SONG NOH

119 Academy Rd., Yeonsu-gu, Incheon 22012, Republic of Korea
(+82)32-835-8284 ⋄ songnoh@inu.ac.kr ⋄ www.songnoh.com

EDUCATION

Ph.D. in Electrical and Computer Engineering — Dec. 2015
Purdue University, West Lafayette, IN, USA
Advisor: Prof. Michael Zoltowski and Prof. David Love
Dissertation Title: "Advanced Design of Space-Time Training and Beamforming for Large-Scale Multi-Antenna Communication Systems"

M.S. in Electrical Engineering — Feb. 2010
Korea Advanced Institute of Science and Technology, Daejeon, Republic of Korea
Advisor: Prof. Youngchul Sung

B.E. in Electrical Engineering — Feb. 2008
Soongsil University, Seoul, Republic of Korea

EMPLOYMENT AND CAREER

Associate Professor, Dept. of Information and Telecommunication Engineering, Incheon National University, Incheon, Republic of Korea — Sep. 2022 - Present

Assistant Professor, Dept. of Information and Telecommunication Engineering, Incheon National University, Incheon, Republic of Korea — Sep. 2018 - Aug. 2022

System Engineer, Next Generation and Standards (NGS), Intel Corporation, Jones Farm 3, Hillsboro, OR, USA — Dec. 2015 - Jul. 2018

RESEARCH INTERESTS

Wireless Communications, Sub-terahertz Communications, and Deep Learning

Research History

Wireless Communications, Sub-terahertz Communications, and Deep Learning, INU — 2018 - Present
Flexible Duplex Transmission, Integrated Access and Backhaul, and System Level Simulations (3GPP Release 15+), Intel — 2015 - 2018
Wireless Communications and Millimeter-wave Communications, Purdue University — 2011 - 2015

HONORS AND AWARDS

Academic Research Award, Incheon National University — 2020, 2021, 2022, 2023

Next Generation and Standards (NGS) Division Recognition Award, Intel — Q3 2017

Wireless Communication Research (WCR) Division Recognition Award, Intel — Q1 2017

IEEE Transactions on Communications Exemplary Reviewer — Apr. 2015

Silver Prize in the 21st HumanTech Paper Contest sponsored by Samsung — Feb. 2015

IEEE Global Communications Conference (Globecom) Best Paper Award — Dec. 2014

JOURNAL ARTICLES

International Journals

<Submitted or In preparation>

[J29] Jeongwon Jeon, **Song Noh**, *et al.*, "Low-complexity deep unfolded direction finding based on semidefinite programming," in preparation for submission, 2024.

[J28] Junse Lee, **Song Noh**, Sooyeob Jeong, and Namyoon Lee, "Coverage analysis of LEO satellite downlink networks: Orbit geometry dependent approach," in preparation for submission, 2024.

[J27] Kyungsik Seo, Jeongwon Jeon, Gilwon Lee, Jaekoo Lee, and **Song Noh**, "Deep sequential feature learning for phase noise compensation in sub-THz systems," submitted to *IEEE Trans. Commun.*, Jul. 2024.

<Published or Accepted>

[J26] Daehee Kim, Sungmin Lee, Junghyeon Seo, **Song Noh**, and Jaekoo Lee, "Compatibility review for object detection enhancement through super-resolution," *Sensors*, vol. 24, no. 11, May 2024.

[J25] Kyungsik Seo, Jeongwon Jeon, Gaeun Choi, Hyunchae Chun, and **Song Noh**, "Aerial RIS-assisted direction finding under Doppler effect based on atomic norm minimization," *IEEE Trans. Veh. Technol.*, vol. 73, no. 3, pp. 4482 – 4486, Mar. 2024.

[J24] Jungsook Bae, Waqas Khalid, Anseok Lee, Heesoo Lee, **Song Noh**, and Heejung Yu, "Overview of RIS-enabled secure transmission in 6G wireless networks," to be published in *Digital Commun. Netw.*, Mar. 2024.

[J23] Jiho Song, Jong-Ho Lee, and **Song Noh**, "Position-based adaptive beamforming and roadside unit sectorization for V2I communications," *IEEE Trans. Veh. Technol.*, vol. 73, no. 2, pp. 2960 - 2965, Feb. 2024.

