

## Poster and Demonstration (GJWS7-PD1)

Keio Future Photonic Network Open Lab.

Naoaki Yamanaka, Koichi Adachi, Hiroyuki Tsuda and Satoru Okamoto (KeioUniv)

Keio University has established the Future Photonic Open Research Center to pursue optical technology research through open innovation. Hollowcore fiber has been deployed across Keio's campuses, enabling collaborative researchers to utilize it together. Hollowcore fiber not only transmits data at speeds 1/3 times faster than conventional fiber and carries 1,000 times more energy, but also exhibits low nonlinearity and supports Anrog Radio over fiber (RoF.) In the booth, we will show new ONU(User access box) which has power over fiber interface without AC power supply. And also RoF demonstration will show by video. This makes it a major breakthrough for 6G.

**Keio University**

**Yamanaka Laboratory, Keio University, Japan**

**Analog Radio-over-Fiber based 5G smart mobile fronthaul networking testbed using Hollow-Core Fiber**

**Power-saving B3G wireless base station system with "analog" radio over fiber technology using air-hole core (hollow-core) fibers**

**Proposal of Switched RoF as a New Mobile Fronthaul**

- Insertion of Optical switch and Optical coupler between CU/DU and optical powered small antennas
- Controlling Microcells based on UE location detection in Macrocell using Hierarchical cell structure

**Details at the bottom of the hierarchy**

1. Powering off empty cells
2. Using multi-cell connection in low-user-density areas
3. Using one-to-one connection in high-user-density areas

**Experiment of Analog Radio-over-Fiber Using Field-installed Hollow-Core Fiber Links**

**Demonstration of Switched RoF with Energy-Efficient Cell Selection Optimization**

**Switching scenario**

**No throughput degradation after switching**

This work was supported in part by the National Institute of Information and Communications Technology (NICT) (JP2012368C07101). This research was conducted at the Keio Future Photonic Network Open Lab

