Mobile Communications Research Group
Tokyo Institute of Technology

2023
ANNUAL REPORT

Contents

Tokyo Institute of Technology

Overview

Tokyo Institute of Technology (Tokyo Tech) is the top national university for science and technology in Japan with a history spanning more than 130 years. Of the approximately 10,000 students at the Ookayama, Suzukakedai, and Tamachi campuses, half are in their bachelor's degree program while the other half are in master's and doctoral degree programs. International students number 1,200. There are 1,200 faculty and 600 administrative and technical staff members. In the 21st century, the role of science and technology universities has become increasingly important. Tokyo Tech continues to develop global leaders in the fields of science and technology, and contributes to the betterment of society through its research, focusing on solutions to global issues. The Institute's long-term goal is to become the world's leading science and technology university.

Mission

As one of Japan's top universities, Tokyo Tech seeks to contribute to civilization, peace and prosperity in the world, and aims at developing global human capabilities par excellence through pioneering research and education in science and technology, including industrial and social management. To achieve this mission, we have an eye on educating highly moral students to acquire not only scientific expertise but also expertise in the liberal arts, and a balanced knowledge of the social sciences and humanities, all while researching deeply from basics to practice with academic mastery. Through these activities, we wish to contribute to global sustainability of the natural world and the support of human life.

Main Building (Honkan) with "Sakura".

Tokyo Tech Seal

The Tokyo Tech seal was designed in 1947 by Mr. Shinji Hori, who was at that time a professor at the Tokyo Fine Arts School. The backdrop represents the Japanese character "工", which is the first character of "engineering, 工業". This part of the seal also evokes the image in silhouette of a window opening out on the world. Window is the second character of "school, 学窓". The central figure of the seal depicts a swallow and represents the Japanese character "大", which is the first character of "university, 大学". In Japan, swallows traditionally portend good fortune.
(Source: Tokyo Institute of Technology Profile, https://www.titech.ac.jp/english/about/)

Mobile Communication Research Group

Home page: https://www.mcrg.ee.titech.ac.jp

Mobile Communication Research Group (MCRG) of Tokyo Tech was established in 2001. The objective of the group is to conduct advanced research related to mobile communications. MCRG conducts comprehensive research on the development of mobile communication systems covering a wide range of cutting edge technologies in the field of the antenna design, wireless propagation, transmission systems, hard ware development, signal processing, and integrated circuit development.

MCRG Members

MCRG includes 5 core and 4 cooperate laboratories. Totally 8 professors, 5 associate professors, and 3 assistant professors belong to MCRG, in which Prof. Jun-ichi Takada is the principal researcher. The synergy in MCRG creates an ideal environment for cross-disciplinary discussions and tapping of expertise resulting in various notable joint projects and developments.

Core Laboratories

- Takada Laboratory (Propagation Lab.):
  Prof. Jun-ichi Takada, Assist. Prof. Hang Song
- Sakaguchi and Tran Laboratory (System Lab.):
  Prof. Kei Sakaguchi, Assoc. Prof. Gia Khanh Tran, and Emeritus Prof. Kiyomichi Araki
- Hirokawa Laboratory (Antenna Lab.):
  Prof. Jiro Hirokawa and Assist. Prof. Takashi Tomura
- Fukawa Laboratory (Signal Processing Lab.):
  Prof. Kazuhiko Fukawa and Assist. Prof. Yuyuan Chang
- Okada Laboratory / Shirane Laboratory (Device Lab.):
  Prof. Kenichi Okada and Assoc. Prof. Atsushi Shirane

Cooperate Laboratories

- Aoyagi Laboratory:
  Assoc. Prof. Takahiro Aoyagi
- Nishikata Laboratory:
  Assoc. Prof. Atsuhiro Nishikata
- Fujii and Omote Laboratory:
  Specially Appointed Prof. Teruya Fujii, and
  Specially Appointed Assoc. Prof. Hideki Omote
- Okumura Laboratory:
  Visiting Prof. Yukihiko Okumura

Activities

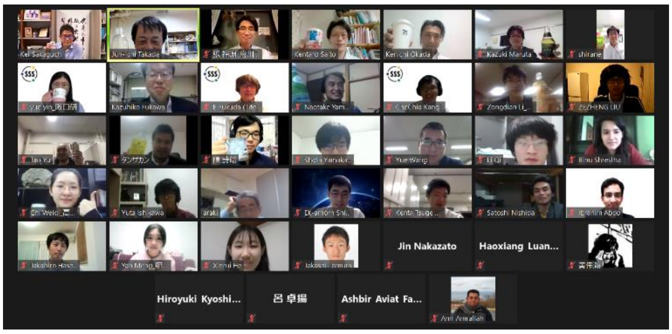
Beside the general research activities, for encouraging closer cooperation within MCRG and with the external companies, institutes and organizations, "Open House" and "Future Communication Research Workshop" are holed regularly. In addition, irregular invited speeches and lectures are also hold to broaden the horizons of MCRG members, especially the students.

