PAPER NAME

Gain-Bandwidth Enhancement of Subarray CP

AUTHOR

Alfin Subuh

WORD COUNT

3067 Words

CHARACTER COUNT

16351 Characters

PAGE COUNT

5 Pages

FILE SIZE

432.4KB

SUBMISSION DATE

Nov 22, 2022 7:30 PM GMT+7

REPORT DATE

Nov 22, 2022 7:30 PM GMT+7

20% Overall Similarity

The combined total of all matches, including overlapping sources, for each database.

- 2% Internet database
- Crossref database
- 2% Submitted Works database
- 20% Publications database
- Crossref Posted Content database

Excluded from Similarity Report

- Bibliographic material
- Manually excluded text blocks

Gain-Bandwidth Enhancement of Subarray CP antenna for L Band CP-SAR

Subuh Pramono
Dept. of Electrical Engineering
Universitas Sebelas Maret
Surakarta, Indonesia
subuhpramono@staff.uns.ac.id
0000-0001-9505-1588

Feri Adriyanto
Dept. of Electrical Engineering
Universitas Sebelas Maret
Surakarta, Indonesia

Joko Slamet Saputro
Dept. of Electrical Engineering
Universitas Sebelas Maret
Surakarta, Indonesia

Alfin Hikmaturokhman
Telecommunication Engineering
Institut Teknologi Telkom Purwokerto
Purwokerto, Indonesia

Helmy
Dept. of Electrical Engineering
Politeknik Negeri Semarang
Semarang, Indonesia

***Abstract*—This paper presents a new subarray design of circularly polarized antenna for L band CP-SAR application with an operating frequency of 1.275 GHz. This proposed subarray CP antenna provides a high gain and bandwidth with RHCP. It increases the gain and bandwidth of the proposed subarray CP antenna by applying the SSR technique. It consists of four-unit element antennas. The patch radiator of the unit element antenna is made of a truncated-corner and crossed-slot square patch. The unit element antennas are connected serially by using the serial-sequential-rotation technique. In addition, the proposed subarray CP antenna uses a full ground plane. Slotting and corner truncation of the patch radiator generates a circular polarization of the CP antenna. Applying array antennas is to make higher gain and broaden bandwidth. For a single CP antenna, the simulated impedance bandwidth (S11 ⩽ -10 dB) and axial ratio bandwidth (⩽ 3 dB) is achieved at approximately 132 MHz and 118 MHz, respectively. Furthermore, the subarray CP antenna yields a broad bandwidth, 421 MHz of impedance bandwidth, and 409 MHz of axial ratio bandwidth. There is a significant improvement in gain, a single CP antenna provides a 7.84 dBic of gain, and a subarray CP antenna generates a 12.016 dBic of gain.**

Keywords—Circular polarization, SAR, L band, Subarray, Gain-bandwidth enhancement.

