



Design of a Receiving Array Antenna with a Trapezoidal Configuration Using Multiple Rectifier Circuits for Wide-Angle Reception

Taekyeong Jin¹ · Eunjung Kang² · Minjae Ahn³ · Hyunchul Ku³ ·

Seunghyeok Hong⁴ · Hosung Choo^{1,*}

Abstract

This paper proposes a receiving array antenna with a trapezoidal configuration that combines multiple rectifier circuits for wide-angle reception. The proposed receiving antenna system consists of three antenna elements operating at 5.8 GHz and the same number of rectifier circuits. To resolve the degradation in power transmission efficiency caused by misalignment, the receiving array antenna is designed in a trapezoidal configuration, and a quasi-air substrate is adopted for each antenna to achieve a high gain with the required beamwidth. All antenna elements in this system have measured reflection coefficients of less than -10 dB, and the overall beam coverage of the system is 205° . The power measurements of the receiving system are performed at 5° intervals within the beam coverage, and the results demonstrate that power is reliably received within the beam coverage through the proposed receiving antenna system.

Key Words: Receiving Antenna, Rectifier Circuit, Wide-Angle Reception, Wireless Power Transmission (WPT).

I. INTRODUCTION

Given the rapid development of wireless power transfer (WPT) technologies in recent decades, WPT has been employed in a wide range of applications, including portable electronic devices, medical devices, electronics in space environments, and industrial robots [1–3]. These WPT technologies are generally classified into three methods: magnetic induction, magnetic resonance, and microwave power transmission (MPT) [4].

MPT not only enables long-distance power transmission but

can also deliver power to various locations through electronic beam steering techniques. Research on transmitting antennas for MPT, which can improve transmission efficiency and enable various beam steering, has been widely conducted [5, 6]. However, in terms of overall power transmission efficiency, the performance of the receiving antenna is as critical as that of the transmitting antenna [7–9]. For example, even a slight misalignment of the receiver antenna can significantly reduce the transmission efficiency of the overall system. To overcome these receiver problems, various studies have been conducted to improve power

Manuscript received June 19, 2024 ; Revised September 19, 2024 ; Accepted October 07, 2024. (ID No. 20240619-131J)

¹Department of Electronic and Electrical Engineering, Hongik University, Seoul, Korea.

²4th R&D Institute, Agency for Defense Development, Daejeon, Korea.

³Department of Electronics, Information and Communication Engineering, Konkuk University, Seoul, Korea.

⁴Division of Social Science & AI, Hankuk University of Foreign Studies, Seoul, Korea.

*Corresponding Author: Hosung Choo (e-mail: hchoo@hongik.ac.kr)

This is an Open-Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/4.0>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

© Copyright The Korean Institute of Electromagnetic Engineering and Science.

conversion efficiency by optimizing rectifier circuits, including a full-bridge rectifier [10, 11] and an auto-adaptive impedance matching rectifier [12]. In addition, to resolve this issue from a receiving antenna perspective, extensive studies have been carried out to derive the high-gain characteristics of receiver antennas using higher-order modes [13, 14], a metamaterial superstrate [15], and flexible reflectors [16]. However, these types of antennas cannot be fundamental solutions to the degradation in power transmission efficiency caused by misalignment.

In this paper, we propose a receiving array antenna with a trapezoidal configuration that can be equipped with multiple rectifier circuits for wide-angle reception to resolve misalignment. The proposed receiving antenna system is composed of three individual antenna elements operating at 5.8 GHz and the same number of rectifier circuits. Each antenna is designed to have a half-power beamwidth (HPBW) of 65° , and the angles of the trapezoidal configuration are determined to achieve wide-angle reception. To increase the gain and obtain the required beamwidth, a quasi-air substrate is utilized between the radiator and the ground plate, and the designed antennas are connected separately to each rectifier circuit. The rectifier circuits are printed on the circuit board and designed to have a power conversion efficiency of 60% at 20 dBm input power. The outputs of each rectifier circuit are combined in parallel to reliably harvest power into the receiver system.

The proposed receiving array antenna is investigated using the CST Studio Suite full electromagnetic (EM) simulator [17] and is fabricated to verify the antenna performance, including radiation patterns and reflection coefficients. With an optimized angle of the trapezoidal configuration, overall beam coverages of $195^\circ (= 65^\circ \times 3)$ by simulation and 205° by measurement are achieved. We also measure the output power of the three rectifier circuits connected in parallel. The measured power range is from 48.14 mW to 168.75 mW at a distance of 1 m and from 12.74 mW to 40.51 mW at a distance of 2 m. These results

demonstrate that the proposed receiving antenna system can harvest stable power even when there is misalignment between the transmitter and receiver.

II. DESIGN OF A RECEIVING ANTENNA SYSTEM WITH A WIDE RECEPTION COVERAGE

Fig. 1 shows the geometry of the proposed wireless power receiving array antenna system for wide-angle reception. The system is designed to be mounted on the back of a health monitoring chair; thus, the target reception angle is set to 200° to cover the entire chairback.