Future Communication Research Workshop

An Future Communication Research Workshop (未来研究会) is organized every two months to share the latest research outcomes among internal laboratories and to gain insight on our research activities by the presentation and discussing in the seminar and poster section of each workshop.

Open House

From 2005, an Open House is organized yearly in April to introduce MCRG activities and build a network with external companies, institutes and organizations in the field of mobile communications. Distinguished speakers from both the academe and industry are invited to give key note speeches and lectures to contribute their visions and viewpoints for the future research and development of the mobile communications. From 2016, the Open House is organized in the collaboration with Advanced Wireless Communication Center (AWCC) of The University of Electro-Communications, and it brings on the further active research activities of both MCRG and AWCC.



Takada Laboratory

Home page: http://www.ap.ide.titech.ac.jp

Professor Jun-ichi Takada

Prof. Jun-ichi Takada was born in 1964, Tokyo, Japan. He received the B.E. and D.E. degree from Tokyo Institute of Technology in 1987 and 1992, respectively. He was a Research Associate at Chiba University during 1992-1994. He was an Associate Professor at Tokyo Institute of Technology in 1994-2006, and he has been a Professor since 2006. He is currently with the Department of Transdisciplinary Science and Engineering, School of Environment and Society. He is also serving as the Dean, School of Environment and Society. He was a part time researcher in National Institute of Information and Communications Technology from 2003 to 2007. His current research interests are the radio wave propagation and channel modeling for various wireless systems, applied radio measurements and information technology for regional/rural development. He is a fellow of IEICE, a senior member of IEEE, and a member of Japan Society for International Development (JASID). He has been serving as a vice president of JASID during 2020-2023.

Assistant Professor Hang Song

Dr. Hang Song received the B.S. and M.S. degrees in electronic science and technology from Tianjin University, Tianjin, China, in 2012 and 2015, respectively. He received the Ph.D. degree from Hiroshima University, Hiroshima, Japan in 2018. From 2019 to 2020, he was a lecturer with the school of microelectronics, Tianjin University, China. From 2020 to 2022, he was a specially appointed researcher with the University of Tokyo, Japan. He is currently an assistant professor with Tokyo Institute of Technology. His research interests include wireless sensing, microwave and millimeter-wave imaging, wireless communication and networks, permittivity measurement, biomedical applications of microwave engineering. He is a member of IEICE and IEEE.

Postdoctoral Researcher Nopphon Keerativoranan

Dr. Nopphon Keerativoranan was born in 1989, Bangkok, Thailand. He received the B.E. degree (Hons.) from Thammasat University, Thailand, in 2012, the M.S. degree from Seoul National University, South Korea, in 2015, and the D.E. degree from the Tokyo Institute of Technology, Japan, in 2020. In 2012, he was a Telecommunication Engineer with Advance Info Service (AIS), Thailand. From 2015 to 2016, he was a Research Assistant with the National Electronics and Computer Technology Center (NECTEC), Thailand. His research interests include radio propagation channel modeling, RF-based motion sensing, radio channel modeling, and measurements for wireless communication system and application. He is a member of IEICE and IEEE.

Postdoctoral Researcher Sawaros Thanapornsangsuth

Dr. Sawaros (Sam) Thanapornsangsuth's research interests explore how education can be a foundational tool for sustainable development. Her goal is to study and promote a lifelong and innovative learning process that enables people to develop the knowledge, values, and skills. Driven by this goal, Dr. Thanapornsangsuth has extensive fieldwork experience in informal learning settings, both in the United States and abroad. Dr. Thanapornsangsuth was a tenure-track lecturer at the Department of Education Policy, Management and Leadership, Chulalongkorn University in Thailand. She graduated with a Doctor of Education degree from the Communication, Media, and Learning Technologies Design Program at Columbia University (USA).

Postdoctoral Researcher Xin Du

Dr. Xin Du was born in 1992, Harbin, China. He received the B.E., M.S., and D.E. degrees from the Tokyo Institute of Technology in 2017, 2019, and 2022, respectively. From 2017 to 2019, he was a Research Assistant in the School of Environment and Society, Tokyo Institute of Technology. His research interests include numerical electromagnetic simulation, diffraction theory, and reconfigurable intelligent surfaces. He is a member of the IEICE and IEEE.