I. Introduction

Currently, wireless communication systems are growing rapidly and have several advantages over other communication systems, including; support for mobile communication and high data rate transfer capability. Wireless communication systems have been implemented in various communication technologies, including digital broadcasting, cellular communication, satellite communication, radar, etc. Particularly, radar technology has been deployed in various fields. One of the fields is for civil remote sensing applications. Synthetic Aperture Radar (SAR) is a remote sensing method. This method is an active radar in which the SAR system sensor emits an amount of energy through electromagnetic waves to the earth's surface and recaptures a certain amount of energy in the waves reflected by the earth's surface[1]. In their atmospheric propagation, electromagnetic waves will be reflected, refracted, and scattered by particles, molecules, clouds, etc. Several platforms have been used to carry out SAR technology, including spaceborne, micro-satellite, airborne, and unmanned aerial vehicles (UAV) [2]. SAR technology deploys a circularly polarized antenna is well known as circularly polarized-SAR (CP-SAR) [3]. Circular polarization has many advances to reduce the impact of imperfect wireless propagation [4][5]. In electromagnetic wave propagation, multipath fading happens when the transmitted signals arrive at the receiver through many paths so that the accumulative signal's strengths and phases change. As a result, it causes a fluctuated power level in the receiver. In addition, polarization mismatch often occurs in wireless propagation, when we use a transmitter with linear polarization (horizontal or vertical polarization), during the wireless channel, the wave changes polarization so that the wave that reaches the receiver has a different polarization from the transmitter. Furthermore, absorption, phase changing, reflection, diffraction, and scattering are the main interest in wireless propagation. One of the solutions to overcome the abovementioned issues is by using the circularly polarized antenna [6][7]. The long-distance between the SAR platform and the sensed object on the earth's surface causes a significant attenuation [8][9][10]. It is necessary to develop a circularly polarized antenna with high gain and broadband bandwidth [11][12][13]. In circularly polarized antenna design, axial ratio bandwidth (ARBW), impedance bandwidth (IBW), and gain are essential issues [14][15]. Several techniques have been proposed to provide both broadband ARBW, IBW, and high gain of CP antenna. The low dielectric constant of the substrate gives a higher antenna efficiency, but it has a large dimension. Increasing the thickness of the substrate yields a wider bandwidth, but antenna efficiency will decrease [16]. Furthermore, applying some techniques also generate a wider IBW and AXBW, such as adding the stub [17], slot geometries [18], and ground plane modification [19]. An array antenna generates a higher gain. To keep the compactness of the array antenna with higher gain and wider bandwidth, it could apply a combination of truncated corner and slotting at the radiator patch. The proposed subarray CP antenna is designed with an optimized array antenna structure to keep a level of axial-ratio and parameter S. Based on the simulated results, the proposed antenna has good IBW, ARBW, and gain performance in the L band spectrum for CP-SAR application. This proposed subarray CP antenna has RHCP polarization and four-element antennas, which are separated by a feedline network of quarter-wave impedance transformers.

978-1-6654-7150-3/22/$31.00 ©2022 IEEE

This work presents the L band subarray CP antenna with the truncated corners, and an asymmetric cross slotting patch radiator is simulated and designed. This proposed L band subarray CP antenna has a compact size of 132 x 158 x 1.67 mm^3. The total thickness of 1.67 mm consists of a substrate thickness is 1.6 mm and two sides of the copper layer with a thickness of 0.7 mm. Our proposed antenna yields high gain and wide bandwidth characteristics within circular polarization. This antenna has a high gain of 12.016 dBic and wide bandwidth, both the ARBW (axial ratio bandwidth) of 409 MHz and the IBW (impedance bandwidth) of 421 MHz. In addition, it also has a low VSWR of 1.18 at the center frequency of 1.275 GHz. Furthermore, the proposed antenna has an impedance of 55.7-i3.38 Ω at the center frequency of 1.275 GHz. It is close to an ideal intrinsic impedance of 50 Ω. Based on the simulation, the simulated results show good performance of the main parameters of the antenna, including ARBW, IBW, gain, VSWR, and impedance in a center frequency of 1.275 GHz. This work is structured as follows: Section I briefly review the wireless communication problem and CP antenna, Section II delivers the detailed design of subarray CP antenna dimension and its practical development stages, Section III analyzes and gives a detailed explanation of simulated numerical results of the proposed antenna, and Section IV concludes the performance of the subarray CP antenna.

II. SUBARRAY CIRCULARLY POLARIZED ANTENNA DESIGN

A. Single Circularly Polarized Antenna

It has to go through some development stages to make an optimal dimension of a single circularly polarized antenna. The first stage is a square patch, as shown in Fig. 1(a), and then continued by applying corner truncation at the second stage (Fig.1(b)). The last stage is adding the cross slot at the center of the patch radiator (Fig.1(c)). The detailed geometrical design of a single CP antenna is shown in Fig.2. The single CP antenna consists of three parts: a patch radiator, a $\lambda/4$ impedance transformer, and a feedline of 50 Ω. Patch radiator is formed through several stages, as shown in Fig.1.