Fig. 1(a) illustrates the geometry of the receiving array antenna system with a trapezoidal configuration that can be equipped with multiple rectifier circuits for wide-angle reception. The system consists of three individual antenna elements operating at 5.8 GHz. To overcome the issue of misalignment between the transmitting antenna and the receiving antenna, the receiving array antenna has a trapezoidal configuration. α represents the angle between the adjacent ground plates; it is set at 115° to obtain a total reception angle of 200° .

Fig. 1(b) shows the isometric view of the proposed single element, which is designed by adopting a quasi-air substrate ($\epsilon_r = 1.05$) to improve the gain and the required beamwidth. In general, a conventional single patch antenna with a dielectric substrate has a gain of less than 8 dBi. However, by using a quasi-air substrate, which sustains very low losses, a higher gain can be achieved [18]. The dimensions (width $w \times$ length l) of the radiator are 22 mm $\times$ 22 mm, and the quasi-air substrate thickness (h) is 3.5 mm. Each square ground plate has a side length (g) of 70 mm.

Fig. 1(c) presents the top view of the receiving array antenna system, including the rectifier circuits. The receiving array antenna is connected to the rectifier circuit through an SMA connector. This antenna receives the transmitted power and delivers RF power to the rectifier circuit. Each antenna is designed to have an

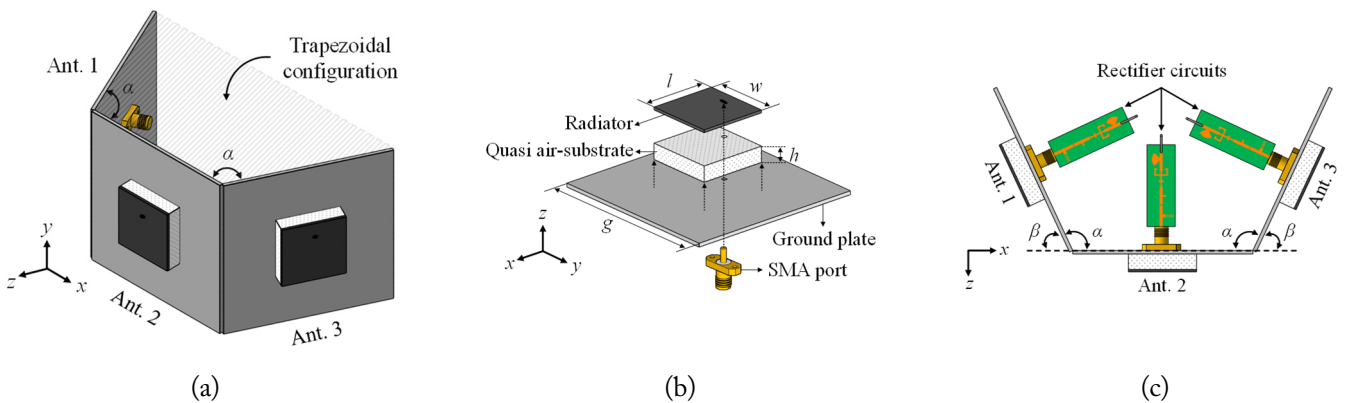


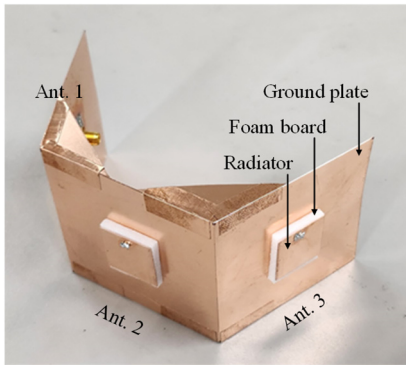
Fig. 1. Geometry of the proposed receiving array antenna system: (a) isometric view of the receiving array antenna, (b) isometric view of the single element, and (c) top view of the receiving array antenna.

HPBW of 65° ($= 180^\circ - \alpha$) in the zx -plane. The HPBW of each element is an important factor in obtaining wide-angle reception. Rectifier circuits that convert RF power to DC power are designed using microstrip lines, which are printed on the circuit board (RO4350B, $\epsilon_r = 3.66$, $\tan\delta = 0.0037$).

Fig. 2(a) presents a photograph of the fabricated receiving array antenna. The radiator and ground plate are fabricated using copper plates, and the quasi-air substrate is manufactured using a foam board, which has a dielectric constant similar to that of air. During the assembly process, three individual grounds are made by bending a $210 \text{ mm} \times 70 \text{ mm}$ copper plate. In addition, triangular-shaped plates are inserted between the ground plates to ensure the trapezoidal configuration. The total dimensions (width $w \times$ length $l \times$ height h) of the fabricated receiving antenna are $129 \text{ mm} \times 63 \text{ mm} \times 70 \text{ mm}$.