Recent Research Topics

■ **Radio Propagation Simulation and Channel Modeling Research**

- Enabling Channel Emulation of Device-to-Device Communication with Two Layer Grid-based Channel Emulation Technique
- Angular-Domain Parameter Matching Utilizing Clustering Technique for Grid-Based Wireless Channel Emulation
- Motion Captured Point Cloud-based Human Model for Sub-THz Radio Channel Affected by Human Body Shadowing
- Design of Passive Reflectors for Illumination of Shadowed Regions in 28 GHz
- Comparison of Monte-Carlo Physical Optics and Stochastic Kirchhoff Approximation in Application of Random Surface Scattering at Millimeter Wave Band
- Low Computational Cost Unequal Interval Mirror Kirchhoff Approximation for Predicting Shadowing Effect
- Estimation of Channel Response from Sparsely Sampled Measurements for Site-specific Wireless Emulator

■ **Applications of Radio Wave for Detection, Sensing, and Measurement**

- Development of Imaging Technology for Detecting Object Concealed by Dielectric Slab Using FMCW Radar
- Measurement of Complex Permittivity by FMCW Radar With a Small Distance Increment Method
- Tracking of the Micro-Doppler Signature of Human Gait Based on a Sequence of Estimated Doppler Frequency Differences
- Modeling and Validation Micro-Doppler Signature of a Person Falling Scenario Utilizing Wi-Fi Channel State Information
- Effects of Human Body Shadowing on 5G Millimeter Wave Propagation and Sensing of Human Movement

Takada Laboratory

Enabling Channel Emulation of Device-to-Device Communication with Two Layer Grid-based Channel Emulation Technique

(Supported by the Ministry of Internal Affairs and Communications JPJ000254)

New wireless system is expected to incorporate a huge number of wireless devices that communicate not only with the base station (BS) but also between moving devices (D2D). Compared to exhaustive tests in a real environment, wireless channel emulator (WCE) is time- and cost-efficient in synthesizing channel response in site-specific scenarios. The main challenge of WCE for synthesizing channel in site-specific scenario is the high computational complexity of deterministic propagation model (DM) with radio propagation simulation. In this work, the two-layered GBCE grid-based channel emulation technique (2L-GBCE) is presented to enable channel emulation for D2D by mitigating DM's huge computation in an offline process. Two-layer grid structures representing both transmitted and received devices are introduced with pre-computed DM path parameters between each pair of grid nodes. As depicted in the figure below, the 2L-GBCE channel could synthesize overall power delay profile similar to that produced directly from ray tracing (RT) simulation

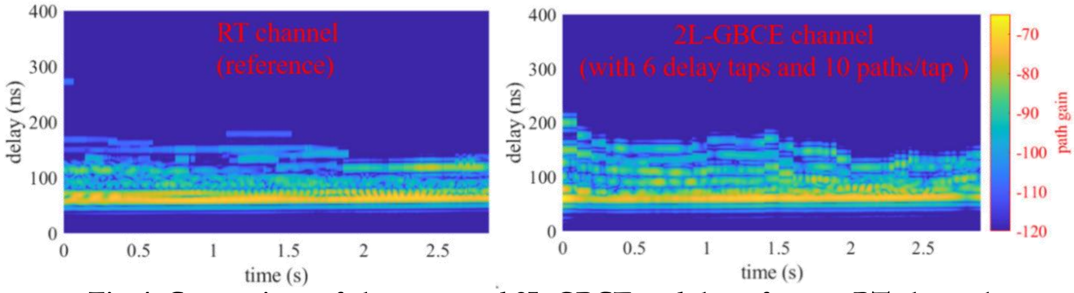


Fig. 1. Comparison of the proposed 2L-GBCE and the reference RT channels

Angular-Domain Parameter Matching Utilizing Clustering Technique for Grid-Based Wireless Channel Emulation

(Supported by the Ministry of Internal Affairs and Communications JPJ000254)

To evaluate the performance of wireless systems, the utilization of a wireless channel emulator and channel modeling is imperative. Deterministic channel modeling is accurate but computationally intensive, particularly with moving receivers (Rx). A solution is grid-based channel emulation technique (GBCE), where channel parameters at grid nodes are determined by deterministic methods such as ray-tracing (RT) simulation. The channel impulse response (CIR) for a fixed transmitter (Tx) and moving Rx is then created by interpolating path parameters from these nodes. However, as path parameters are estimated separately at each node, a parameter matching is necessary before interpolation. This study proposes a new parameter matching algorithm using a clustering approach on angular-domain parameters for path interpolation. The algorithm's effectiveness is validated by comparing the synthesized time-variant CIR and the statistical properties of the interpolated channel with the proposed parameter matching method with the RT channel as a ground truth. The result in Fig. 1 showed that the interpolated channel exhibits the similar fading characteristics with the RT. This can qualitatively assert the performance of the GBCE using proposed path matching algorithm.