(a) (b) (c)

Fig. 1. Stages of the CP patch radiator

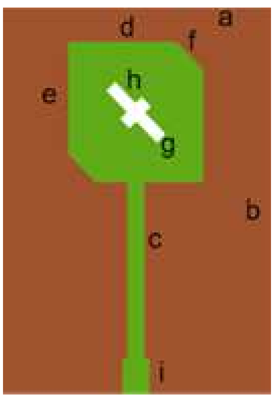

Fig. 2. Single L band CP antenna

B. Subarray CP Antenna

The complete design of the subarray CP antenna is figured in Fig. 3 – Fig. 5 and table 1. Fig. 3 shows the side view of the proposed antenna. There are three layers the top layer is placed by patch and feedline, the middle layer is the substrate, and the bottom layer, the last, is a ground plane layer. In addition, the detailed geometry of the patch radiator and feedline of the subarray CP antenna is illustrated in Fig. 4. It comprises four patch radiator element antennas, formation of 2 x 2, which are connected serially with serial-sequential-rotation (SSR) technique. Each patch radiator is separated by a quarter of lambda (λ/4). This subarray CP antenna is aimed to operate at a center frequency of 1.275 GHz. The ground plane is laid on the bottom layer, while four patch radiators and their feedline network are placed on the top layer of the substrate. Our new unique patch radiator is structured by a truncated corner and cross-slotted square patch. Asymmetric cross slotting is applied at the center of the radiator patch, and specific sized-corner truncations are placed at two diagonal corners. Truncated-corner and asymmetric cross slotting patch radiator are addressed to support the circular polarization. The subarray CP antenna has a single dielectric substrate with its specification in thickness of 1.6 mm, dielectric constant (ε_r) of 2.2, copper cladding of 0.035, and dissipation factor (tan δ) of 0.0005.

TABLE I. NUMERICAL OPTIMIZED DIMENSION OF THE L BAND SUBARRAY CP ANTENNA

Parameter	Value (mm)	Parameter	Value (mm)
a	103	i	14
b	124	j	132
c	38	k	158
d	78	l	38
e	78	m	38
f	14	n	38
g	8	o	88
h	38		

Fig. 3. Side view of the subarray L band CP antenna

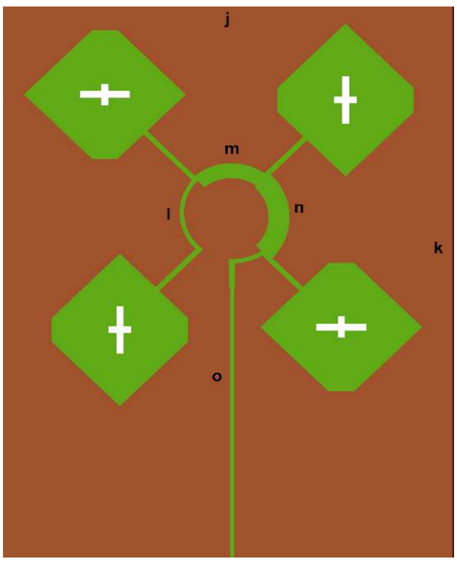

Fig. 4. Patch radiators and feedlines of subarray CP antenna with serial sequential rotation on the top layer

Fig. 5. Full ground plane of subarray CP antenna on the bottom layer

TABLE II. COMPARISON OF REPORTED SUBARRAY CP ANTENNA WITH THE PROPOSED SUBARRAY CP ANTENNA

Ref	Size ($\lambda_0{}^3$)	ARBW (%)	IBW (%)	Gain (dBic)
[20]	1.4 x 1.4 x 0.057	38.8 %	14.3 %	9.4
[21]	0.67 × 0.45 × 0.21	15.3 %	31.7 %	7.64
[22]	0.48 x 0.48 x 0.08	2.1 %	4.3 %	4.5
[23]	1.20 x 1.20 x 0.45	20.4 %	34.6 %	8.4
Proposed antenna	0.56 x 0.67 x 0.007	32.07 %	33.02 %	12.016

Table II summarizes some important key indicators of the other CP antennas and the proposed subarray CP antenna. Based on table II, we can see that our proposed antenna has good bandwidth and gain with compact size compared to others CP antennas.