Fig. 2(b) shows a photograph of the receiving antenna mounted on a health monitoring chair. The proposed antenna is located on the back of the health monitoring chair to receive RF power wirelessly and supply power to the bio-signal measurement sensor.

Fig. 3 presents the performance of the proposed antenna elements. The measured reflection coefficients of each antenna (Ant. 1, 2, and 3) operating at 5.8 GHz are -19.05 dB , -18.14 dB , and -25.57 dB , respectively, as shown in Fig. 3(a). The



(a)



(b)

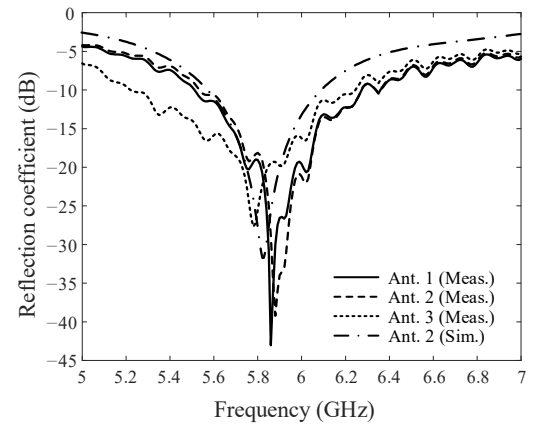
Fig. 2. Photographs of the fabricated receiving array antenna: (a) isometric view and (b) view of the antenna mounted on a health monitoring chair.

simulated reflection coefficient of the center element (Ant. 2) is -31.67 dB at 5.8 GHz, and the measured and simulated reflection coefficients are both less than -10 dB .

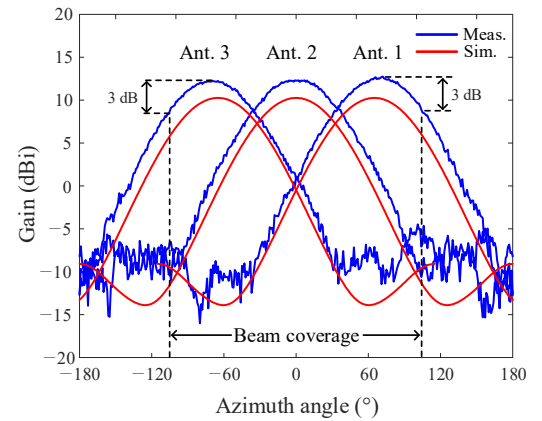
Fig. 3(b) shows the measured and simulated 2D radiation patterns. The blue and red lines indicate the measured and simulated results, respectively. At 5.8 GHz, each antenna element has a HPBW of 65° in both simulation and measurement, with a measured gain of more than 11 dBi . The overall beam coverage of this system is 195° in simulation and 205° in measurement. These results show that a wide reception angle is achieved by adopting the trapezoidal configuration.

Fig. 4(a) presents a schematic of the proposed multiple rectifiers. Three rectifiers are connected in parallel to the power management integrated circuit (PMIC). The PMIC has a maximum power point tracking (MPPT) function, which adjusts the output voltage to half of the open circuit voltage, ensuring maximum power transfer.

Fig. 4(b) shows the equivalent circuit of multiple rectifiers. The n -th rectifier, which received the RF power of $P_{R,n}$, is represented by a serial connection of $V_{OC,n}$ and $R_{Th,n}$ [19]. The open-circuit voltage of the array antenna system is biased to-



(a)



(b)

Fig. 3. Performance of the proposed antenna elements: (a) measured and simulated reflection coefficients and (b) 2D radiation patterns.

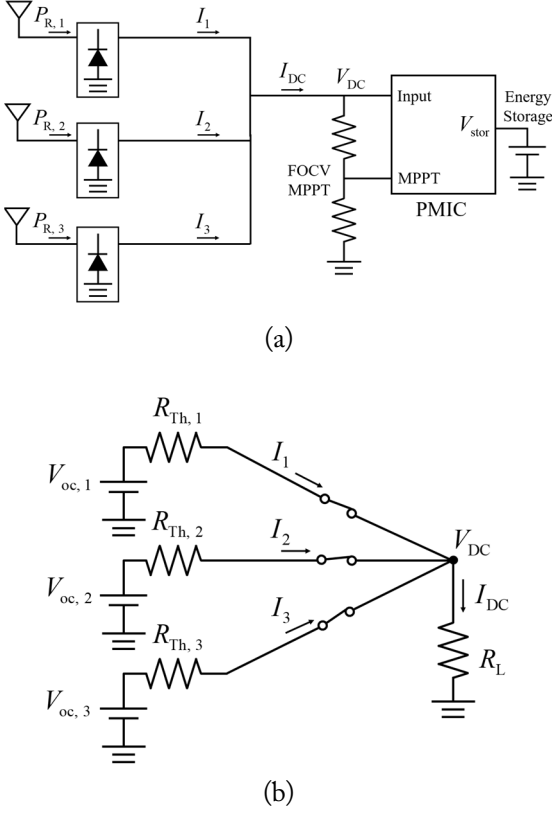


Fig. 4. Schematic of the proposed multiple rectifiers: (a) schematic of multiple rectifiers and (b) an equivalent circuit of multiple rectifiers.