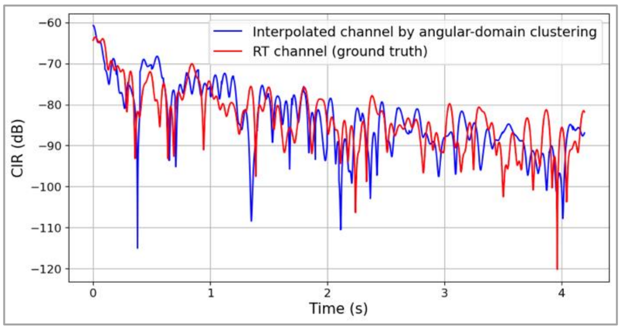


Fig. 1. Comparison of 1-tap time-variant CIR

Motion Captured Point Cloud-based Human Model for Sub-THz Radio Channel Affected by Human Body Shadowing

(Supported by the National Institute of Information and Communications Technology 02701)

Access points at sub-THz (300 GHz) band point the main beam to the line-of-sight (LoS) toward the mobile stations. However, communication relying on only LoS channel suffers from a disconnection due to human body shadowing (HBS). In this work, the vertical screen and human body-shaped screen based on the captured point cloud (PC) of the human body has been developed as the human model to predict the impact due to HBS. To validate the PC-based human models, synchronized measurement of dynamic channel and motion capture was conducted in the corridor scenario. The comparison results between the measurement and the simulation show that the proposals simulate the time of the HBS caused disconnection well. The proposals provide reliable simulation for developing resilient networking techniques.

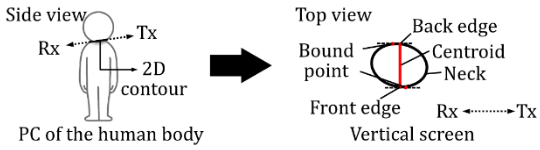


Fig.1. PC-based 2D screen model

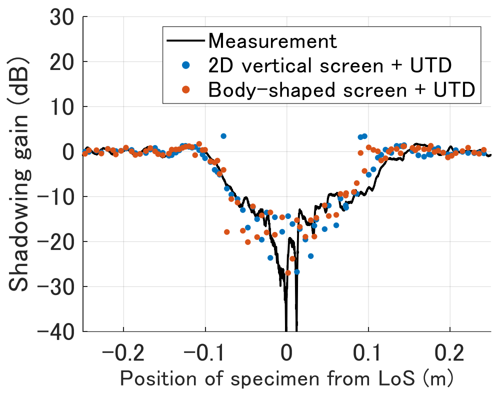
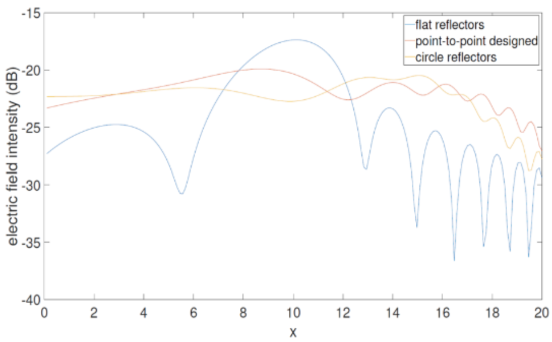


Fig. 2. Comparison of the HBS measurement and simulations

Design of Passive Reflectors for Illumination of Shadowed Regions in 28 GHz

(Supported by the National Institute of Information and Communications Technology 02701 and JSPS KAKENHI 23K22753)

The basic technical challenges to offer services at the mm-wave frequency are the very high propagation losses in free space and shadowing effect. One economic way to slove the problem is by using passive reflectors, because they do not need energy supply. However, traditional reflectors such as flat and spherical reflectors suffer from the small coverage area problem. Therefore, it is necessary to design the reflector and enlarge the coverage area. In this research, one method to design the reflectors only depend on the position of antenna and ground was proposed, which called point-to-point design. The basic idea is a is dividing the reflector and the ground into small enough part and assign each part of reflector correspond to one part in the area. For each part, the reflected wave point at the center of the ground it was assigned. As the result, each part of the reflector have almost the same size and it will cover the ground with equal size. The electric field density in certain area was simulated by using the method. The result in 28 Ghz is s shown in Fig.1. For point-to-point designed reflector, the variance of the energy distribution is smallest, which means it have more uniform energy distribution in certain area and larger coverage area.