III. RESULTS AND ANALYSIS

The subarray CP antenna has been designed and simulated. This design has generated some results of the antenna parameters. The simulated parameter S (S11), Axial Ratio, VSWR, and gain are shown in Fig. 6 - Fig.10.

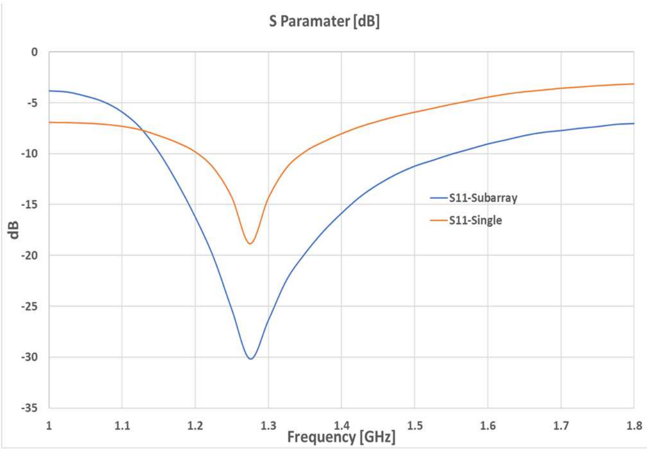

Fig. 6. Simulated result of parameter S

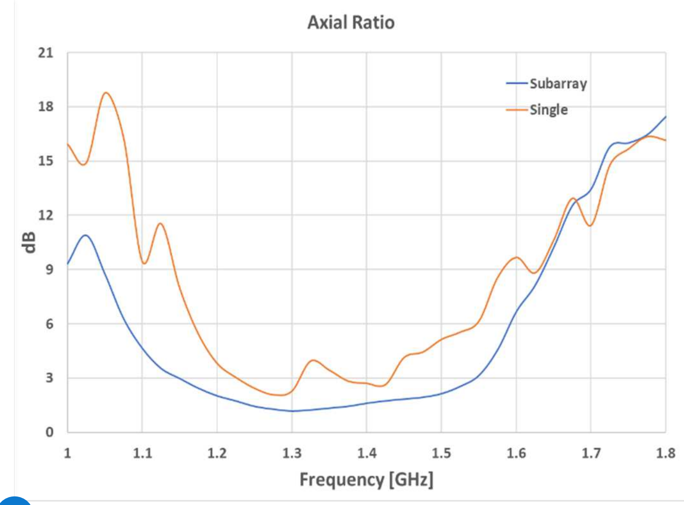

Fig. 7. Simulated result of axial ratio

Based on Fig. 6 and Fig. 7, simulated axial ratio bandwidth /ARBW (⩽3 dB) and impedance bandwidth/IBW (S11⩽-10 dB) of the single CP antenna is achieved at approximately 118 MHz and 132 MHz (yellow line), respectively. Furthermore, applying the subarray CP antenna with four-element patch radiators yield the IBW and ARBW of 421 and 409 MHz (blue line), respectively. It is wider about 3.5 - 4 times than the single CP antenna.

