Dual-Band Circular Microstrip Patch Antenna Based on Reactively Loaded Dual Frequency Technique And DGS for RFID Reader

Nanang Ismail[1], Elita Wijayanti[2], Folin Oktafiani[3], Abdul Latip[4]
{nanang.is@uinsgd.ac.id[1], wijayantielita@gmail.com, oktafiani@gail.com, abdullatip1110@gmail.com}

Electrical Engineering Department, UIN Sunan Gunung Djati Bandung[1,2,4],
Research Center for Electronic and Telecommunication Indonesian Institute of Sciences[3]

Abstract. One of the superior wireless technologies in the identification of various objects that are efficient, fast, cheap, and effective, especially in the field of logistics, namely technology of Radio Frequency Identification (RFID). Differences in the working frequency of RFID technology used for logistics needs can be overcome by designing a reader antenna that has two working frequencies (dual-band). This paper proposes a dual-band microstrip antenna design with patch circular for RFID readers. The method used to generate two working frequencies is the Reactively Loaded Dual Frequency method, which is to load the antenna in the form of two slots and one stub on the patch circular. Besides, the antenna is also designed with the addition of the Defected Ground Structure (DGS) in the form of a rectangular slot to improve the S-parameters. The antenna is realized using a substrate made from FR-4 with a thickness of 1.6mm, the dielectric constant is 4.3, and uses a coaxial probe type. The measurement results prove that the microstrip antenna is capable of producing two working frequencies namely 2.48 GHz and 5.768 GHz which are by following the standards of ISO 18000-4 and ISO 18000-5. At a frequency of 2.48 GHz, the values of S_{11} is -11.453 dB, VSWR 1.741, and bidirectional radiation patterns were obtained. At a frequency of 5.768 GHz, values of S11 is -11,490 dB, VSWR 1,728 and bidirectional radiation patterns were obtained. VSWR resulting from the measurement shows the results that meet the mirostrip antenna criteria, which is ≤ 2. The S_{11} produced is in accordance with the specifications, with a value of $\leq$ -10 dB.

Keywords: Microstrip Antenna, Dual-band, Patch Circular, Reactively Loaded Dual Frequency, DGS, RFID.

1 Introduction

Wireless communication requires high mobility [1] so that to support this the microstrip antenna can be used which has the characteristics of small and light size, a neat structure, affordable price, and easy to be integrated with other components [2]. One of the applications of wireless communication is Radio Frequency Identification (RFID). The technology of RFID can do many things in the identification of various objects, can be used to identify the operation of any distribution system so that it is efficient, fast, cheap, and effective, especially in logistics. Various agencies and companies in Indonesia have used electronic identification [1]. Microstrip antenna for RFID reader has been developed with a variety of methods and various work frequencies [3] [4].

ICONISTECH 2019, July 11-12, Bandung, Indonesia

DOI 10.4108/eai.11-7-2019.2297771

The regulation of RFID work frequency allocation in each country is different. The allocation of the frequency of RFID work in Indonesia is issued by the Director General of Post and Telecommunications of the Ministry of Communication and Information which refers to the International Standards Organization (ISO). The frequency allocation for RFID is in the range of 923 MHz - 925 MHz [1] [5]. Table 1 shows the standard allocation of RFID working frequency in Indonesia.

Table 1. Frequency Allocation of RFID in Indonesia

Standard	Frequency	Application
ISO 11784		Animal Identification (read only)
ISO 14223/1	125 kHz/135 kHz	Animal Identification (read/write)
ISO 18000-2		Logistics
ISO 10536 (ID1 format)	0 to 30 MHz	High security
ISO 14443		Proximity cards (contactless controller)
ISO 15693		Vicinity cards (contactless memory)
ISO 18000-3	13.56 MHz	Logistics
EPC Class I RF		Electronic product code
NFC ECMA 340		Mobile near-field communications (smartcard payment)
ISO 18000-7	433 MHz	Logistics
ISO 18000-6		Logistics
EPC Class I Gen 2	860 to 960 MHz	Electronic product code (reading of multiple tags)
ISO 18000-4	2.4 to 2.4835 GHz, 2.45 GHz	Logistics
ISO 18000-5	5.725 to 5.875 GHz	Logistics

Various antenna development for the application of UHF RFID reader has been developed, starting from near field antenna [6] [7] [8] to far-field antenna [9]. Based on Table 1, there are several RFID working frequencies for logistics applications. The use of one antenna for one application is not profitable. So there are various techniques for making dual-band or multi-band antenna. Various research and development of dual-band antenna have been widely done with the aim of antenna efficiency because if one antenna only covers one frequency band, the amount becomes inefficient . The dual-band antenna is discussed in that can work at frequency 2.3 and 3.5 GHz. Other dual-band antennas for RFID readers are discussed in paper , where antennas are made for Portable RFID Readers. One technique for generating more than one working frequency on an antenna is to use the Reactively Loaded Dual Frequency technique, which is by adding a load to the antenna. Loads can be in the form of stubs, slots, pins, and others.