ward that of the rectifier receiving the highest RF power. V_{DC} is expressed as follows:

$$V_{DC} = 0.5 \cdot \max(V_{oc,1}, V_{oc,2}, V_{oc,3}). \quad (1)$$

If one or more rectifiers face a condition in which their V_{DC} is higher than their open-circuit voltage, those rectifiers cannot harvest power and are excluded from the circuit [20]. The current from the n -th rectifier is defined as follows:

$$I_n = \begin{cases} \frac{V_{oc,n} - V_{in}}{R_{Th,n}}, & V_{oc,n} > V_{DC} \\ 0, & V_{oc,n} \leq V_{DC} \end{cases} \quad (2)$$

The rectified power P_{DC} of the proposed system is calculated as follows:

$$P_{DC} = V_{DC} I_{DC} = V_{DC} \sum_{n=1}^3 I_n. \quad (3)$$

Fig. 5(a) illustrates a schematic diagram of the rectifier circuit combined with the proposed receiving antenna. The rectifier consists of a matching network, DC block capacitor, diode, harmonic suppression structure, smoothing capacitor, and load. A single stub is employed as the matching network, and the DC block capacitor is used to block the effect of the DC bias voltage when the RF source is directly connected to the rectifier input

port. For energy harvesting, the system employs the PMIC (SPV1050; STMicroelectronics, Coppel, TX, USA) as the load, which supports the MPPT function to handle open-circuit voltages up to 18 V. The rectifier is designed with a single shunt diode structure using an Advanced Design System (ADS) simulator. A harmonic suppression structure is employed to increase power conversion efficiency by terminating the second and third harmonics [21]. The components of the rectifier are summarized in Table 1.

Fig. 5(b) shows the input impedance of the rectifier circuit at 5.8 GHz with varying input power from -20 dBm to 30 dBm. The rectifier is confirmed to be closely matched to 50Ω for input powers ranging from 17 dBm to 25 dBm due to the matching network. Fig. 5(c) presents a photograph of the fabricated rectifier, which is printed on a RO4350B board ($16.4 \text{ mm} \times 41.6 \text{ mm} \times 0.508 \text{ mm}$).

Fig. 6(a) represents the measured and simulated results of a single rectifier circuit. The input power range is determined to span from 8 dBm to 25 dBm, considering the cold start minimum input voltage of 2.6 V of the PMIC and the MPPT system to be used in the experiment. In the experimental setup, the PMIC is used as the load, and a load of 200Ω is utilized in the simulation. The diode model under large signals in ADS has modelling inaccuracy in the junction capacitance and series resistance due to variations in frequency and power, resulting in simulation errors [22, 23]. The rectifier with the MPPT function achieves over 60% efficiency for input powers ranging from 17 dBm to 24 dBm. In addition, Fig. 6(b) shows the V_{oc} and R_{Th} values, which are determined by measuring the voltage and current of the rectifier and then extracting the input power. It has an open-circuit voltage value below the maximum allowable value (18 V) of SPV1050.

Fig. 7 shows the measured power of the proposed receiving antenna system, with measurements obtained under a transmitting antenna gain of 20 dBi and a transmit power of 16 W. The measured power levels at distances of 1 m and 2 m are represented by the blue and red lines, respectively. The output power is

Table 1. Components used in a rectifier element

TL	W (mm)	L (mm)	Element	Description
TL 1	1.07	6.69	C_{in}	5 pF
TL 2	1.07	1.40	C_{out}	10 pF
TL 3	1.07	4.88	Radial stub	$r = 5.4 \text{ mm}$, $\theta = 90^\circ$
TL 4	1.07	5.58	Diode	HSMS-282B
TL 5	1.07	5.83	Load	PMIC (SPV1050)
TL 6	1.07	7.71	—	—
TL 7	1.07	6.25	—	—