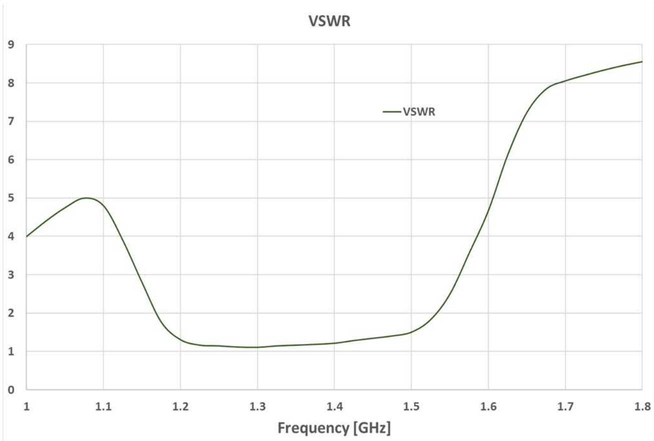

Fig. 8. Simulated result of VSWR

One of the main parameters of the antenna is VSWR (Voltage Standing Wave Ratio). VSWR describes the ratio between reflected and transmitted voltage standing waves due to mismatches between antenna and transmission line intrinsic impedance. VSWR can be formulated as a function of the reflection coefficient (Γ), the VSWR is formulated as follows:

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|} \quad (1)$$

$$\Gamma = \frac{V^-}{V^+} \quad (2)$$

Fig.8 shows the simulated result of VSWR. Based on Fig.8, the simulated numerical VSWR values of less than two exist along with the spectrum frequency of 1.17 to 1.52 GHz. Specifically, the VSWR value of 1.18 appears in the center frequency of 1.275 GHz. Therefore, using equations (1) and (2), the VSWR value of 1.18 equals 8.5 % of forwarding voltage is reflected.

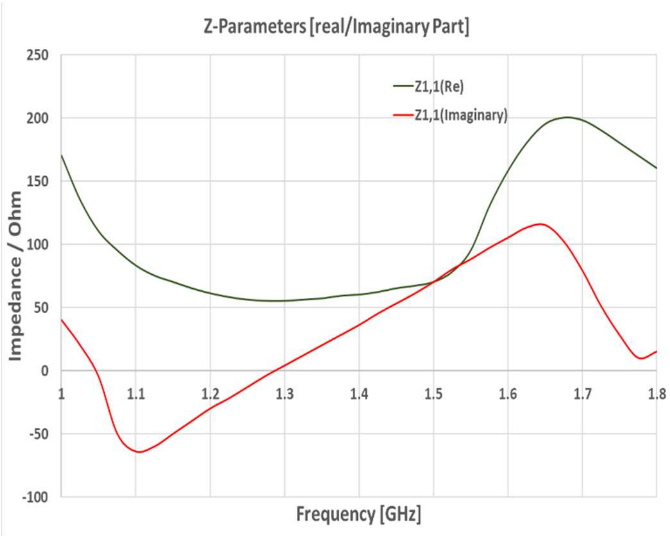

Fig. 9. Simulated result of parameter Z

In addition, Fig.9 shows the obtained antenna impedance. The subarray CP antenna has an impedance of 55.7-i3.38 Ω at the center frequency of 1.275 GHz. This antenna impedance is very close to the internal SMA connector impedance of 50 Ω, and the matching condition is most probably achieved.

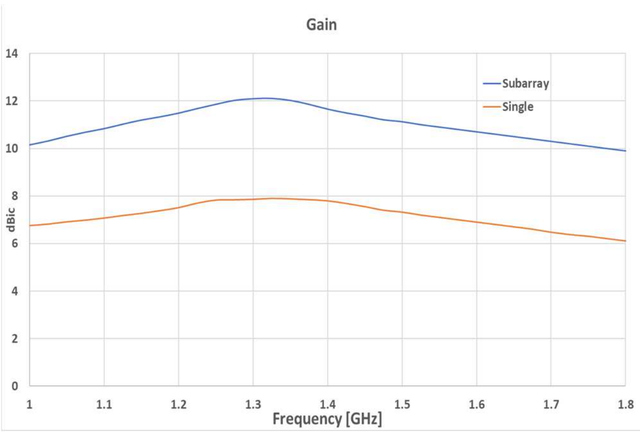

Fig. 10. Simulated result of gain

Based on Fig. 10, the gain profile is figured out through a spectrum frequency of 1 GHz – 1.8 GHz. The gain of the single CP antenna is achieved at about 7.84 dBic, while the subarray CP antenna gives a total gain of 12.016 dBic at the center frequency of 1.275 GHz. There is an improvement of gain of about 4.176 dBic.