Based on the above explanation, this paper discusses the proposed dual-band microstrip antenna design for RFID applications with patch circular that work on two frequencies in the range of 2.4 - 2.4835 GHz (ISO 18000-4) and 5.725 - 5.875 GHz (ISO 18000-5). The antenna was developed with the Reactively Loaded Dual Frequency technique for generating dual-frequency. Improved antenna performance is done by adding a Defected Ground System (DGS).

DGS is one way to suppress surface waves which will indirectly affect the performance of an antenna. DGS technique is done by etching the groundplane area, one of them by adding rectangular slots [2].

2 Proposed Antenna Design

The antenna is designed to meet the specifications as listed in Table 2.

Table 2. Targeted antenna specifications

Parameter	Specifications
Frequency	Dual-band in the range 2.4 – 2.4835 GHz (ISO 18000-4) and 5.725 – 5.875 GHz (ISO 18000-5)
Substrate type	FR-4
Thickness of the substrate (h)	1,6mm
Permettivity (ε_r)	4.3
S11	≤ -10 dB
VSWR	≤ 2

The antenna is designed in two stages, namely the antenna design stage of single-band, and the antenna design stage of dual-band with the Method of Reactively Loaded Dual Frequency. At each stage, characterization is carried out to obtain results that are by following the targeted specifications

2.1 Stage I: Design of a Single-Band Antenna

The design begins with the determination of the initial dimensions through theoretical calculations. The parameters calculated are the dimensions of the patch, the feed channel, the dimensions of the groundplane, and the dimensions of the substrate. The results of the calculations are made into the initial design of a single-band antenna with the antenna specifications listed in Table 3.

Table 3. Initial dimensions of a single-band antenna

Parameter	Specification
Speed light reference	$3x10^8$ m/s
The radius of the patch (r)	17.26 mm
Minimum dimensions of the groundplane	38.3 x 32.2 mm
Dimensions of the substrate	38.3 x 32.2 mm
Dimension of the feed line	r_in = 1.2 r_out = 4

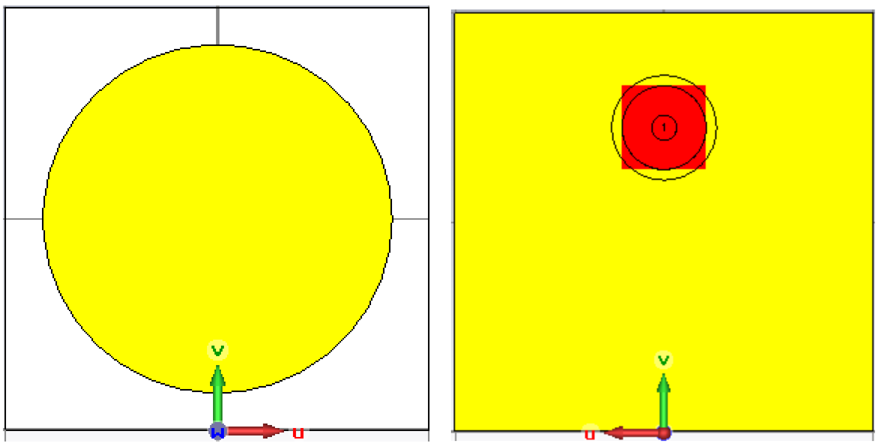
The calculation refers to the 2.4 GHz frequency value, the speed of light 3 x 10^8 m / s, FR-4 substrate with a thickness of 1.6 mm, and permittivity (ε_r) which is 4.3.

The simulation results show that the value does not meet the target specifications, so the characterization of the size of the circular patch radius affects the frequency shift and changes in the value of S_{11}. Table 4 shows the results of the characterization of the size of the patch radius.