**Keio Future Photonic Network Open Lab.**

- Challenge of the next generation networking with Hollow-Core Fibers -

<https://pilab.jp/OpenLab/>

**Hollow-Core Fiber (HCF)**

**Challenge of the next generation networking with Hollow-Core Fibers**

**Hollow-Core Fiber (HCF)**

**Application of HCF to Access Systems**

**Ultra-High Splitting Ratio PON Technology**

**Power over Fiber (PoWF) PON Technology**

**Applications of PoWF**

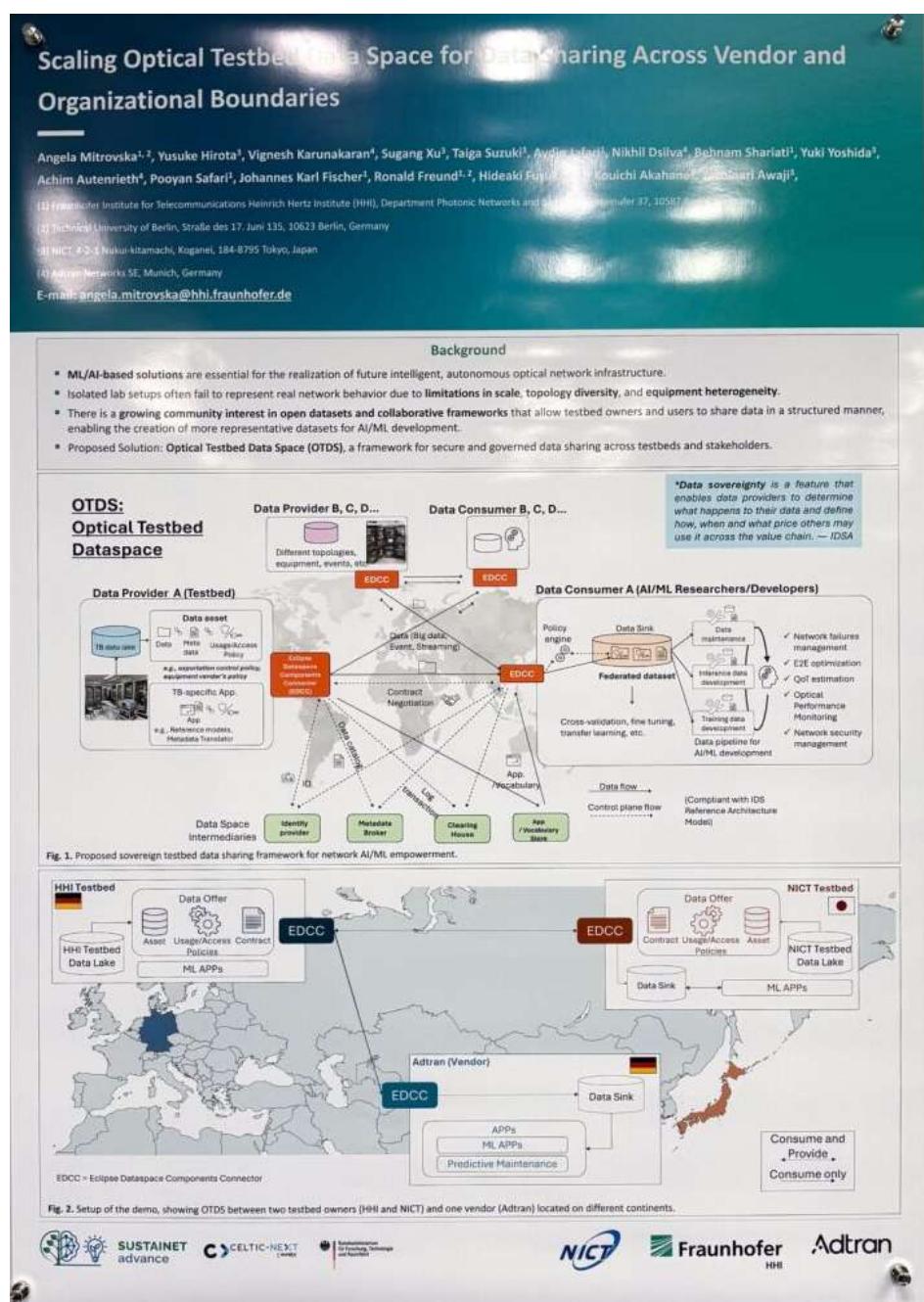
## Poster and Demonstration (GJWS7-PD2)

### Scaling Optical Testbed Data Space for Data Sharing Across Vendor and Organizational Boundaries

Angela Mitrovska<sup>1, 2</sup>; Yusuke Hirota<sup>3</sup>; Vignesh Karunakaran<sup>4</sup>; Sugang Xu<sup>3</sup>; Taiga Suzuki<sup>1</sup>; Aydin Jafari<sup>1</sup>; Nikhil Dsilva<sup>4</sup>; Behnam Shariati<sup>1</sup>; Yuki Yoshida<sup>3</sup>; Achim Autenrieth<sup>4</sup>; Pooyan Safari<sup>1</sup>; Johannes Karl Fischer<sup>1</sup>; Ronald Freund<sup>1, 2</sup>; Yoshinari Awaji<sup>3</sup>;

1. Fraunhofer-Institut für Nachrichtentechnik Heinrich-Hertz-Institut HHI, Berlin, BE, Germany.
2. Technische Universität Berlin, Berlin, BE, Germany.
3. National Inst of Information & Comm Tech, TOKYO, Koganei, Japan.
4. Adtran Networks SE, Martinsried, BY, Germany.

We demonstrate a data-sharing platform enabling on-demand sovereign data exchange across optical testbeds and system vendors to support ML development and predictive maintenance, through advanced vendor-, anonymization- and purpose-based governance controls.