Type of reflector	Variance of the energy distribution
flat	19.73
cylindrical	2.71
point-to-point designed	1.73

Takada Laboratory

Development of Imaging Technology for Detecting Object Concealed by Dielectric Slab Using FMCW Radar

(Supported by Suematsu award, Tokyo Institute of Technology)

Since radar is compact and radio waves can penetrate shielding, it is attracting attention as a new method of non-destructive testing. In this research, the effectiveness of FMCW radar in detecting objects hidden in dielectric slabs was verified. First, Hybrid Physical Optics and Geometrical Optics (HPGO) approximation was developed to simulate the wave propagation of radar signals through a dielectric slab. Second, using Synthetic Aperture Radar (SAR) theory, the distribution of reflection intensity was obtained from the received signal. Third, an imaging experiment system using FMCW radar was developed to verify the consistency between simulation and experiment. As a result, the location and characteristics of shielded objects were estimated from the signals obtained after radar scanning in both simulation and experiment. Thus, the usefulness of the developed non-destructive detection technique was demonstrated.

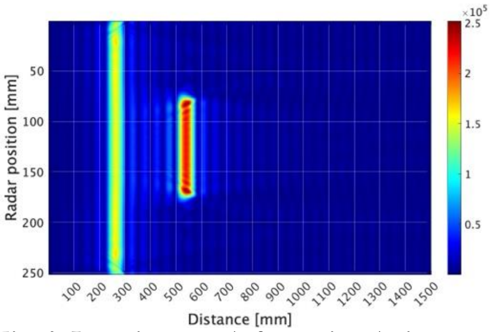


Fig. 1. Imaging result from simulation

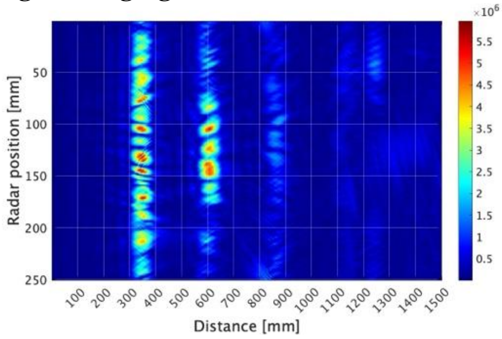


Fig. 2. Imaging result from experiment

Measurement of Complex Permittivity by FMCW Radar With a Small Distance Increment Method

(Supported by Suematsu award, Tokyo Institute of Technology)

Measuring the complex permittivity of material can be utilized for many applications such as the quality inspection, component analysis, security check. Conventionally, the measurement of complex permittivity can be carried out with approaches such as resonant method, waveguide method, and open-space method. However, the vector network analyzer (VNA) is required to conduct the measurement. In order to achieve the portability and easy accessibility, utilizing FMCW radar for permittivity measurement was proposed (Fig. 1). The radar is placed perpendicularly to the material surface at a certain distance. Then, To derive the relationship between the reflection coefficient with the complex permittivity, the planar wave propagation is considered. A small distance increment (SDI) method is proposed to non-destructively measure the complex permittivity of material. The evaluation was carried out on the acrylic plate. With the proposed method, the estimated complex permittivity of acrylic plate shows good agreement with the literature values (Fig. 2), demonstrating the efficacy of SDI method for characterizing the complex permittivity of material with FMCW radar.

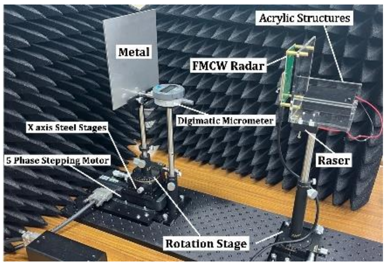


Fig. 1. Measurement system

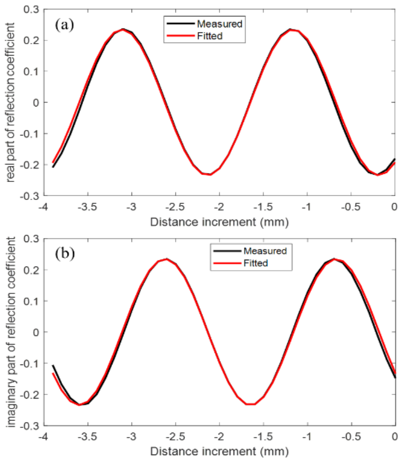


Fig. 2. Measured and fitted results

Tracking of the Micro-Doppler Signature of Human Gait Based on a Sequence of Estimated Doppler Frequency Differences