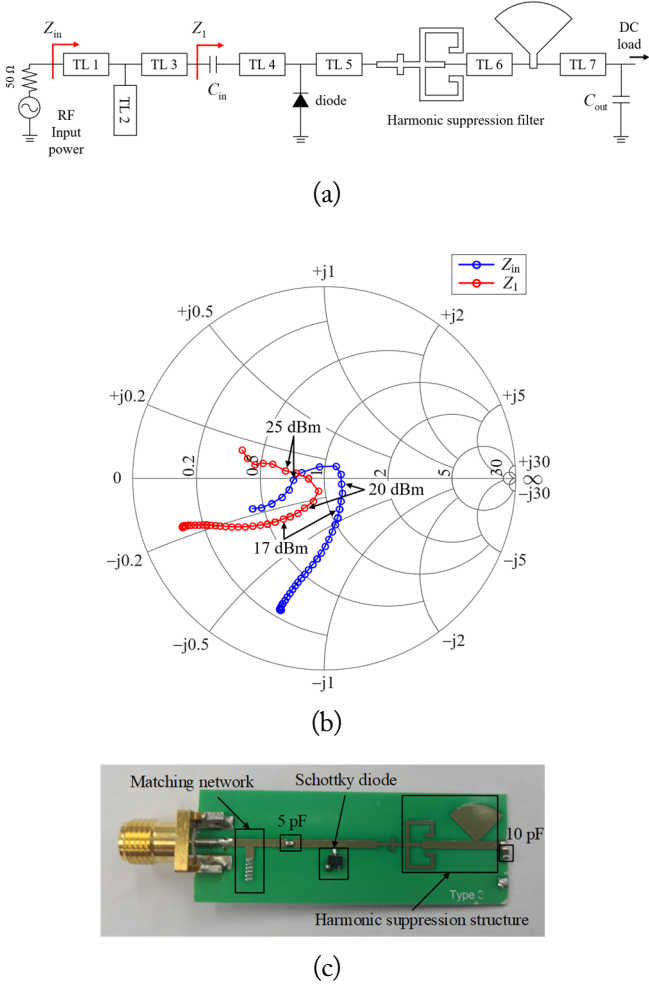


Fig. 5. Schematic and performance of the proposed multiple rectifiers: (a) schematic of a single rectifier circuit, (b) simulated input impedance of a single rectifier circuit with 5.8 GHz RF input power from -20 dBm to 30 dBm, and (c) a photograph of the fabricated rectifier.

measured at 5° intervals within the beam coverage range, as shown in Fig. 7(a). The three rectifier circuits are connected in parallel, as shown in Fig. 7(b). Each rectifier circuit has a conversion efficiency of 60% when the input power is about 20 dBm. The measured power is between 48.14 mW and 168.75 mW at a distance of 1 m, and between 12.74 mW and 40.51 mW at a distance of 2 m. From the boresight direction, the received power at a distance of 1 m is measured to be 168.75 mW, resulting in a WPT efficiency of 1.05% . At a distance of 2 m, the received power decreases to 40.51 mW, with a WPT efficiency of 0.25% , as shown in Fig. 7(c). These results validate that power is reliably received through the proposed receiving antenna system, even with potential misalignment.

III. CONCLUSION

A receiving array antenna with a trapezoidal configuration was proposed for wide-angle reception. The receiving antenna sys-

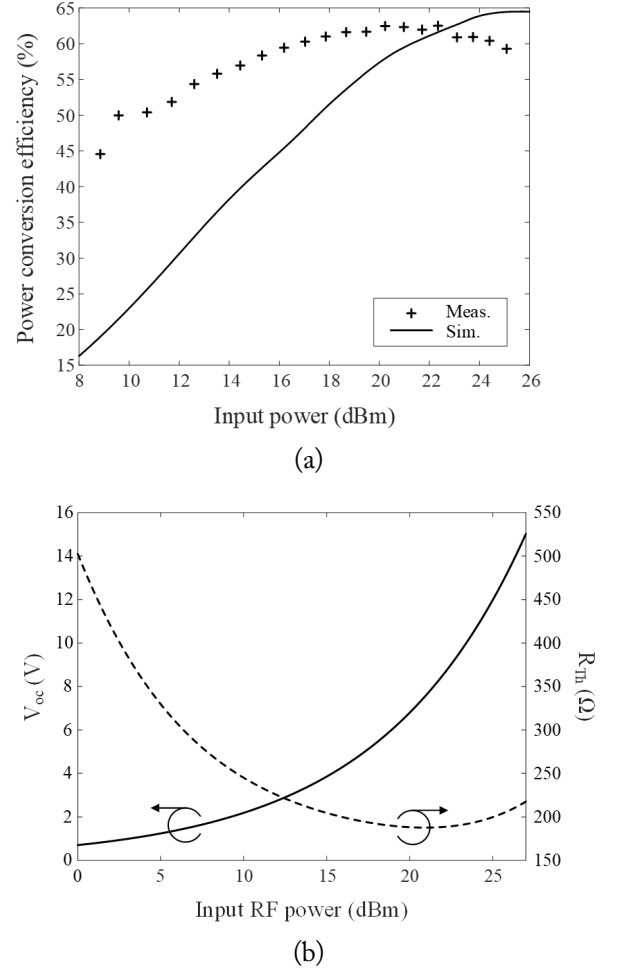


Fig. 6. Measurement results for a single rectifier circuit: (a) the power conversion efficiency of a single rectifier circuit and (b) the equivalent circuit value of a single rectifier circuit.