IV. Conclusions

This paper presents the L band subarray CP antenna with a center frequency of 1.275 GHz. This proposed antenna is addressed for L band SAR application. The development stages to achieve an optimal dimension of the proposed subarray CP antenna is presented. The optimal design of the subarray CP antenna has some development stages of slotting-truncation in patch radiator and SSR technique for improving the bandwidth (ARBW and IBW) of the subarray CP antenna. In addition, using an array of four-element antennas also increases the gain. The simulated results show that the simulated axial ratio bandwidth (⩽ 3 dB) and impedance bandwidth (S11 ⩽ -10 dB) are achieved at approximately 118 MHz and 132 MHz for a single CP antenna, respectively. Furthermore, the subarray CP antenna has increased the bandwidth and gain. The subarray CP antenna yields a broad bandwidth, 421 MHz of impedance bandwidth and 409 MHz of axial ratio bandwidth. The single CP antenna provides a 7.84 dBic of gain, while the subarray CP antenna generates a 12.016 dBic of gain. There is an improvement of gain of about 4.176 dBic

Acknowledgment

The authors gratefully acknowledge financial support from Ministry of Education, Culture, Research and Technology of The Republic of Indonesia.

References

[1] Z. Wu, L. Zhang, and H. Liu, "Generalized Three-Dimensional Imaging Algorithms for Synthetic Aperture Radar With Metamaterial Apertures-Based Antenna," IEEE Access, vol. 7, pp. 59716 – 59727, 2019.

[2] E. Arnieri, L. Boccia, G. Amendola, S. Glisic, C. Mao, S. Gao, T. Rommel, P. Penkala, M. Krstic, U. Yodprasit, A. Ho, O. Schrape, and M. Younis, "An Integrated Radar Tile for Digital Beamforming X-/Ka-Band Synthetic Aperture Radar Instruments," IEEE Transactions on Microwave Theory and Techniques, vol. 67, no. 3, pp. 1197 – 1206, 2019.

[3] M. F. E. Purnomo, V. Kusumasari, R. Ambarwati, I. Sukma, E. B. Purnomowati, and A. Kitagawa, "Development of Single Triangular Truncated Microstrip Antenna for CP-SAR Sensor," in Proceeding of 10th Electrical Power, Electronics, Communications, Controls and Informatics Seminar, Malang, Indonesia, 2020.

[4] Y. H. Yang, B. H. Sun, and J. L. Guo, "A Single-Layer Wideband Circularly Polarized Antenna for Millimeter-Wave Applications," IEEE Transactions on Antennas and Propagation, vol. 68, no. 6, pp. 4925 – 4929, June 2020.

[5] J. K. Pakkathillam, and M. Kanagasabai, "Circularly Polarized Broadband Antenna Deploying Fractal Slot Geometry," IEEE Antennas and Wireless Propagation Letters, vol. 14,pp. 1286 – 1289, 2015.

[6] R. Li, Y. X. Guo, B. Zhang, and G. Du, "A Miniaturized Circularly Polarized Implantable Annular-Ring Antenna," IEEE Antennas and Wireless Propagation Letters, vol. 16, pp. 2566 – 2569, 2017.

[7] R. Xu, J. Li, Y. X. Qi, Y. Guangwei, and J. J. Yang, "A Design of Triple-Wideband Triple-Sense Circularly Polarized Square Slot Antenna," IEEE Antennas and Wireless Propagation Letters, vol. 16, pp. 763 – 1766, 2017.

[8] S. Pramono, and Sugihartono, "The Performance of Turbo Coded Orthogonal Frequency Division Multiplexing in Rayleigh Fading Channel," in Proceeding of International Conference on Instrumentation, Communication, Information Technology, and Biomedical Engineering, Bandung, Indonesia, 2009.