Human motion capture (HCM) involves capturing human movement and one notable focus is on motion capture using micro-Doppler signatures through Wi-Fi sensing due to its broad applications and advantages. The micro-Doppler signature refers to frequency changes resulting from micro-scale motion or the structure of individual targets. This study aims to explore micro-Doppler signature intra-segment tracking based on a sequence of estimated Doppler frequency differences. Channel state information (CSI) simulated from the Boulic human walking model serves as input for this investigation. The micro-Doppler frequency, extracted from CSI, is estimated using 1-D block processing based on state-space identification. The estimated Doppler frequency is then tracked by considering the differences in estimated Doppler frequencies to gain insights into how the frequency has changed. Overall, the proposed tracking method demonstrates success in aligning with the Doppler frequency of individual human body components. However, certain limitations exist due to variations in the detected number of human body components.

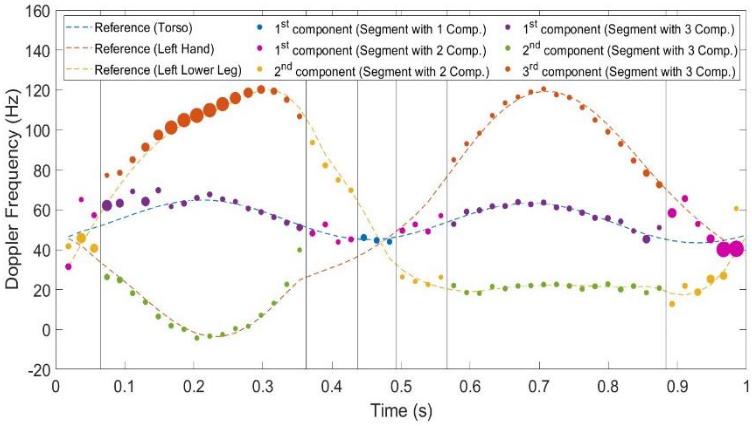


Fig. 1. Result of micro-Doppler signature intra-segment tracking

Modeling and Validation Micro-Doppler Signature of a Person Falling Scenario Utilizing Wi-Fi Channel State Information

Intelligent detection of falling incidents increasingly becomes important for medical care among the elderly in the growing aging population. Accurate modeling of micro-Doppler signature during a fall event enables us to synthesize bigdata set for training the effective falling detection system without relying on the cost- and time-inefficient measurement. In this work, the deterministic micro-Doppler channel model is presented based on a combination of radar cross-section (RCS) scattering and spheroid human models for the falling incident. The measurement system that consists of the Wi-Fi-based channel sounder and the Kinect motion capture system is utilized to simultaneously acquire measured channel state information (CSI) and human skeletal data, respectively. The CSI measurement is conducted at 5.32 GHz and the performance of the proposed model with the captured skeletal is investigated via comparison of the time-variant Doppler spectrum. As depicted in figure, the majority of the micro-Doppler components could be reproduced by the simulated model. However, discrepancy in terms of Doppler power is observed. Further investigation is needed to verify the source of the discrepancy and thus improve the performance of the model.

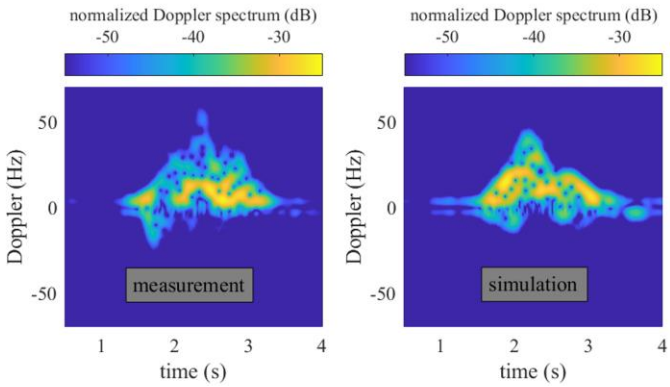


Fig. 1. Comparison of simulated micro-Doppler signature during a falling incident