tem consisted of three individual antenna elements, each paired with a corresponding rectifier circuit. A trapezoidal configuration was utilized for wide-angle reception and designed with an angle of 115° between adjacent antennas. This configuration had a wide-angle reception range of 205° through the measurement of 2D radiation patterns. To achieve high-gain characteristics and the required HPBW, a quasi-air substrate was used for each antenna element. The measured reflection coefficients for the individual antenna elements were less than -10 dB. Furthermore, the measured power recorded at 1 m and 2 m distances ranged from 48.14 mW to 168.75 mW and 12.74 mW to 40.51 mW, respectively. These measurements of the receiving power within the beam coverage demonstrated that the system can reliably receive MPT signals, even in cases of potential misalignment.

This research has been supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (No. NRF-2017R1A5A1015596) and the NRF grant funded by the Korea government (No. 2015R1A6A1A03031833).

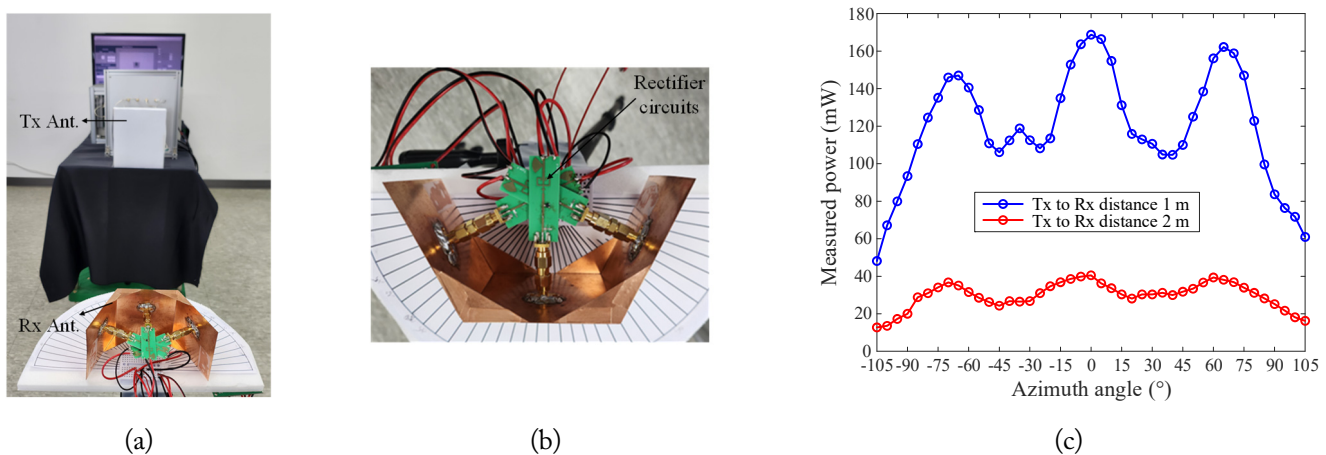


Fig. 7. Measurement of the proposed receiving antenna: (a) measurement setup, (b) top view of the fabricated array antenna system, and (c) measured power.