Table 4. Characterization of circular patch for single-band antenna

No	r (mm)	Fr (GHz)	S11 (dB)
1	17.26	2.294	-8.0791
2	16.76	2.358	-9.9925
3	16.26	2.429	-9.8189
4	16.50	2.407	-11.362

In Table 4, characterization is performed for each radius reduction Δr = 0.5 mm. The 3rd characterization produces frequencies that exceed 2.4 GHz so that at the 4th characterization, the radius is raised again 16.50 mm and produces f_r = 2.407 GHz and S_{11} is -11.362 dB. Figure 1 is a stage I design of a single-band antenna for working frequencies in the range 2.4 - 2.4835 GHz.



a). b).

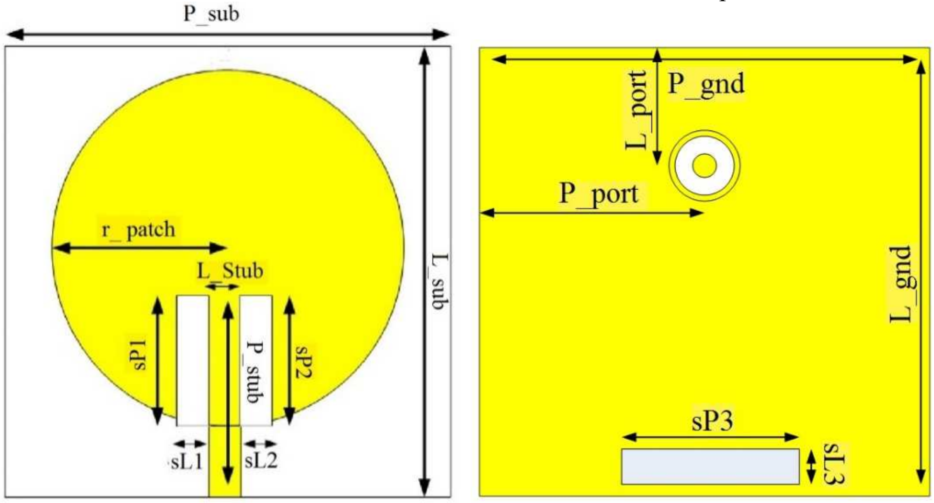
Figure 1. Stage I: design of a single-band antenna, a). front view, b). back view

Table 1. Comparison of Reliability of SUTTE, SMA, dan MACD

Indicator	MSE	MAD
SUTTE	1.385	0.832
SMA	2.590	1.090
MACD	14.670	2.952

2.2 Stage II: Design of the Dual-Band Antenna

After obtaining the first working frequency, the next stage is the antenna design for the second working frequency. The method used to generate two working frequencies is Reactively Loaded Dual Frequency, namely by adding a load of 2 slots and 1 stub to the patch circular. Besides, the groundplane section is then added with DGS in the form of a rectangular slot. Characterization was carried out on the dimensions of the patch, dimensions of the groundplane, dimensions of the slots, dimensions of the stub, and dimensions of DGS until the results were obtained according to the targeted specifications. Figure 2 shows the final design of a dual-band antenna for RFID readers, while Table 5 shows the dimensions of each parameter.



a). b).

Figure 2. Final design of a dual-band antenna: a). front view, b). back view

Table 5. Final dimensions of dual-band antenna

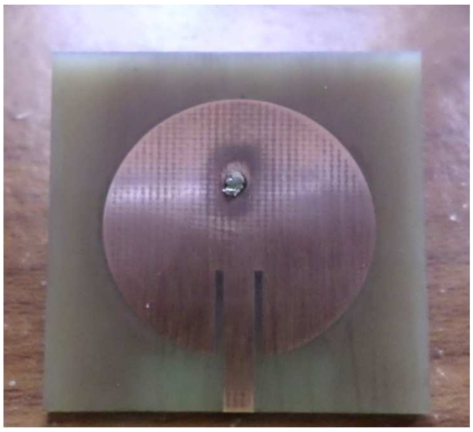
No	Parameter	Symbol	Dimension (mm)
1	Length of groundplane	P_gnd	40
2	Width of grounplane	L_gnd	40
3	Length of substrate	P_sub	40
4	Width of substrate	L_sub	40
5	Length of the 1st slot	sP1	10
6	Width of the 1st slot	sL1	1
7	Length of the 2nd slot	sP2	10
9	Width of the 2nd Slot	sL2	1
10	Length of the stub	P_stub	8.285
11	Width of stub	L_stub	3.1