## Poster and Demonstration (GJWS7-PD3)

### Resilient Relay-Assisted mmWave Communication for Mobile Robots with ML-Based RSSI Prediction

Nguyen Nam Khanh, Nann Win Moe Thet, Kenichi Takizawa, and Haris GACANIN (RWTH Aachen University), Firooz Bashashi Saghezchi (RWTH Aachen University)

Millimeter-wave (mmWave) communication is particularly vulnerable to blockage, posing a significant challenge to maintaining reliable connectivity in mobile robotic systems under severe channel environments. This work presents a resilient relay-assisted mmWave communication framework that leverages machine learning (ML)-based received signal strength indicator (RSSI) prediction with environment awareness at the robot to enable proactive link adaptation. As the robot moves, future RSSI values are predicted to anticipate channel degradation and non-line-of-sight (NLoS) conditions. When the RSSI of the current connection is predicted to be weak, communication switches to an amplify-and-forward (AF) relay with independent transmit and receive beamformers to mitigate self-interference; otherwise, direct transmission is maintained. The proposed approach eliminates the need for instantaneous channel state information, enabling low-complexity and fast adaptation in dynamic environments.

**NICT** Sustainable ICT Systems Laboratory, Resilient ICT Research Center, Network Research Institute, NICT, Japan  
**RWTHAACHEN** UNIVERSITY Chair of Distributed Signal Processing, RWTH Aachen University, Germany

### Leveraging Machine Learning and Full Duplex Relay for Resilient Robot Communication

**Mission** Provide high-quality wireless communication for robot control by **optimizing the use of communication resources and detecting the radio environment**, even in severe radio environments.

**ABSTRACTS**

**Challenge:** mmWave links in mobile robotic systems are highly vulnerable to blockage and NLoS conditions.

**Objective:** Demonstrate a resilient mmWave communication setup under severe blockage.

**Approach:** Implement a **relay-assisted mmWave network** between a base station and a remote device when the direct path is blocked.

**Relay Design:** Use an **amplify-and-forward (AF) relay** with independent transmit and receive beamformers to mitigate self-interference.

**Outcome:** The relay restores connectivity and improves link robustness in blocked mmWave scenarios without requiring instantaneous CSI.

**SYSTEM MODEL**

Fig. 1: Proposed robot communication system with mmWave links for robust connectivity in dynamic, obstructed environments.

**EXPERIMENTAL SETUP**

Fig. 2: Experimental demo setup for 28GHz mmWave relay-assisted communication system

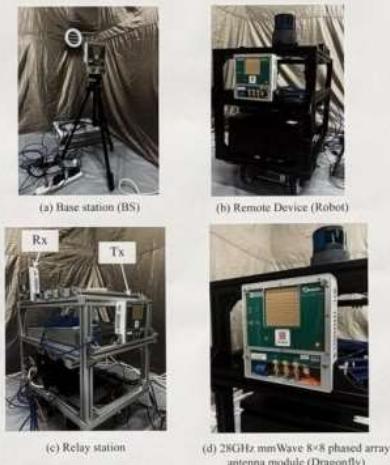


Fig. 3: Base station, relay station, and mobile robot used in the experimental setup.

### EVALUATION

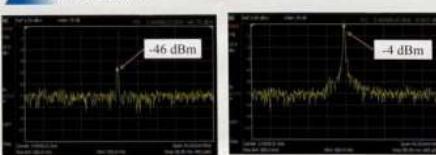


Fig. 4: Received signal power spectrum at the remote device (Robot)

### Conclusion

- Relay-assisted mmWave communication restores links under blockage.
- AF relay with independent beamforming improves NLoS robustness without CSI.
- Future work: integrate RSSI prediction for proactive link adaptation and further enhance resilience in dynamic environments.