REFERENCES

- [1] K. W. Bang, S. W. Park, H. G. Bae, B. Y. Lee, H. M. Oh, C. U. Park, and S. H. Baek, "Evaluation of electromagnetic exposure in wireless power transfer systems for electric vehicles," *Journal of Electromagnetic Engineering and Science*, vol. 24, no. 1, pp. 34-41, 2024. <https://doi.org/10.26866/jees.2024.1.r.202>
- [2] J. Park, D. Kim, K. Hwang, H. H. Park, S. I. Kwak, J. H. Kwon, and S. Ahn, "A resonant reactive shielding for planar wireless power transfer system in smartphone application," *IEEE Transactions on Electromagnetic Compatibility*, vol. 59, no. 2, pp. 695-703, 2017. <https://doi.org/10.1109/TEM.2016.2636863>
- [3] L. V. Tung and C. Seo, "A miniaturized implantable antenna for wireless power transfer and communication in biomedical applications," *Journal of Electromagnetic Engineering and Science*, vol. 22, no. 4, pp. 440-446, 2022. <https://doi.org/10.26866/jees.2022.4.r.107>
- [4] W. C. Brown, "The history of power transmission by radio waves," *IEEE Transactions on Microwave Theory and Techniques*, vol. 32, no. 9, pp. 1230-1242, 1984. <https://doi.org/10.1109/TMTT.1984.1132833>
- [5] S. Kumar and A. Sharma, "Switched beam array antenna optimized for microwave powering of 3-D distributed nodes in clustered wireless sensor network," *IEEE Transactions on Antennas and Propagation*, vol. 70, no. 12, pp. 11734-11742, 2022. <https://doi.org/10.1109/TAP.2022.3209744>
- [6] M. Wang, C. Zhang, X. Chen, and S. Tang, "Performance analysis of millimeter wave wireless power transfer with imperfect beam alignment," *IEEE Transactions on Vehicular Technology*, vol. 70, no. 3, pp. 2605-2618, 2021. <https://doi.org/10.1109/TVT.2021.3061653>
- [7] A. Georgiadis, G. V. Andia, and A. Collado, "Rectenna design and optimization using reciprocity theory and harmonic balance analysis for electromagnetic (EM) energy harvesting," *IEEE Antennas and Wireless Propagation Letters*, vol. 9, pp. 444-446, 2010. <https://doi.org/10.1109/LAWP.2010.2050131>
- [8] F. Zhang, X. Liu, F. Y. Meng, Q. Wu, J. C. Lee, J. F. Xu, C. Wang, and N. Y. Kim, "Design of a compact planar rectenna for wireless power transfer in the ISM band," *International Journal of Antennas and Propagation*, vol. 2014, article no. 298127, 2014. <https://doi.org/10.1155/2014/298127>
- [9] Y. Yang, J. Li, L. Li, Y. Liu, B. Zhang, H. Zhu, and K. Huang, "A 5.8 GHz circularly polarized rectenna with harmonic suppression and rectenna array for wireless power transfer," *IEEE Antennas and Wireless Propagation Letters*, vol. 17, no. 7, pp. 1276-1280, 2018. <https://doi.org/10.1109/LAWP.2018.2842105>
- [10] S. A. Rotenberg, S. K. Podilchak, P. D. H. Re, C. Mateo-Segura, G. Goussetis, and J. Lee, "Efficient rectifier for wireless power transmission systems," *IEEE Transactions on Microwave Theory and Techniques*, vol. 68, no. 5, pp. 1921-1932, 2020. <https://doi.org/10.1109/TMTT.2020.2968055>
- [11] M. Fu, Z. Tang, and C. Ma, "Analysis and optimized design of compensation capacitors for a megahertz WPT system using full-bridge rectifier," *IEEE Transactions on Industrial Informatics*, vol. 15, no. 1, pp. 95-104, 2019. <https://doi.org/10.1109/TII.2018.2833209>
- [12] F. Mirzavand, V. Nayyeri, M. Soleimani, and R. Mirzavand, "Efficiency improvement of WPT system using inexpensive auto-adaptive impedance matching," *Electronics Letters*, vol. 52, no. 25, pp. 2055-2057, 2016. <https://doi.org/10.1049/el.2016.3450>
- [13] E. Kang, J. Hur, C. Seo, H. Lee, and H. Choo, "High aperture efficiency array antenna for wireless power transfer applications," *Energies*, vol. 13, no. 9, article no. 2241, 2020. <https://doi.org/10.3390/en13092241>
- [14] Q. U. Khan, M. B. Ihsan, D. Fazal, F. M. Malik, S. A. Sheikh, and M. Salman, "Higher order modes: a solution for high gain, wide band patch antennas for different ve-

- hicular applications," *IEEE Transactions on Vehicular Technology*, vol. 66, no. 5, pp. 3548-3554, 2017. <https://doi.org/10.1109/TVT.2016.2604004>
- [15] A. K. Singh, M. P. Abegaonkar, and S. K. Koul, "High-gain and high-aperture-efficiency cavity resonator antenna using metamaterial superstrate," *IEEE Antennas and Wireless Propagation Letters*, vol. 16, pp. 2388-2391, 2017. <https://doi.org/10.1109/LAWP.2017.2719864>
- [16] W. Peng, X. Li, H. Zhang, Z. Liu, and W. Song, "A 5.8 GHz high-gain flexible receiving antenna for wireless power transmission," *AIP Advances*, vol. 12, article no. 125220, 2022. <https://doi.org/10.1063/5.0133581>
- [17] Dassault Systemes, "CST Studio Suite: Electromagnetic Field Simulation Software," 2024 [Online]. Available: <http://www.cst.com>.
- [18] K. W. S. Al Kharusi, N. Ramli, S. Khan, M. T. Ali, and M. A. Halim, "Gain enhancement of rectangular microstrip patch antenna using air gap at 2.4 GHz," *International Journal of Nanoelectronics and Materials*, vol. 13(special issue), pp. 211-224, 2020.
- [19] T. Miura, N. Shinohara, and H. Matsumoto, "Experimental study of rectenna connection for microwave power transmission," *Electronics and Communications in Japan (Part II: Electronics)*, vol. 84, no. 2, pp. 27-36, 2001. [https://doi.org/10.1002/1520-6432\(200102\)84:2<27::AID-ECJB4>3.0.CO;2-C](https://doi.org/10.1002/1520-6432(200102)84:2<27::AID-ECJB4>3.0.CO;2-C)
- [20] Y. Ishizawa, "Efficiency estimation of microwave power transmission antenna system," *Electronics and Communications in Japan (Part I: Communications)*, vol. 83, no. 8, pp. 94-104, 2000. [https://doi.org/10.1002/\(SICI\)1520-6424\(200008\)83:8<94::AID-ECJA10>3.0.CO;2-H](https://doi.org/10.1002/(SICI)1520-6424(200008)83:8<94::AID-ECJA10>3.0.CO;2-H)
- [21] J. Kim, I. Park, and H. Ku, "Design of a highly efficient N-stage harmonic terminated voltage multiplier for wireless power transfer," *Energies*, vol. 14, no. 21, article no. 7203, 2021. <https://doi.org/10.3390/en14217203>
- [22] H. Zeng, Y. Tang, X. Duan, and X. Chen, "A physical model-based FDTD field-circuit co-simulation method for Schottky diode rectifiers," *IEEE Access*, vol. 7, pp. 87265-87272, 2019. <https://doi.org/10.1109/ACCESS.2019.2926329>
- [23] C. Liu, F. Tan, H. Zhang, and Q. He, "A novel single-diode microwave rectifier with a series band-stop structure," *IEEE Transactions on Microwave Theory and Techniques*, vol. 65, no. 2, pp. 600-606, 2017. <https://doi.org/10.1109/TMTT.2016.2626286>