Takada Laboratory

Comparison of Monte-Carlo Physical Optics and Stochastic Kirchhoff Approximation in Application of Random Surface Scattering at Millimeter Wave Band

With the application of millimeter wave radio in telecommunication, subtle structures of obstacles will gradually affect the scattering pattern due to the wavelength decrease. In future telecommunication systems, it is imperative to conduct electromagnetic wave propagation analysis of millimeter-wave channels involving rough surface reflections. This study compares two high-frequency approximation analysis methods suitable for millimeter-wave propagation, deterministic Physical Optics with Monte-Carlo process and the stochastic Kirchhoff Approximaion. This study compares the simulation results of two different methods for various characteristic rough surfaces through theoretical analysis and numerical simulations. Additionally, based on the stochastic KA method, the Rayleigh and Rice channel models of the scattering field are derived from the perspective of electromagnetic wave propagation.

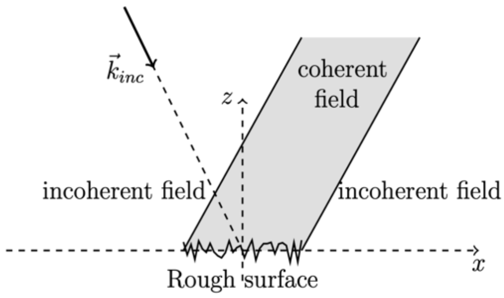


Fig. 1. Backward Scattering Field

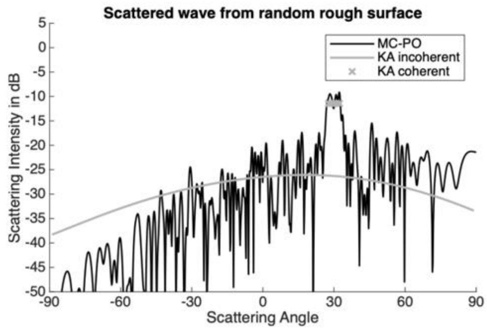


Fig. 2. Scattering Field Intensity

Low Computational Cost Unequal Interval Mirror Kirchhoff Approximation for Predicting Shadowing Effect

(Supported by the National Institute of Information and Communications Technology 02701)

The shadowing effect of the forward scattering problem plays a crucial role in influencing the performance of cellphone links. Recently, the mirror Kirchhoff approximation (MKA) is proposed for predicting the forward scattering problem. Conventional MKA utilizes equal length rectangular which is used to approximate the shape of the scattering. However, unequal length rectangular can reduce computational time. In this research, we propose an unequal interval MKA method which is based on the curvature of the scattering to reduce computational time. Specifically, the length of rectangular is large in the part of scattering which cuverature is small and the length of rectangular is small in the part of scattering which cuverature is large. Simulation results show that the unequal MKA method reduced the computation time by changing the length of the rectangular which is computed by the slope of the scattering object in different segmented intervals without sacrificing much computational accuracy.

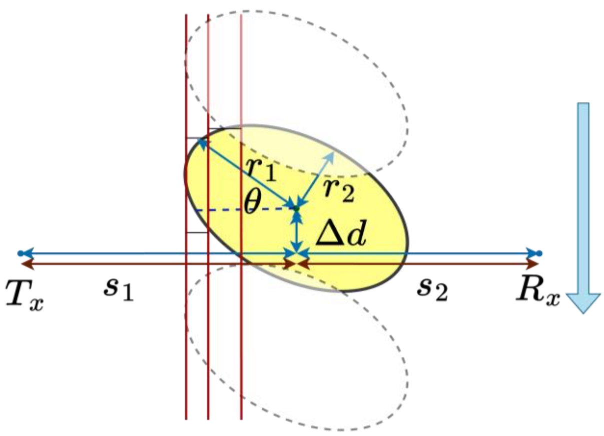


Fig. 1. Simulation scenario

Estimation of Channel Response from Sparsely Sampled Measurements for Site-specific Wireless Emulator

(Supported by the Ministry of Internal Affairs and Communications JPJ000254)

For site-specific wireless emulators, channel responses must be found at every point in space. However, in practice, measurement can only be done at sparse locations, thus, interpolation of channel response is needed. In this work, channel responses measured from antenna arrays at three locations in space are used to interpolate the channel responses for locations inside the triangle made by these vertices. It is done firstly by calculating the discrete angular power spectrum at each vertex, then interpolating these angular powers in a per-angle basis. For validation, measurement data is used, channel responses from the three red vertices are used to interpolate those at the green dots (Fig. 1). The comparison of Spatial Doppler between the measurement and the interpolation shows good interpolation performance (Fig. 2).