[J22] **Song Noh**, Kyungsik Seo, Youngchul Sung, David J. Love, Junse Lee, and Heejung Yu, "Joint direct and indirect channel estimation for RIS-assisted millimeter-wave systems based on array signal processing," *IEEE Trans. Wireless Commun.*, vol. 22, no. 11, pp. 8378 - 8391, Nov. 2023.

[J21] Waqas Khalid, Zeeshan Kaleem, Rehmat Ullah, Trinh Van Chien, **Song Noh**, and Heejung Yu, "Simultaneous transmitting and reflecting-reconfigurable intelligent surface in 6G: Design guidelines and future perspectives," *IEEE Netw.*, vol. 37, no. 5, Sep. 2023.

[J20] Kyungsik Seo, Jaekoo Lee, and **Song Noh**, "Deep learning-based direction finding in the presence of direction-dependent mutual coupling," *ICT Express*, vol. 9, no. 4, Aug. 2023.

[J19] **Song Noh**, Junse Lee, Gilwon Lee, Kyungsik Seo, Youngchul Sung, and Heejung Yu, "Channel estimation techniques for RIS-assisted communication: Millimeter-wave and sub-THz systems," *IEEE Veh. Technol. Mag.*, vol. 17, no. 2, pp. 64 – 73, Jun. 2022.

[J18] Jiho Song, Jong-Ho Lee, **Song Noh**, and Jeongsik Choi, "Millimeter wave reflection pattern codebook design for RIS-assisted V2V communications," *IEEE Trans. Veh. Technol.*, vol. 71, no. 6, pp. 6819 – 6824, Jun. 2022.

[J17] **Song Noh**, Jaekoo Lee, Heejung Yu, and Jiho Song, "Design of channel estimation for hybrid beamforming millimeter wave systems in the presence of beam squint," *IEEE Syst. J.*, vol. 16, no. 2, pp. 2834 – 2843, Jun. 2023.

[J16] Seoyeon Oh, Minseok Yu, Seonghyeon Cho, **Song Noh**, and Hyunchae Chun, "Bi-LSTM augmented deep neural network for multi-Gbps VCSEL based visible light communication link," *Sensors*, vol. 22, no. 11, May 2022.

[J15] **Song Noh**, Jiho Song, Junse Lee, and Heejung Yu, "High-resolution and low-complexity direction of arrival estimation for hybrid array of subarrays," *IEEE Access*, vol. 10, pp. 54922 – 54935, May 2022.

[J14] Ji Min Park, Juphil Cho, **Song Noh**, and Heejung Yu, "Optimal pilot and data power allocation for joint communication-radar air-to-ground networks," *IEEE Access*, vol. 10, pp. 52336 – 52342, May 2022.

[J13] **Song Noh**, Heejung Yu, and Youngchul Sung, "Training signal design for sparse channel estimation in intelligent reflecting surface-assisted millimeter-wave communication," *IEEE Trans. Wireless Commun.*, vol. 21, no. 4, pp. 2399 – 2413, Apr. 2022.

[J12] Waqas Khalid, Heejung Yu, Dinh Thuan Do, Zeeshan Kaleem, and **Song Noh**, "RIS-aided physical layer security with full-duplex jamming in underlay D2D networks," *IEEE Access*, vol. 9, pp. 99667 – 99679, Jul. 2021.

[J11] Jaekoo Lee, Myungkeun Yoon and **Song Noh**, "Advanced Network Sampling with Heterogeneous Multiple Chains," *Sensors*, vol. 21, no. 5, pp. 6737 – 6751, Mar. 2021.

[J10] **Song Noh**, Jiho Song, Youngchul Sung, and Heejung Yu, "Fast beam search and refinement for millimeter-wave massive MIMO based on two-level phased arrays," *IEEE Trans. Wireless Commun.*, vol. 19, no. 10, pp. 6737 – 6751, Jul. 2020.

[J9] Waqas Khalid, Heejung Yu, and **Song Noh**, "Residual energy analysis in cognitive radios with energy harvesting UAV under reliability and secrecy constraints," *Sensors*, vol. 20, no. 10, May 2020.

[J8] Jiho Song, Byungju Lee, **Song Noh**, and Jong-Ho Lee, "Adaptive multiuser transmission using millimeter wave beam alignment with user selection," *IEEE Trans. Veh. Technol.*, vol. 69, no. 8, pp. 9140 – 9145, May 2020.