12	Length of the 3rd slot	sP3	20
13	Width of the 3rd slot	sL3	5
14	Radius of patch	r_*patch*	14.35
15	Vertical distance of the feed line	L_port	10
16	Horizaontal distance of the feed line	P_port	15

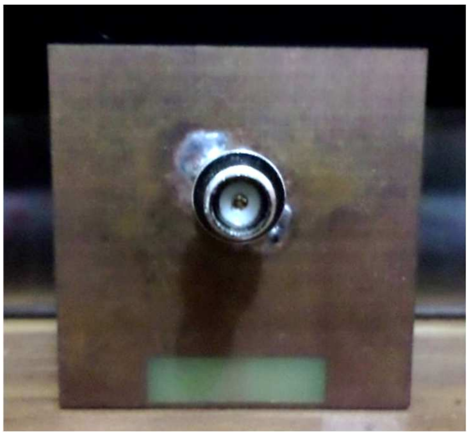
Based on the simulation, the design shown in Figure 2 and Table 5, gives results that are on target. The antenna works at the RFID working frequency according to the target, namely 2.48 GHz with S11 of-27.832 dB and a frequency of 5.768 GHz with S11 of -43.203 dB. VSWR obtained at the time of simulation for a working frequency of 2.48 GHz was 1.1596 and at a frequency of 5.768 GHz, the VSWR value was 1.0068.

3 Results and Analysis

The antenna is realized using FR-4 substrate with a thickness of h=1,6mm and permittivity ε_r=4.3. The antenna realization results can be seen in Figure 3.



a).



b).

Figure 3. The antenna realization: a). front view, b). back view

Measurements are made in two ways: single port and multiple port measurements. Single port measurement is performed to determine the parameters S_{11}, VSWR, bandwidth, and the input impedance of the antenna. Double port measurement is made to determine the polarization and antenna radiation pattern. But in this paper, the discussion is focused on parameters S11, VSWR, polarization, and radiation patterns. The single and double port measurement scheme respectively are shown in Figure 4 and Figure 5.