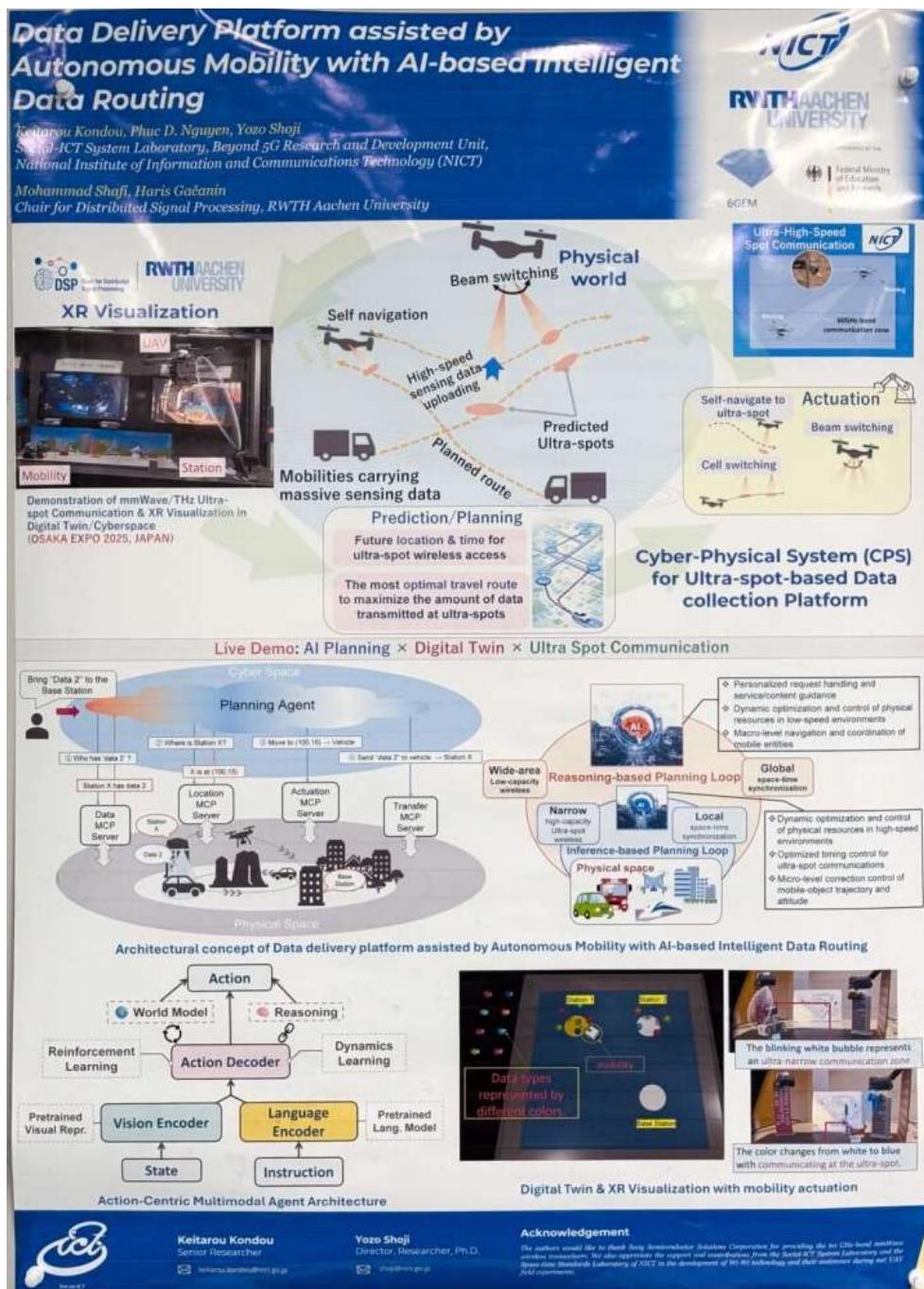
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## Poster and Demonstration (GJWS7-PD4)

### Data Delivery Platform assisted by Autonomous Mobility with AI-based Intelligent Data Routing

Keitarou Kondou (NICT), Phuc D. Nguyen(NICT), Mohammad Shafi, Haris Gačanin (RWTH Aachen University), Yozo Shoji (NICT)

This work explores an architecture for mobility control that optimizes ultra-spot communications using an AI-driven approach. We are studying a concept in which an AI agent performs long-horizon, reasoning-based planning to orchestrate mobility and actions, enabling ultra-spot (localized, high-capacity) communication as a service. XR visualization is employed to present communication status at each ultra-spot. Building on this, we propose a two-layer architecture: (1) a service-level planning loop for global, long-horizon optimization, and (2) an inference-based planning loop for fast, local control using lightweight on-device models (e.g., Vision–Language–Action-style) to achieve real-time alignment and adaptive actuation. This layered approach aims to balance strategic reasoning with responsive control, paving the way for future CPS and digital twin implementations in Beyond 5G/6G environments.

