and Wave Optic. He ever following article writting programme and foreign language training. Some of the research results was presented at International Conferences event in Singapore, Australia, Korea and Indonesia. He interested in research to develop Antenna Design and its applications in Communications Systems. Putu Artawan, M.Si ever goal to get Sandwich Programme scholarship at Chiba University, Japan on 2018 for improving International Publication in Center for Environmental Remote Sensing (CEReS), Josaphat Microwave Remote Sensing Laboratory (JMRS�), Japan. He was receive rewards Satya Lencana Karya Satya X from President Republic of Indonesia. And as a member of Indonesia Physics Society (HFI).