[J7] Byounghak Kim, Heejung Yu, and **Song Noh**, "Cognitive interference cancellation with digital channelizer for satellite communication," *Sensors*, vol. 20, no. 2, Jan. 2020.

[J6] Jiho Song, Byungju Lee, **Song Noh**, and Jong-Ho Lee, "Limited feedback designs for machine-type communications exploiting user cooperation," *IEEE Access*, vol. 7, pp. 95154 - 95169, Sep. 2019.

[J5] **Song Noh**, Michael Zoltowski, and David J. Love, "Multi-resolution codebook and adaptive beamforming sequence design for millimeter wave beam alignment," *IEEE Trans. Wireless Commun.,* vol. 16, no. 9, pp. 5689 – 5701, Sep. 2017.

[J4] Il Y. Chun, **Song Noh**, David J. Love, Thomas M. Talavage, Stephen Beckley, and Sherman J. Kisner, "Mean square error (MSE)-based excitation pattern design for parallel transmit and receive SENSE MRI image reconstruction," *IEEE Trans. Comput. Imag.*, vol. 2, no. 4, pp. 424 – 439, Dec. 2016.

[J3] **Song Noh**, Michael Zoltowski, and David J. Love, "Training sequence design for feedback assisted hybrid beamforming in massive MIMO systems," *IEEE Trans. Commun.*, vol. 61, no. 1, pp 187 – 200, Jan. 2016.

[J2] **Song Noh**, Michael Zoltowski, Youngchul Sung, and David J. Love, "Pilot beam pattern design for channel estimation in massive MIMO systems," *IEEE J. Sel. Topics Signal Process.*, vol. 8, no. 5, pp. 787 – 801, Oct. 2014.

[J1] **Song Noh**, Youngchul Sung, and Michael Zoltowski, "A new precoder design for blind channel estimation in MIMO-OFDM systems," *IEEE Trans. Wireless Commun.*, vol. 13, no. 12, pp. 7011 – 7024, Dec. 2014.

Korean Journals and Magazines

[J5] Jeongwon Jeon, Gaeun Choi, and **Song Noh**, "Research trends in beyond diagonal reconfigurable intelligent surfaces," *Information and Communications Magazine*, vol. 40, no. 12, pp. 56 – 62, Dec. 2023.

[J4] Byungju Lee, Jiho Song, and **Song Noh**, "Research trends in UAV-based cellular networks," *The Magazine of the IEIE*, vol. 48, no. 11, pp. 41 – 53, Nov. 2021.

[J3] Seong-Hwan Hyun, Keunwoo Kim, Seong-Cheol Kim, Jiho Song, **Song Noh**, and Jong-Ho Lee, "Research trends in millimeter-wave V2X communicaitons," *The Magazine of the IEIE*, vol. 48, no. 11, pp. 18 – 32, Nov. 2021.

[J2] Daehee Kim, Youngjun Yoo, Jaekoo Lee, and **Song Noh**, "Enhancing object detection in low quality images using deep neural network based Super-resolution," *The Journal of Korean Institute of Communications and Information Sciences*, vol. 45, no. 12, pp. 2169 – 2176, Dec. 2020.

[J1] **Song Noh** and Hyunchae Chun, "Beamforming algorithms," *The Journal of Korean Institute of Electromagnetic Engineering and Science*, vol. 31, no. 8, pp. 701 – 712, Aug. 2020.

CONFERENCE PAPERS

International Conferences and Workshops

[C9] **Song Noh**, Heejung Yu, and Youngchul Sung, "Training signal design for sparse channel estimation in millimeter-wave communication with intelligent reflecting surfaces," in *Proc. IEEE ICC*, Montreal, Canada, Jun. 2021.

[C8] Hyeong Sook Park, Eun-Young Choi, Young Seog Song, **Song Noh**, and Kyungsik Seo, "DNN-based phase noise compensation for sub-THz communications," in *Proc. ICTC*, Jeju, Korea, Oct. 2020.

[C7] **Song Noh**, Dawei Ying, Qian (Clara) Li, Hassan Ghozlan, Apostolos (Tolis) Papathanassiou, and Geng Wu, "System evaluation for millimeter-wave radio access network," in *Proc. IEEE ICC*, Kansas City, MO, May 2018.

[C6] **Song Noh**, Michael Zoltowski, and David Love, "Multi-resolution codebook based beamforming sequence design in millimeter-wave systems," in *Proc. IEEE Globecom*, San Diego, CA, Dec. 2015.