[9] S. Pramono, and Sugihartono, "Three, four transmit antennas space time block coded MIMO in Rayleigh fading channel: Performance results," in Proceeding of International Conference on System Engineering and Technology, Bandung, Indonesia, 2012.

[10] S. Pramono, and E.Triyono, "Performance of channel estimation in MIMO-OFDM systems," Telkomnika, vol. 11, no. 2, pp. 355–362, 2013.

[11] S. Pramono, L. Alvionita, M.D. Ariyanto, and M.E. Sulistyo, " Optimization of 4G LTE (long term evolution) network coverage area in sub urban, " in Proceeding of 5th International Conference on Industrial, Mechanical Electrical, and Chemical Engineering, Surakarta, Indonesia, 2019.

[12] S. Pramono, T. Hariyadi, and B. B. Subagio, "Performance analysis of transceiver 4 × 4 space time block coded MIMO-OFDM system," in Proceeding of International Conference on Information Technology, Computer, and Electrical Engineering, pp. 426–429, Surakarta, Indonesia, 2016.

[13] S. Pramono, A.O. Putri, E. Warsito, and B. B. Subagio, "Comparative analysis of star topology and multihop topology outdoor propagation based on quality of service (QoS) of wireless sensor network (WSN)," in Proceeding of International Conference on Communication, Networks and Satellite, pp. 152–157, Semarang, Indonesi, 2018.

[14] R. Li, Y. X. Guo, B. Zhang, and G. Du, “A Miniaturized Circularly Polarized Implantable Annular-Ring Antenna,” IEEE Antennas and Wireless Propagation Letters, vol. 16, pp. 2566 – 2569, 2017.

[15] Z. Chen, H. Z. Li, H. Wong, X. Zhang, and T. Yuan, “A Circularly-Polarized-Reconfigurable Patch Antenna With Liquid Dielectric,” IEEE Open Journal of Antennas and Propagation, vol. 2,pp. 396 – 401, 2021.

[16] U. Ullah, I. B. Mabrouk, S. Koziel, “A Compact Circularly Polarized Antenna With Directional Pattern for Wearable Off-Body Communications,” IEEE Antennas and Wireless Propagation Letters, vol. 18, no. 12, pp. 2523 – 2527, 2019.

[17] L. Zhuo, H. Han, X. Shen, and H. Zhao, “A U-shaped wide-slot dual-band broadband NB-IoT antenna with a rectangular tuning stub,” in Proceeding of IEEE 4th Information Technology, Networking, Electronic and Automation Control Conference, Chongqing, China, 2020

[18] Y. M. Cai, K. Li, Y. Z. Yin, X. Ren, “Dual-Band Circularly Polarized Antenna Combining Slot and Microstrip Modes for GPS With HIS Ground Plane,” IEEE Antennas and Wireless Propagation Letters,vol. 14, pp. 1129 – 1132, 2015.

[19] M. A. ul Haq, and S.Koziel, “Impact of ground plane modifications on element isolation in compact wideband MIMO antennas,” in Proceeding of The Loughborough Antennas & Propagation Conference, Loughborough, 2018.

[20] C. Zhao, and C. F. Wang, “Characteristic mode design of wide band circularly polarized patch antenna consisting of h-shaped unit cells,” IEEE Access, vol. 99, pp. 1-6, 2018.

[21] Z. Li, J. Liu, and Y. Long, “A quasi-magnetic-electric circularly polarized antenna with wide bandwidth,” IEEE Antennas and Wireless Propagation Letters, vol. 18, no. 10, pp. 2145–2149, 2019.

[22] S. B. Vignesh, N. Nasimuddin, and A. Alphones, “Stubs integrated-microstrip antenna design for wide coverage of circularly polarised radiation,” IET Microwaves, Antennas & Propagation, vol. 11, no. 4, pp. 444–449, 2017.

[23] Y. M. Pan and K. W. Leung, “Wideband circularly polarized trapezoidal dielectric resonator antenna,” IEEE Antennas and Wireless Propagation Letters, vol. 9, pp. 588–591, 2010.