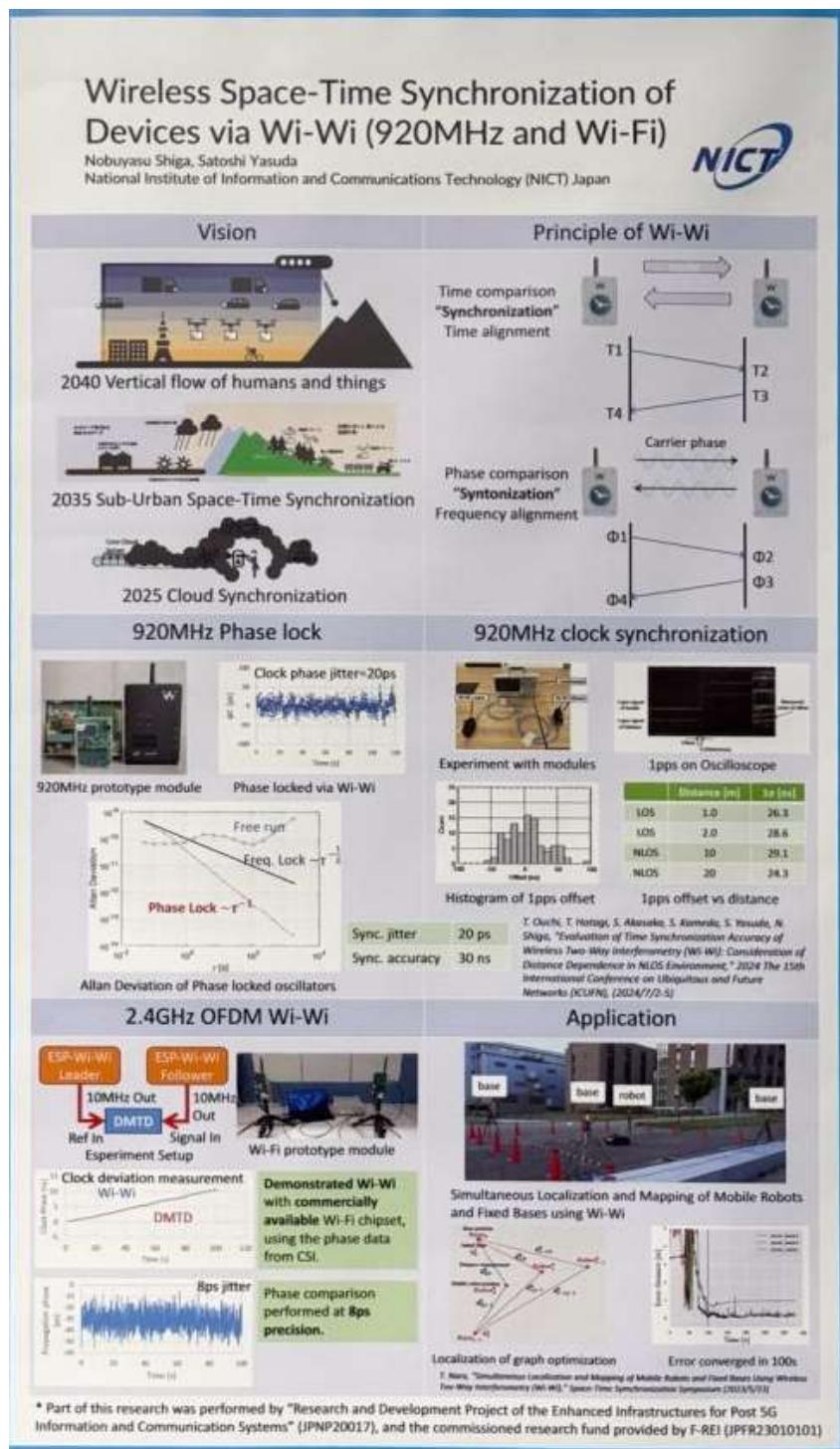


## Poster and Demonstration (GJWS7-PD5)

### Demonstration of Wi-Wi-Based Position Estimation Using Distributed Wireless Time Synchronization

Nobuyasu Shiga, Satoshi Yasuda

Accurate sensing of position estimation and motion is a fundamental requirement for future Beyond 5G/6G cyber-physical systems, including smart factories, distributed robotics, and resilient positioning infrastructure. In this demonstration, we present a real-time position measurement system based on Wi-Wi (Wireless Two-Way Interferometry), a wireless time-synchronization technology that enables sub-nanosecond relative clock alignment between distributed nodes. By exploiting carrier-phase information synchronized through Wi-Wi, small spatial displacements and dynamic motion can be detected without reliance on GNSS or centralized timing references. The demo showcases experimental results of position variation tracking under controlled motion, highlighting robustness against multipath and clock drift.



## Poster and Demonstration (GJWS7-PD6)

### Research and development of optical terahertz receivers using EO polymers

Takahiro Kaji, Toshiki Yamada, Akira Otomo

Radio-over-fiber (RoF) technology, which transmits terahertz (0.1-10 THz) signals as optical signals using optical fiber, is attracting attention for the realization of ultra-high-speed wireless communication in Beyond 5G. In this study, we prototyped and evaluated antenna-coupled optical modulators using electro-optic (EO) polymer waveguides and non-coplanar patch antennas in 150-GHz and 375-GHz band with the aim of realizing devices that directly convert a radio signal to an optical signal in RoF systems.

**The 7th Germany-Japan Beyond 5G/6G Research Workshop** Jan. 21-22, 2026

### Research and development of optical terahertz receivers using EO polymers

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#### Abstract