[C5] **Song Noh**, Michael Zoltowski, and David Love, "Downlink training codebook design and hybrid precoding in FDD massive MIMO systems," in *Proc. IEEE Globecom*, Austin, TX, Dec. 2014. (**Best Paper Award**)

[C4] **Song Noh**, Michael Zoltowski, Youngchul Sung, and David Love, "Training signal design for channel estimation in massive MIMO systems," in *Proc. IEEE ICASSP*, Florence, Italy, May 2014.

[C3] **Song Noh** and Michael Zoltowski, "A new precoder design for precoding-based blind channel estimation for MIMO-OFDM systems," in *Proc. IEEE Globecom*, Atlanta, GA, Dec. 2013.

[C2] **Song Noh** and Michael Zoltowski, "Blind separation for precoding-based blind channel estimation for MIMO-OFDM systems," in *Proc. Asilomar*, Pacific Grove, CA, Nov. 2013.

[C1] **Song Noh**, Michael Zoltowski, Youngchul Sung, and David Love, "Optimal pilot beam pattern design for massive MIMO systems," in *Proc. Asilomar*, Pacific Grove, CA, Nov. 2013.

Korean Conferences and Workshops

[C20] Jeongwon Jeon, Jinho Kwon, Jihyuk Jung, and **Song Noh**, "Research trends in beyond diagonal RIS beam pattern design," *Korean Institute of Communications and Information Sciences (KICS) Summer Conference*, Jeju, Jun. 2024.

[C19] Jinho Kwon and **Song Noh**, "FMCW radar-based initial beam search," *Korean Institute of Communications and Information Sciences (KICS) Winter Conference*, Kwangwon, Feb. 2024.

[C18] Jeongwon Jeon and **Song Noh**, "Research trends in beyond diagonal RIS: Beamforming techniques," *Korean Institute of Communications and Information Sciences (KICS) Winter Conference*, Kwangwon, Feb. 2024.

[C17] Gaeun Choi, Jeongwon Jeon, and **Song Noh**, "Research trends in RIS architectures and modes," *Korean Institute of Communications and Information Sciences (KICS) Fall Conference*, Gyeongju, Nov. 2023.

[C16] Jeongwon Jeon, Gaeun Choi, and **Song Noh**, "Research trends in deep learning-based RIS: Channel estimation techniques," *Korean Institute of Communications and Information Sciences (KICS) Fall Conference*, Gyeongju, Nov. 2023.

[C15] Jinho Kwon, Jeongwon Jeon, Seokjun Hwang, and **Song Noh**, "Radar-assisted beam search in integrated sensing and communication systems," *Korean Institute of Communications and Information Sciences (KICS) Summer Conference*, Jeju, Jun. 2023. (Student Paper Award)

[C14] Jeongwon Jeon, Gaeun Choi, and **Song Noh**, "Research trends in reconfigurable intelligent surface-assisted channel estimation," *Joint Conference on Communications and Information (JCCI)*, Yeosoo, Apr. 2023.

[C13] Jeongwon Jeon, Gaeun Choi, Kyungsik Seo, and **Song Noh**, "Deep learning-based reconfigurable intelligent surface-assisted channel estimation," *Korean Institute of Communications and Information Sciences (KICS) Winter Conference*, Kwangwon, Feb. 2023. (Student Paper Award)

[C12] Seokjun Hwang, Jinho Kwon, Kyungsik Seo, Jeongwon Jeon, and **Song Noh**, "Reconfigurable intelligent surface-assisted channel estimation techniques in millimeter-wave communications," *Korean Institute of Communications and Information Sciences (KICS) Winter Conference*, Kwangwon, Feb. 2023.

[C11] Jeongwon Jeon, Kyungsik Seo, and **Song Noh**, "Performance analysis of autoencoder-based PAPR reduction in orthogonal frequency division multiplexing systems," *Korean Institute of Communications and Information Sciences (KICS) Fall Conference*, Jeju, Jun. 2022.

[C10] Kyungsik Seo, Jeongwon Jeon, and **Song Noh**, "Overview of advanced wireless relay and RIS techniques in relation to 3GPP standards," *Joint Conference on Communications and Information (JCCI)*, Sokcho, May 2022.

