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Implementation of Truncated Microstrip Patch Antenna for Microwave Radio Communication

***Abstract**. This study proposes the realization and implementation of a truncated microstrip patch antenna (MPA) for a microwave radio communication at a resonant frequency of 11 GHz. The truncated corner technique is employed to produce circular polarization with an axial ratio ≤ 3 dB by cutting the patch edges from the microstrip patch antenna. The measurement results confirmed that the proposed antenna has operated at a resonant frequency of 11 GHz with return loss performance ≤ -10 dB and VSWR ≤ 2. Furthermore, the circular polarization of the proposed antenna revealed an axial ratio ≤ 3 dB at resonant frequency of 11 GHz with fractional bandwidth of 6.95 %. From the field testing, a stable receive signal level could be obtained when the antenna's azimuth is in 90°, 180°, and 270°. Therefore, it can be inferred that the proposed antenna can be a future candidate for microwave radio commutation system application.*

***Streszczenie.** W opracowaniu zaproponowano wykonanie i implementację anteny z mikropaskami ściętymi (MPA) do mikrofalowej komunikacji radiowej z częstotliwością rezonansową 11 GHz. Technika ściętego narożnika jest wykorzystywana do uzyskania polaryzacji kołowej ze stosunkiem osiowym ≤ 3 dB poprzez odcięcie krawędzi z anteny mikropaskowej. Wyniki pomiarów potwierdziły, że proponowana antena pracowała z częstotliwością rezonansową 11 GHz przy tłumienności odbiciowej ≤ -10 dB i VSWR ≤ 2. Ponadto polaryzacja kołowa proponowanej anteny wykazała stosunek osiowy ≤ 3 dB przy częstotliwości rezonansowej 11 GHz z ułamkową przepustowością 6,95%. Z testów w terenie można było uzyskać stabilny poziom odbieranego sygnału, gdy azymut anteny wynosi 90 °, 180 ° i 270 °. Dlatego można wywnioskować, że proponowana antena może być przyszłym kandydatem do zastosowania w systemie komunikacji mikrofalowej. (Zastosowanie anteny z mikropaskami do radiowej komunikacji mikrofalowej)*

In **Keywords:** antenna, microstrip, microwave radio, truncated patch
Słowa kluczowe: antena mikrofalowa, mikropaskio, radiokomunikacja.

Introduction

Microwave radio communication systems have been widely used for long-distance wireless communication. Several frequency bands employed in microwave radio communications include S Band, C Band, X Band, and Ku Band [1]. The microwave radio communication system requires an excellent receive signal level to support communication between the transmitter and receiver. However, systems have short wavelength that decreases the quality of the received signal level if it is interrupted by an obstacle [2]. To solve this problem, circular polarization can be adopted as a solution to control the quality of the reception signal level to be more stable.

One type of antenna that can be optimized to produce circular polarization is microstrip antenna [3-4]. Circular polarization on the microstrip antenna has an axial ratio ≤ 3 dB [5]. In this case, several techniques have been used to obtain circular polarization, including truncated corner [6-9], fractal [9-12], and proximity coupling [13-14]. A previous study by [15] employed truncated corners and shifted feed lines to obtain a circular polarization with axial ratio ≤ 3 dB, return loss of -26.04 dB, and VSWR 1.1 at a frequency of 1575 MHz for the L Band. Furthermore, in [16], the truncated corner microstrip patch antenna was optimized with an array of 2×2 elements to obtain a return loss of -19.34 dB or VSWR 1,551 with a bandwidth of 59 MHz, HPBW of 50 °, and an axial ratio of 2.53 dB for the S Band frequency.

In this study, the truncated corner technique was adopted to produce a circular polarization antenna with an axial ratio ≤ 3 dB. To increase the gain and bandwidth of the proposed antenna, an array method with 4×1 element was applied by arranging the antenna in a horizontal position connected to a microstrip line. Furthermore, field testing was conducted to measure the receive signal level stability of the proposed antenna.

Antenna Design

In this study, the proposed antenna was designed to work at a resonant frequency of 11 GHz. It was realized on a double-layer FR-4 substrate with relative permittivity (εr) of 4.3, substrate thickness (h) of 1.6 mm, and loss tangent (tan α) of 0.0265. The dimension of the proposed antenna can be seen in Fig. 1. The feed line used from the proposed antenna is a microstrip line with an input impedance of 50 Ω.