Radio-over-fiber (RoF) technology, which transmits terahertz (0.1-10 THz) signals as optical signals using optical fiber, is attracting attention for the realization of ultra-high-speed wireless communication in Beyond 5G. In this study, we prototyped and evaluated antenna-coupled optical modulators using electro-optic (EO) polymer waveguides and non-coplanar patch antennas in 150-GHz and 375-GHz band with the aim of realizing devices that directly convert a radio signal to an optical signal in RoF systems.

#### Background

**Ultra-high-speed wireless-to-optical signal conversion technology in Beyond 5G**

**5G (10-20Gbps @2020~)**  
**Beyond 5G (>100Gbps ? @2030~?)**  
**XR (VR/AR/MR) (Fusion of cyber and physical)**  
**Beyond 5G communication**  
**Frequency**  
1 GHz 10 GHz 100 GHz 1 THz 10 THz  
5G (28 GHz) **Terahertz waves** Nondestructive sensing

**[Radio-over-fiber (RoF) systems]**  
• RoF remote antenna  
Optical fiber      Optical signal      Remote antenna  
THz signal (0.1-10 THz)  
User terminal

**[Optical and wireless mutual signal conversion technologies]**  
[Transmitter] Optical signal → THz signal → Optical signal  
[Receiver] Optical signal → THz signal → Optical signal  
E/O      E/O  
Uni-traveling-carrier photodiodes (UTC-PD) etc.  
RF mixer      Amplifier      Optical modulator  
LO      THz optical modulator

**Problems [receiver]**  
THz signal → electrical signal → optical signal conversions  
(Complex mechanism, power consumption, manufacturing cost)

**[This work]**  
THz-to-optical direct signal conversion  
(Simple mechanism, ultrafast, ultrabroadband, ultra low latency, no external power supply, small size, low cost)

#### Results

**Antenna-coupled optical modulators using non-coplanar patch antennas**

**Electromagnetic field simulation results**  
• Electric field enhancement factor ( $E_x/E_0$ ):  $\sim 121$  @150 GHz  $\rightarrow 2.9$  times larger than the coplanar type  
• 3 dB bandwidth:  $\sim 15$  GHz

**Device fabrication and evaluation results**  
• D-band waves  
• Au patch antenna array ( $N=10$ )  
• Nonpolarized light  
• EO polymer waveguide  
• COP lower clad  
• Ground electrode  
• Input light (5.335 nm)  
• Cross-sectional SEM image  
• Microscope image  
• Carrier-to-sideband ratio (CSR) of 42.3 dB ( $m=15.3$  mrad) ( $\theta=34.3$  W/m<sup>2</sup>)  
• Demonstrated direct optical modulation using 150 GHz electromagnetic waves