[C9] Jeongwon Jeon, Kyungsik Seo, and **Song Noh**, "Performance analysis of deep learning-based PAPR reduction in orthogonal frequency division multiplexing systems," *Korean Institute of Communications and Information Sciences (KICS) Winter Conference*, Kwangwon, Feb. 2022.

[C8] **Song Noh**, "Reconfigurable intelligent surfaces-assisted millimeter-wave and terahertz communications," *Korean Institute of Communications and Information Sciences (KICS) Fall Conference*, Yeosoo, Nov. 2021.

[C7] Kyungsik Seo and **Song Noh**, "Deep learning-based channel estimation and detection for reconfigurable intelligent surfaces," *Korean Institute of Communications and Information Sciences (KICS) Summer Conference*, Kwangwon, Jun. 2021.

[C6] Kyungsik Seo and **Song Noh**, "Performance analysis of deep learning-based nonlinear system identification," *Korean Institute of Communications and Information Sciences (KICS) Winter Conference*, Kwangwon, Feb. 2021.

[C5] Kyungsik Seo, Jeongwon Jeon, Gaeun Choi, and **Song Noh**, "Analysis of DNN-based data detection with phase noise for Teraherz OFDM systems," *Korean Institute of Communications and Information Sciences (KICS) Fall Conference* (Online), Nov. 2020.

[C4] Kyungsik Seo and **Song Noh**, "Evaluation of DNN-based channel estimation techniques in millimeter wave systems," *Korean Institute of Communications and Information Sciences (KICS) Summer Conference*, Kwangwon, Aug. 2020. (Student Paper Award)

[C3] Kyungsik Seo and **Song Noh**, "Performance analysis of beam search techniques in millimeter wave systems," *Korean Institute of Communications and Information Sciences (KICS) Winter Conference*, Kwangwon, Feb. 2020.

[C2] **Song Noh**, Kyungsik Seo, Mirae Kim, and Junghwan Im, "Beam misalignment-aware beamforming system design," *Korean Institute of Communications and Information Sciences (KICS) Fall Conference*, Seoul, Korea, Nov. 2019.

[C1] **Song Noh**, Junghwan Im, Mirae Kim, and Kyungsik Seo, "Beamformed signal classification based on multiple hypothetical testing," *Korean Institute of Communications and Information Sciences (KICS) Summer Conference*, Jeju, Jun. 2019.

FUNDED RESEARCH PROJECTS

Current Projects

International Collaborative Research for Next-Generation Communications

Funding Agent: INU
Role: Principal Investigator
Period: 2024.05 – 2026.04 (Total 2 years)

EQM-level Satellite Communication System Designs Featured by Real-time SatCom Routing Optimization

Funding Agent: Ministry of Science and ICT (MSIT)
Role: Co-Principal Investigator
Period: 2023.07 – 2029.12 (Total 7.5 years)

Development of Signal Processing Technologies for Sub-Terahertz Bands

Funding Agent: ETRI
Role: Principal Investigator
Period: 2023.04 – 2025.12 (Total 2.7 years)

AI-powered Reconfigurable Intelligent Surfaces

Funding Agent: Ministry of Trade, Industry and Energy (MOTIE)
Role: Co-Principal Investigator
Period: 2022.11 – 2024.10 (Total 2 years)

Intelligent Non-terrestrial Network Management

Funding Agent: National Research Foundation (NRF) of Korea
Role: Principal Investigator

Period: 2022.06 – 2025.02 (Total 2.7 years)

Past Projects

Research on Reconfigurable Intelligent Surface Technology for Non-Terrestrial Networks and Consulting on the Development of System-Level Simulator

Funding Agent: ETRI
Role: Principal Investigator
Period: 2022.06 – 2022.11

Development of Physical Layer Technologies for xG Communications

Funding Agent: INU
Role: Principal Investigator
Period: 2022.05 – 2024.04 (Total 2 years)

Research on Machine Learning-based Beam Management and Feature Space Estimation

Funding Agent: National Research Foundation (NRF) of Korea
Role: Principal Investigator
Period: 2019.03 – 2021.02 (Total 2 years)

Research on Enhancing Transmission Efficiency in Extremely High Frequency

Funding Agent: ETRI
Role: Principal Investigator
Period: 2019.05 – 2022.11

Research on Machine Learning-based Beam Management and Feature Space Estimation

Funding Agent: National Research Foundation (NRF) of Korea
Role: Principal Investigator
Period: 2019.03 – 2021.02 (Total 2 years)