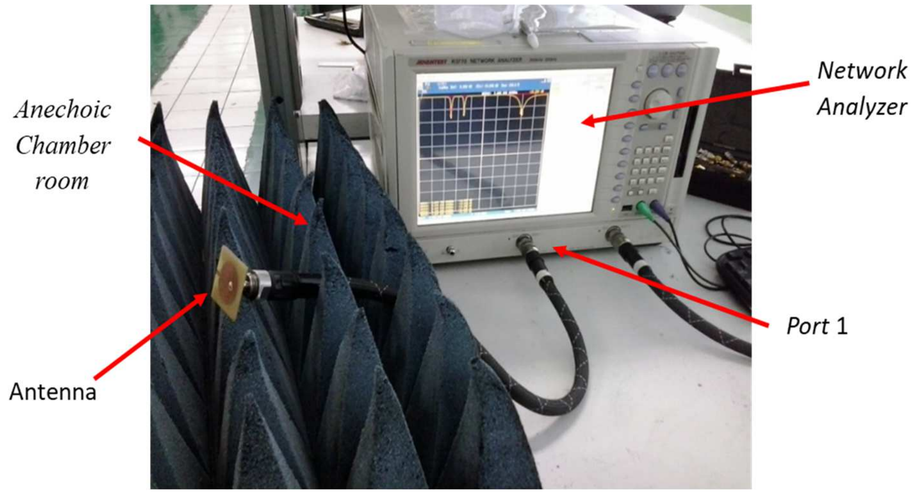


Figure 4. Single port measurement scheme

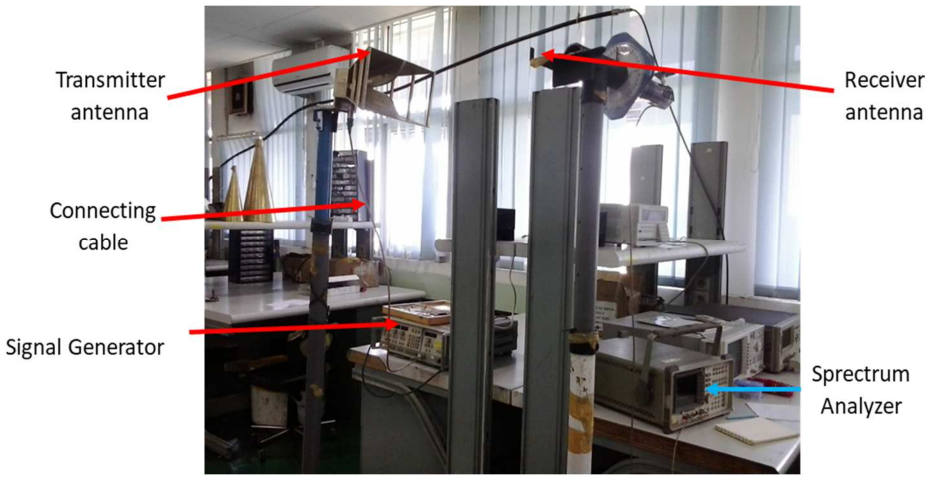


Figure 5. Multiple port measurement Scheme

Based on the measurement results at 2.48 GHz frequency, S11 of -11.453 dB is obtained and at 5.768 GHz frequency, S11 of -11.490 dB is obtained. Graphically, the S11 parameter can be seen in Figure 6.

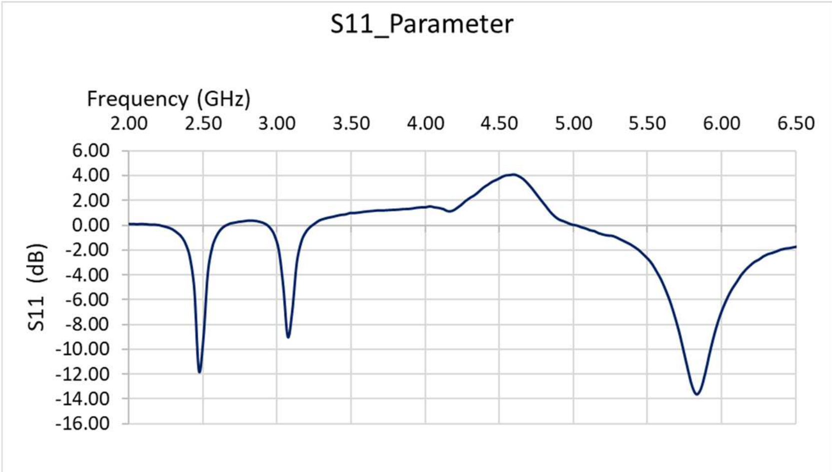


Figure 6. S11 of the dual-band antenna

Meanwhile, at a frequency of 2.48 GHz, a VSWR 1.741 is generated and a frequency of 5.748 GHz is generated at a VSWR 1.728. VSWR generated by both working frequencies has fulfilled the microstrip antenna criteria, namely ≤ 2. Graphically, VSWR can be seen in Figure 7.

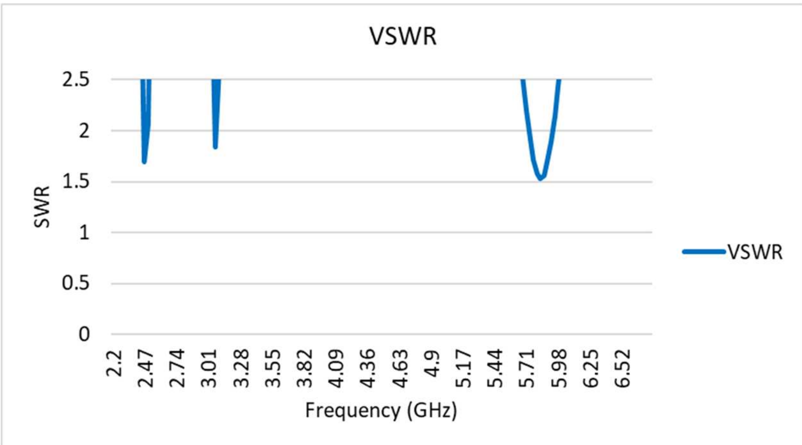


Figure 7. Grafik VSWR antena dual-band

Based on the results of multiple port measurements, at a frequency of 2.48 GHz, azimuth field radiation patterns are generated at an angle of 0° by -21.97 dBm while the radiation pattern of the elevation field at an angle of 90° is -45.89 dBm. At a frequency of 5.768 GHz the azimuth field radiation pattern is produced at an angle of 0° by -43.07 dBm while the radiation pattern of the elevation field at an angle of 90° is -45.95 dBm. Radiation patterns at the frequencies of 2.48 GHz and 5.678 GHz produced the type of bidirectional radiation pattern leading to angles of 0° and 190 °. At 2.48 GHz frequency, polarization at 0° angle is -21.97 dBm while at 5.768

GHz frequency polarization is generated at an angle of 0° -42.07 dBm. The second frequency polarization is in the form of imperfect linear polarization (ellipse). Radiation and polarization patterns at each work frequency can be seen in Figure 8, Figure 9, Figure 10, and Figure 11.