Taekyeong Jin

<https://orcid.org/0009-0003-8712-5366>



received the B.S. and M.S. degrees in electronic and electrical engineering from Hongik University, Seoul, Republic of Korea, in 2017 and 2019, respectively. He worked as an engineer at Hanwha Systems, Gumi, Republic of Korea, from 2019 to 2022. He is currently pursuing a Ph.D. in electronic and electrical engineering at Hongik University. His research interests include radar systems, machine learning, array antennas, microwave remote sensing, and electromagnetic wave propagation.

Minjae Ahn

<https://orcid.org/0000-0002-3122-9495>



received his B.S. degree in electrical and electronics engineering from Konkuk University, Seoul, South Korea, in 2022. He is currently pursuing his M.S. & Ph.D. degree in electronics, information and communication engineering at the same institute. His current research interests include wireless power transfer, RF power amplifiers, and digital RF systems.

Eunjung Kang

<https://orcid.org/0000-0002-0265-1144>



received the B.S. degree in electronic and electrical engineering from Hongik University, Sejong, South Korea, in 2016, and the M.S. and Ph.D. degrees in electronic and electrical engineering from Hongik University, Seoul, South Korea, in 2020 and 2023, respectively. She was a Research Engineer with the Korea Electronics Technology Institute (KETI), Seongnam, South Korea, from 2016 to 2017. She is currently a Senior Researcher with the Agency for Defense Development, Daejeon, South Korea. Her research interests include array antenna for electronic warfare, wireless power transfer systems, LEO satellite electromagnetic wave propagation, direction finding, and GPS antennas.

Hyunchul Ku

<https://orcid.org/0000-0002-1961-5166>



received his B.S. and M.S. degrees in electrical engineering from Seoul National University, Seoul, South Korea, in 1995 and 1997, respectively, and a Ph.D. in electrical and computer engineering from the Georgia Institute of Technology, Atlanta, GA, USA, in 2003. From 1997 to 1999, he worked at the Wireless Communication Research Center in KT, Seoul. From 2004 to 2005, he was employed at the Research and Development Laboratory, Mobile Communication Division, Samsung Electronics, Suwon, South Korea. Since 2005, he has worked as a professor at Konkuk University. His research interests include digital RF systems, RF power amplifiers, RF front-end design, and wireless power transfer systems.

Seunghyeok Hong

<https://orcid.org/0000-0003-4242-7638>



received his B.S. degree in Electronics from Sogang University, followed by both his M.S. and Ph.D. in Biomedical Engineering through an interdisciplinary program at Seoul National University. From 2020 to 2025, he was a faculty member in the Division of Data Science at the University of Suwon (USW) in Hwaseong, South Korea. Since 2025, he has been with the Division of Social Science & AI at Hankuk

University of Foreign Studies (HUFS) in Seoul, South Korea. His research centers on the application of artificial intelligence in human-computer interfaces safety, and healthcare. His current interests include deep learning applications in computer vision, sensor technology, audio processing, and language models for human-centered solutions. He places particular emphasis on leveraging generative AI and physical AI to enhance happiness and well-being.

Hosung Choo

<https://orcid.org/0000-0002-8409-6964>



received the B.S. degree in radio science and engineering from Hanyang University, Seoul, South Korea, in 1998, and the M.S. and Ph.D. degree in electrical and computer engineering from the University of Texas at Austin, in 2000 and 2003, respectively. In September 2003, he joined the School of Electronic and Electrical Engineering, Hongik University, Seoul, where he is currently a professor. His principal areas

of research include electrically small antennas for wireless communications, reader and tag antenna for RFID, on-glass and conformal antennas for vehicles and aircraft, and array antenna for GPS applications.