INVITED TALKS

4. **Song Noh**, "Signal processing for sub-terahertz communications: Phase noise compensation and reconfigurable intelligent surface," at Emerging Researchers Special Session (KICS), Feb. 2023
3. **Song Noh**, "Beamforming tutorial: Algorithms," at Workshop on Microwave and mmWave Technology (KIEES), Jul. 2020
2. **Song Noh**, "Array signal processing for enhanced beam management," at Future & Emerging Technologies by Young Scientists (KICS), Jun. 2019
1. **Song Noh**, "Channel estimation initiatives through training signal design in large-scale MIMO," Soongsil University, Sep. 2014, and KAIST, Aug. 2014

TEACHING

Digital Logic — Fall 2018 – Fall 2023
Dept. of Information and Telecommunication Engineering, INU

Signals and Systems — Fall 2018 – Fall 2023
Dept. of Information and Telecommunication Engineering, INU

Computer Architecture — Spring 2019 – Spring 2024
Dept. of Information and Telecommunication Engineering, INU

Linear Algebra — Spring 2023 – Spring 2024
Dept. of Information and Telecommunication Engineering, INU

Communication Engineering — Spring 2019 – Spring 2024
Dept. of Information and Telecommunication Engineering, INU

Wireless Communication Systems — Fall 2020
Dept. of Information and Telecommunication Engineering, INU

Advanced Digital Communication — Fall 2021, Fall 2023
Dept. of Information and Telecommunication Engineering, INU

Teaching Assistant, Digital Signal Processing I (ECE 538) — Fall 2014
School of Electrical and Computer Engineering, Purdue University

PATENTS

International Patents

18. "Method and apparatus for estimating channel in communication system," PR20210716US.
17. "Signaling for resource allocation and scheduling in 5G-NR integrated access and backhaul," US10992358.
16. "Next generation node-B (GNB) for integrated access and backhaul (IAB) relay in new radio (NR) networks," US10785699.
15. "Mobile communication system, mobile device, user equipment, network node, NodeB, circuits, apparatuses, methods, machine readable media and computer programs for mobile devices, user equipment, network nodes, and NodeBs," US20200213052A1.
14. "Pre-grant packet header processing," WO2018119458A3.
13. "Enodeb assisted network UE scheduling in 5G NR-things sidelink," WO2018084880A1.
12. "Power based contention resolution during a random access procedure," WO2018084877A1.
11. "Timing based contention resolution during a random access procedure," WO2018084879A1.
10. "Buffer status reporting in 5G NR-things sidelink communications," WO2018080561A1.
9. "Network-assisted transmission mode for vehicle-to-vehicle (v2v) communication," WO2018080568A1.
8. "Subframe structure and communication procedure for 5G NR-things vehicle to vehicle," WO2018080566A1.
7. "Data transfer and reception procedures in 5G NR-things sidelink communications," WO2018080565A1. 2018.05.03.
6. "Procedures and signaling for scheduling and resource assignment in 5G NR-things sidelink communication system," WO2018071051A1.

5. “Retransmission procedures for fifth generation (5G) new radio (NR) things sidelink (tSL) communication,” WO2018071050A1.
4. “Measurement reporting with number of available beams,” WO2018063436A1.
3. “Method of heterogeneous BRS transmission in NR,” WO2018031583A1.
2. “Signal degradation detection and recovery,” WO2018031065A1.
1. “Higher layer design for user plane packet processing in fifth generation (5G) new radio (NR) things sidelink (tSL) communication,” WO2017192164A1.

Korean Patents

4. “재구성 가능한 지능형 표면의 방향 탐지 방법 및 장치 (도플러 효과를 고려한 이동체 탑재 지능형 반사 표면체의 방향 탐지 기법),” PR20231032.
3. “통신 시스템에서 신호 수신 방법 및 장치 (서브테라헤르츠 대역 위상 잡음 보상 및 데이터 복호를 위한 딥러닝 기반 통신 시스템 구조),” PR20220946KR.
2. “밀리미터파 대역 지능형 반사 표면 기반 통신 시스템 채널 추정 기법,” PR20210716KR.
1. “하이브리드 빔포밍을 기초로 한 빔 탐색 방법 및 장치,” 10-2020-0065063.