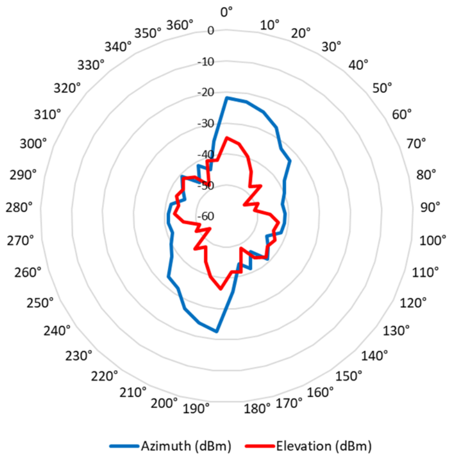


Figure 8. Antenna radtiation pattern at the 2.48 GHz frequency

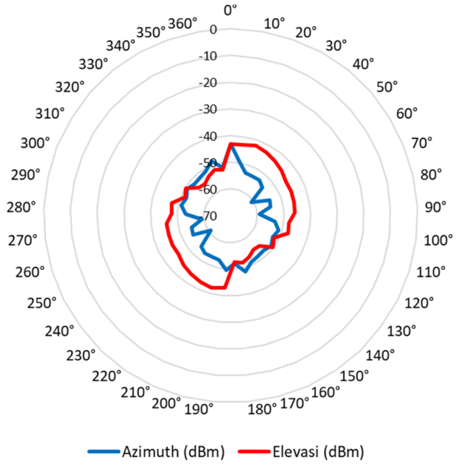


Figure 9. Antenna radiation pattern at the 5.768 GHz frequency

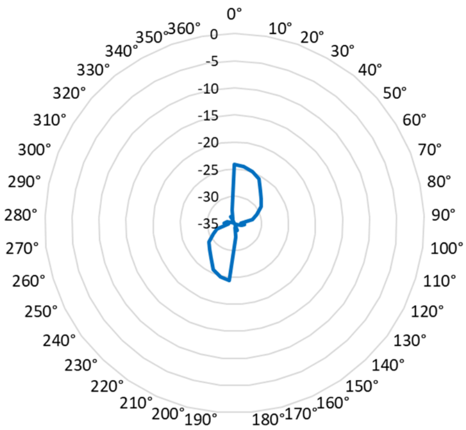


Figure 10. Antenna polarization at the 2.48 GHz frequency

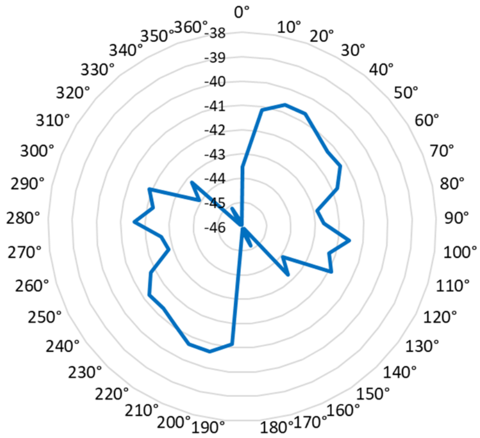


Fig 11. Antenna radiation pattern at the 5.768 GHz frequency

4 Conclusions

The Reactively Loaded Dual Frequency method used successfully generated two working frequencies on the designed antenna. The measurement results prove that the microstrip antenna as an RFID reader is able to produce two working frequencies (dual-band) namely 2.48 GHz and 5.768 GHz which are by following the standards of ISO 18000-4 and ISO 18000-5.

Acknowledgments

On this occasion, we present our gratitude to the Faculty of Science and Technology UIN Sunan Gunung Djati, which provides the facility for research, and to the Research and Publishing Centre of UIN SGD Bandung for support to this activity.