**Wireless transmission evaluation results**  
[Wireless transmission evaluation system]  
• 5 Gbaud QPSK  
• Demonstration of wireless transmission of 10 Gbps QPSK signal (BER:  $2.2 \times 10^{-3}$ ) in the 140 GHz band  
[Constellation diagram of the received signal]

**Fiber-optic connected modules**  
[375GHz-band optical modulator module]  
• Fiber optic connection  
• DFB modulator  
• Single-mode fiber array  
• 10 mm  
• DFB modulator  
• Power (dBm) vs. Wavelength (nm)  
• CSR: 42.3 dB @ 375 GHz

**Operating principle of antenna array devices**  
[Multiple antenna elements with inverted placement]  
• The "positive" and "negative" peaks of the THz electromagnetic waves share modulate the light, which doubles the efficiency.

**Nano-scale Functional Assembly ICT Laboratory, Kobe Frontier Research Center, Advanced ICT Research Institute**

**NICT** National Institute of Information and Communications Technology

## Software-Controlled Analog Beamforming for Network-Controlled Repeater

Jin Nakazato (Tokyo University of Science)

Millimeter-wave (mmWave) communication enables high data rates but suffers from limited coverage and blockage. Network-Controlled Repeaters (NCRs), standardized in 3GPP Release 18, offer a cost-effective solution using analog beamforming. This paper presents a software-controlled beamforming method for NCRs based on Taylor amplitude distribution to obtain extremely low sidelobe level. A 32-element phased array with phase-control ICs was implemented, and the radiation patterns were measured in an anechoic chamber at 28.0 GHz. The results confirm effective beam manipulation and sidelobe reduction, demonstrating the feasibility of software-defined NCR control.



### Research Background

- Since 2019, 5G service has been started worldwide.
- However, most of 5G vendors use Sub-6 (e.g., 3.4 GHz, 4.0 GHz).
- mmWave bands have signal propagation challenges.  
(e.g., path loss, atmospheric absorption, and blockage effects)

Repeater and Intelligent Surface have potential to extend mmWave coverage

- Repeater has two kinds of types (AF and DF); NCR has AF structure.
- Intelligent surface has also two kinds of types (RIS/IRS and Metasurface)

This paper focuses on NCR because its structure is easy to extend coverage

Repeater	Processing	Noise	Latency	Cost
AF	Amplify	✗	Low	Low
DF	Decode	○	High	High

Prototype: 310mm x 310mm

3GPP TR 38.807, Study on NR network controlled repeaters, Oct. 2022

### Software-controlled Analog Beamforming

- Development of a software-controllable mmWave analog beamformer device prototype.
- Software architecture and implementation with management functions for deploying multiple NCRs.

Antenna Pattern: Radiation Pattern, Each Antenna Element Phase and Amplitude

Overview of beam control:  $\theta$ ,  $\phi$ ,  $\psi$

Device Configuration: Rx Antenna Gain: 19dBi, Amplify: 45.8dB, Tx Antenna Gain: 17dBi, Total Gain = 81.8dB, Device M-plane, 1.75 m, Horn (15 dBi)

### Single/Multi-hop and End-to-End Evaluation

Center Freq.: 28GHz, two types of experiment (continuous wave (CW), end-to-end (gNB, COTS UE))

**Single/Multi-hop: Theoretical and Experimental values agree**

**3 NCRs can improve throughput compared to one gNB**

Single-hop: Theory: -34.4 dBm; Exp.: -36.4 dBm

Multi-hop: Theory: -34.4 dBm; Exp.: -36.4 dBm

End-to-End Evaluation: BW: 100MHz, MCS 27, TDD (50:50)

Detected power: -36.4 dBm

Relative Power (dB): -32.8 dB

(a) UDP Throughput: 1-hop, 2-hop, 3-hop

(b) MCS Result: 1-hop, 2-hop, 3-hop

(c) BLER Result: Hop ON (1/2/3-hop)