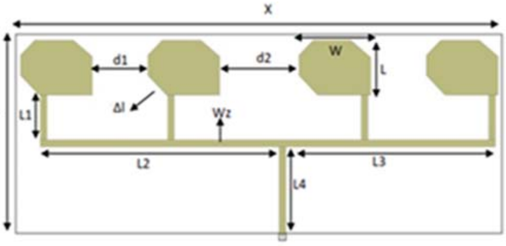

Fig. 1. Proposed Antenna Design

Fig. 1 shows the proposed antenna design developed using an array with four elements. Each patch antenna is separated by distance d1 and d2. This spacing arrangement between patches was implemented to prevent interference between the radiating elements. The overall dimension of the proposed antenna can be seen in Table 1.

Table 1. The Proposed Antenna Dimension

Parameter	Dimension (mm)	Parameter	Dimension (mm)
X	51.5	L2	25.4
Y	20	L3	22
W	7.8	L4	10
L	5.1	Wz	0.7
Δl	2.5	d1	5.9
L1	4.5	d2	8.4

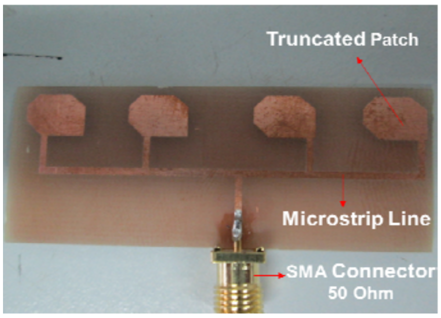

Fig.2. Proposed Antenna Design

Fig. 2 shows the proposed antenna fabrication consisting of four patch antennas that have three slices at the edges. In this case, the edges were cut to produce a circular polarization with an axial ratio ≤ 3 dB.

Result and Discussion

After the proposed antenna was fabricated, it was measured. The parameters measured and observed were return loss, VSWR, gain, axial ratio, and radiation pattern at the resonant frequency of 11 GHz. Figure 3 and Figure 4 present simulation comparison and measurement of return loss and VSWR of the proposed antenna.

Furthermore, Fig. 3 and Fig. 4 show that the antenna has been operating at 11 GHz resonant frequency with return loss values of 10 dB and VSWR 2. The resonant frequency was slightly shifted to 11.5 GHz. However, it was still meet the specified criteria. Comparison of simulation results and measurements of axial ratio and gain can be seen in Fig. 5 and Fig. 6.