References

[1] "CHAINWAY - Handheld Computer_Handheld RFID Reader_Handheld Terminal." [Online]. Available: https://www.chainway.net/?gclid=CjwKCAiA6vXwBRBKEiwAYE7iS_27XnrF3DkaAO5qi2lZELqAqfpTRFc_t5eG8_8jxTy772YTHju4yhoCbtsQAvD_BwE. [Accessed: 15-Jan-2020].

[2] "N. Ismail, T. S. Gunawan, S. K. Sari, T. Praludi and E. A. Hamidi, 'Design of microstrip hairpin bandpass filter for 2.9 GHz – 3.1 GHz s-band radar with defected ground structure,' Malaysian Journal of Fundamental and Applied Sciences, vol. 14, no. 4, pp. 448-455, 2018. - Penelusuran Google." [Online]. Available: https://www.google.com/search?q=N.+Ismail%2C+T.+S.+Gunawan%2C+S.+K.+Sari%2C+T.+Praludi+and+E.+A.+Hamidi%2C+%22Design+of+microstrip+hairpin+bandpass+filter+for+2.9+GHz+–+3.1+GHz+s-band+radar+with+defected+ground+structure%2C%22+Malaysian+Journal+of+Fundamental+and+Applied+Sciences%2C+vol.+14%2C+no.+4%2C+pp.+448-455%2C+2018.&rlz=1C1CHBD_idID878ID878&oq=N.+Ismail%2C+T.+S.+Gunawan%2C+S.+K.+Sari%2C+T.+Praludi+and+E.+A.+Hamidi%2C+%22Design+of+microstrip+hairpin+bandpass+filter+for+2.9+GHz+–+3.1+GHz+s-band+radar+with+defected+ground+structure%2C%22+Malaysian+Journal+of+Fundamental+and+Applied+Sciences%2C+vol.+14%2C+no.+4%2C+pp.+448-455%2C+2018.&aqs=chrome..69i57.462j0j4&sourceid=chrome&ie=UTF-8. [Accessed: 15-Jan-2020].

[3] C. S. Nair and M. Shah, *External quality audit : has it improved quality assurance in universities?* .

[4] S. Chen, X. Yang, and H. Sun, "Circularly polarized stacked circular microstrip antenna with an arc feeding network," in *Lecture Notes in Electrical Engineering*, 2011, vol. 98 LNEE, no. VOL. 2, pp. 927–932, doi: 10.1007/978-3-642-21765-4_115.

[5] "Regulation of Frequency and Standardization - SDPPI Regulation - Direktorat Jenderal Sumber Daya dan Perangkat Pos dan Informatika." [Online]. Available: https://www.postel.go.id/?mod=main&cid=3&page_id=93&lang=en. [Accessed: 15-

Jan-2020].

[6] "[IEEE 2012 IEEE International Conference on RFID-Technologies and Applications (RFID-TA) - Nice, France (2012.11.5-2012.11.7)] 2012 IEEE International Conference on RFID-Technologies and Applications (RFID-TA) - Use of transmission lines as near field antenna in UHF RFID." [Online]. Available: https://dokumen.tips/documents/ieee-2012-ieee-international-conference-on-rfid-technologies-and-applications-58ccb394786ea.html. [Accessed: 15-Jan-2020].

[7] "Active Rfid Tags,uhf Rfid Reader Manufacturers | Marktraceiot.com." [Online]. Available: https://www.marktraceiot.com/?gclid=CjwKCAiA6vXwBRBKEiwAYE7iS3ISoZNRw9rLtnO7DTs7ayMVRKGjUgBDfKFzEv6T7_35meUpLfFsVBoCPXEQAvD_BwE. [Accessed: 15-Jan-2020].

[8] M. Al-Gabri, C. LI, and L. Li, "Improving ZigBee AODV Mesh Routing Algorithm Topology and simulation analysis," *TELKOMNIKA Indones. J. Electr. Eng.*, vol. 12, no. 2, Feb. 2014, doi: 10.11591/telkomnika.v12i2.3576.

[9] "RFID Tags - RFID Tags Application, RFID Tracking System, Best rfid tag Manufacturer in india." [Online]. Available: http://www.omniatags.com/?gclid=CjwKCAiA6vXwBRBKEiwAYE7iS2dlzqypGggwLZq9uB2JdX45p2YOcFKWtUUs5ms3txi_FhQLwwAfUxoCkVIQAvD_BwE. [Accessed: 15-Jan-2020].