20% Overall Similarity

Top sources found in the following databases:

- 2% Internet database
- 20% Publications database
- Crossref database
- Crossref Posted Content database
- 2% Submitted Works database

TOP SOURCES

The sources with the highest number of matches within the submission. Overlapping sources will not be displayed.

1	Subuh Pramono, Feri Adriyanto, Joko Slamet Saputro, Alfin Hikmaturo... Crossref	20%

Excluded from Similarity Report

- Bibliographic material
- Manually excluded text blocks

EXCLUDED TEXT BLOCKS

9th ICITACEE 2022 - Semarang, Indonesia, August 25-26, 2022Gain-Bandwidth En...

Subuh Pramono, Feri Adriyanto, Joko Slamet Saputro, Alfin Hikmaturokhman, Helmy. "Gain-Bandwidth Enha...

Abstract—This paper presents a new subarray design ofcircularly polarized antenn...

Subuh Pramono, Feri Adriyanto, Joko Slamet Saputro, Alfin Hikmaturokhman, Helmy. "Gain-Bandwidth Enha...

Subuh PramonoDept. of Electrical EngineeringUniversitas Sebelas MaretSurakarta,...

Subuh Pramono, Feri Adriyanto, Joko Slamet Saputro, Alfin Hikmaturokhman, Helmy. "Gain-Bandwidth Enha...

Dept. of Electrical EngineeringUniversitas Sebelas Maret

jurnal.uns.ac.id

Alfin HikmaturokhmanTelecommunication EngineeringInstitut Teknologi Telkom P...

Subuh Pramono, Feri Adriyanto, Joko Slamet Saputro, Alfin Hikmaturokhman, Helmy. "Gain-Bandwidth Enha...

HelmyDept. of Electrical EngineeringPoliteknik Negeri SemarangSemarang, Indon...

Subuh Pramono, Feri Adriyanto, Joko Slamet Saputro, Alfin Hikmaturokhman, Helmy. "Gain-Bandwidth Enha...

Fig. 9. Simulated result of parameter ZIn addition, Fig.9 shows the obtained antenn...

Subuh Pramono, Feri Adriyanto, Joko Slamet Saputro, Alfin Hikmaturokhman, Helmy. "Gain-Bandwidth Enha...

Table II summarizes some

Subuh Pramono, Feri Adriyanto, Joko Slamet Saputro, Alfin Hikmaturokhman, Helmy. "Gain-Bandwidth Enha...

increases the gain. The simulated results show that thesimulated axial ratio band...

Subuh Pramono, Feri Adriyanto, Joko Slamet Saputro, Alfin Hikmaturokhman, Helmy. "Gain-Bandwidth Enha...

deploys a circularly polarized antenna

Subuh Pramono, Feri Adriyanto, Joko Slamet Saputro, Alfin Hikmaturokhman, Helmy. "Gain-Bandwidth Enha...

Fig. 8. Simulated result of VSWROne of the main parameters of the antenna is VS...

Subuh Pramono, Feri Adriyanto, Joko Slamet Saputro, Alfin Hikmaturokhman, Helmy. "Gain-Bandwidth Enha...

4. Patch radiators and feedlines of subarray CP antenna with serialsequential rotat...

Subuh Pramono, Feri Adriyanto, Joko Slamet Saputro, Alfin Hikmaturokhman, Helmy. "Gain-Bandwidth Enha...

subarray CP antenna has a compact size of 132 x 158 x 1.67

Subuh Pramono, Feri Adriyanto, Joko Slamet Saputro, Alfin Hikmaturokhman, Helmy. "Gain-Bandwidth Enha...

a)(b)(c)Fig. 1. Stages of the CP patch radiatorFig. 2. Single L band CP antennaB. S...

Subuh Pramono, Feri Adriyanto, Joko Slamet Saputro, Alfin Hikmaturokhman, Helmy. "Gain-Bandwidth Enha...