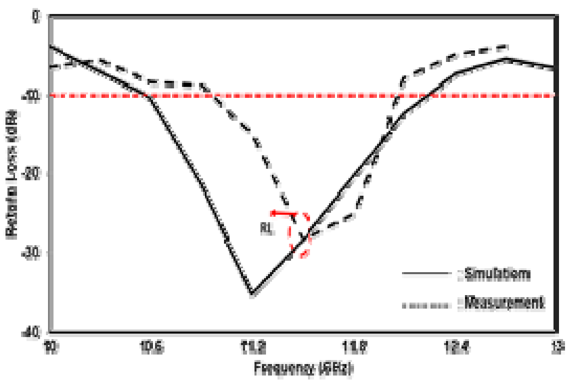

Fig.3. Comparison Result of Return Loss

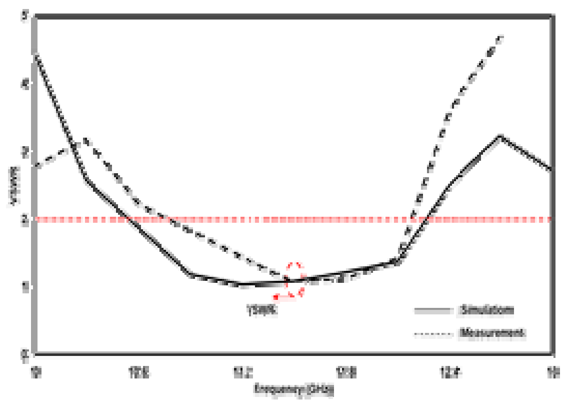

Fig.4. Comparison Result of VSWR

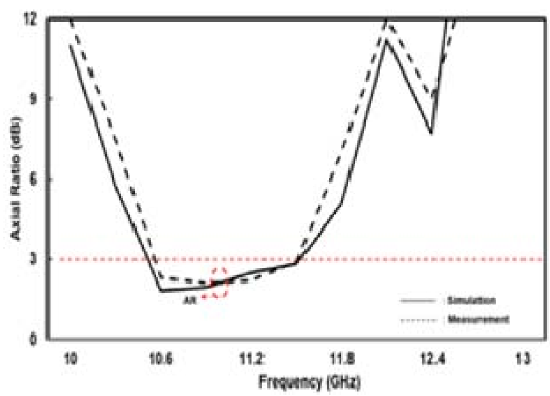

Fig.5. Comparison Result of Axial Ratio

Circular polarization with an axial ratio ≤ 3 dB can be seen in Figure 5. Moreover, Fig. 6 shows a comparison of the simulation and measurement process. The gain obtained from the measurement process was in accordance with the simulation process, which was in the range of 5.6 dBi. The radiation pattern of the proposed antenna can be seen as shown in Fig. 7.

Fig. 7 shows the radiation pattern of the proposed antenna at the resonant frequency of 11 GHz. Half Power Bandwidth (HPBW) of the proposed antenna was 40° compared with the radiation pattern of the isotropic antenna (3 dB). The overall results of the simulation and measurement process can be observed in Table 2.

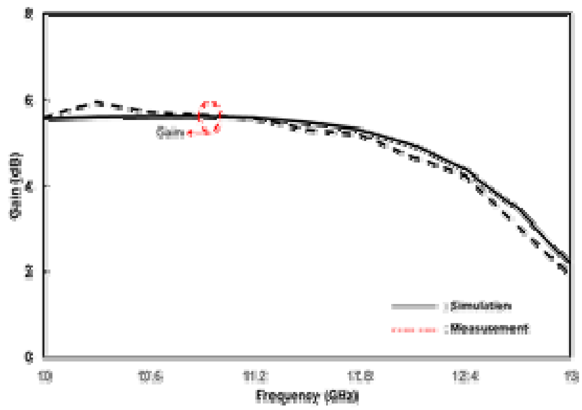

Fig.6. Comparison Result of Gain

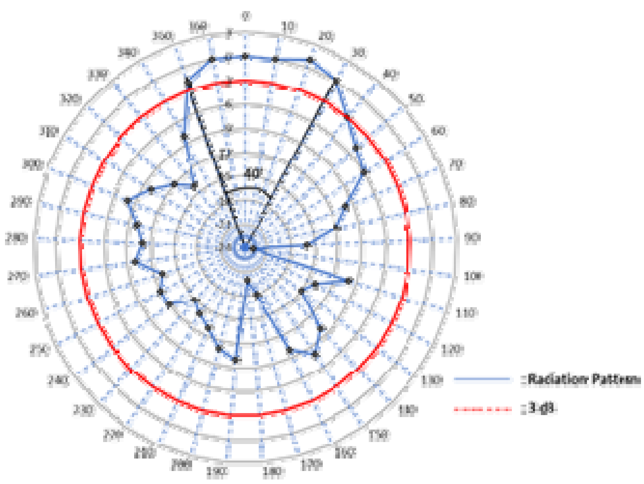

Fig.7. Radiation Pattern of Proposed Antenna

Table 2. Simulation and Measurement Result of the Proposed Antenna

Parameter	Process	
	Simulation	Measurement
Return Loss	-35.29 dB	-14.50 dB
VSWR	1.03	1.42
Axial Ratio	1.96 dB	2.1 dB
Gain	5.57 dB	5.48 dB

In this study, a field test was performed to observe the signal reception characteristics of the proposed antenna. The configuration of the field test is presented in Fig. 8 and Fig. 9.

Fig.8. Radiation Pattern of Proposed Antenna

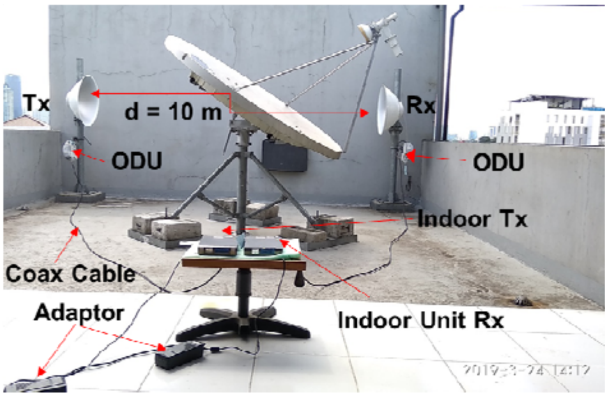

Fig.9. Field Test Configuration

Fig. 8 shows the proposed antenna was installed in a microwave radio at a resonant frequency of 11 GHz. The equipment configuration of the transmitter and receiver can be seen in Fig. 9. Furthermore, the power was transmitted from the radio that was controlled through an indoor unit (IDU). On the other hand, the proposed antenna was connected to the outdoor unit (ODU) using a spiral-shaped pigtail cable. The transmit power used in this field test was 6 dB. On the other hand, the signal reception level was observed at azimuths 90°, 180°, and 270°. The azimuth arrangement of the proposed antenna can be observed as shown in Fig. 10. The distance between the transmitting radio (Tx) and the receiving radio (Rx) is d = 10 meters as shown in Fig. 9. The application of reflectors to microstrip antennas has been described in previous studies [17]. The use of a reflector aims to increase the gain of the antenna.

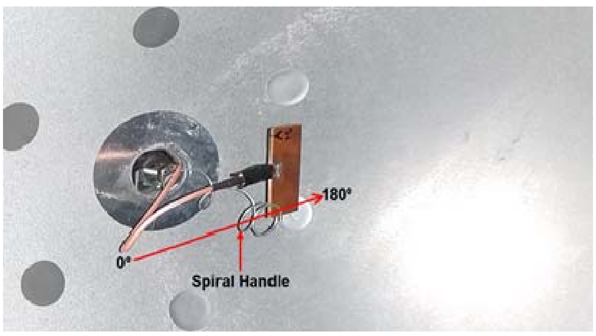

Fig.10. Azimuth of Proposed Antenna

Based on the field test observation, the received signal level from the proposed antenna was consistent at azimuths 90°, 180°, and 270°. The field test results can be seen in Fig. 11 and Table 3.

Attributes	Value	Units
Wireless		
Wireless Link Status	Up	
Maximum Transmit Power	6.0	dBm
Remote Maximum Transmit Power	6.0	dBm
Channel Bandwidth	10	MHz
Transmit Power	10.0, 6.2, 6.0, 6.0	dBm
Receive Power	-61.0, -65.3, -70.0, -65.5	dBm
Vector Error	-28.9, -30.8, -32.0, -30.9	dB
Link Loss	80.6, 76.2, 74.6, 76.1	dB
Transmit Link Capacity	13.89	Mbps
Receive Link Capacity	13.89	Mbps
Transmit Capacity Limit	20	Mbps
Transmit Capacity Limit Detail	Running At The Capacity Limit	
Transmit Modulation Mode	QPSK 0.86	
Receive Modulation Mode	QPSK 0.86	

RSL

Fig.11. Microwave Radio System Status

Table 3. Simulation and Measurement Result of the Proposed Antenna

Azimuth	Receive Signal Level (dBm)	
	Tx	Rx
0°	-65	-66
90°	-65	-66
180°	-65.5	-66
270°	-65.5	-65.5

Fig. 11 reveals that the radio transmit power was 6 dB and the received signal level was -65 dB at an azimuth of 0°. The received signal level at azimuth 90°, 180°, and 270° in Table 3 seem to be consistent at -65 dB. From the results, it can be inferred that the circular polarization of the proposed antenna successfully mitigated the signal instability issue due to cross-polarization. The electrical dimension of proposed antenna is 0.3 λ_0 x 0.19 λ_0 x 0.06 λ_0 corresponding to the center of operating-frequency of 11.3 GHz with range frequency of 10.9 GHz - 11.7 GHz.

Conclusion

This paper proposed the use of truncated patch microstrip antenna for microwave radio communication system. The measurement results obtained a return loss of -14.50 dB and VSWR 1.42, covering a bandwidth up to 800 MHz. In addition, circular polarization with an axial ratio below 3 dB was also obtained using the truncated corner technique. It was also revealed that the gain of the proposed antenna was 5.48 dB with Half-Power Beamwidth (HPBW) of 40°. Based on the test, a stable receive signal level was obtained at azimuths of 90°, 180°, and 270° after using the proposed antenna. These findings denote that the proposed antenna satisfy the criteria to be applied in microwave radio communications.

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