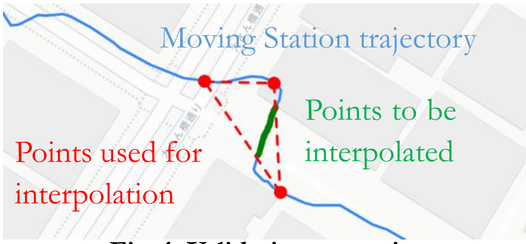


Fig. 1. Validation scenario

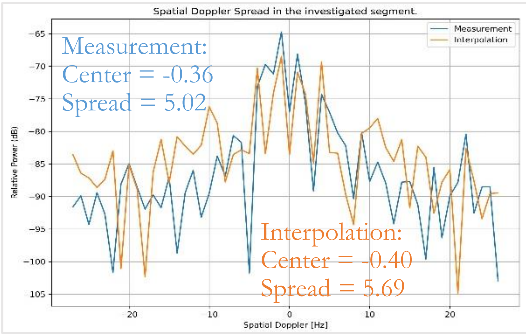


Fig. 2. Comparison of Spatial Doppler between measurement and interpolation

Effects of Human Body Shadowing on Millimeter Wave Propagation and Sensing of Human Movement

The adoption of millimeter waves, characterized by their shorter wavelengths, plays a fundamental role in addressing these needs due to their capability to offer higher data rates and broader bandwidth. However, these signals are notably susceptible to obstructions, such as the human body, which can significantly influence signal propagation.

Given the critical impact of human obstruction on signal transmission, this study aims to explore the shadowing effect induced by the human body on millimeter wave propagation. To achieve this, the research focuses on evaluating signal behavior in unobstructed environments and comparing it with scenarios where signals encounter human obstacles. The objective is to quantify the attenuation caused by human shadowing on signal transmission. The measurement setup was built with a transmitter in 25 GHz band and a spectrum analyzer. Measurements show a decline in signal strength as more people pass between them. This suggests a relationship between signal strength and people moving, indicating that changes in signal strength could potentially be used for human sensing.

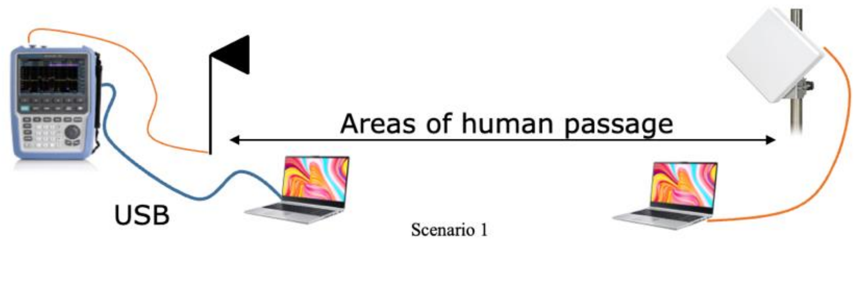


Fig. 1. Measurement design diagram

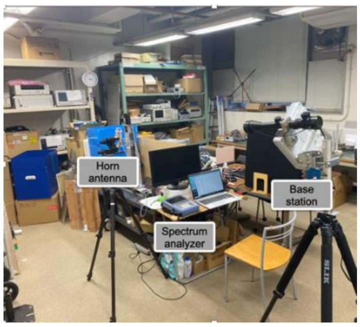


Fig. 2. Measurement scenario

Sakaguchi-Tran Laboratory

Professor Kei Sakaguchi

Prof. Kei Sakaguchi received the M.E. degree in Information Processing from Tokyo Institute Technology in 1998, and the Ph.D degree in Electrical & Electronics Engineering from Tokyo Institute Technology in 2006. Currently, he is working at Tokyo Institute of Technology in Japan as a Dean in Tokyo Tech Academy for Super Smart Society and as a Professor in School of Engineering. At the same time, he is working for oRo, Co.,Ltd. in Japan as an outside director. He received the Outstanding Paper Awards from SDR Forum and IEICE in 2004 and 2005 respectively, and three Best Paper Awards from IEICE communication society in 2012, 2013, and 2015. He also received the Tutorial Paper Award from IEICE communication society in 2006. His current research interests are in 5G cellular networks, millimeter-wave communications, wireless energy transmission, V2X for automated driving, and super smart society. He is a fellow of IEICE, and a member of IEEE.

Associate Professor Gia Khanh Tran

Assoc. Prof. Gia Khanh Tran was born in Hanoi, Vietnam, on February 18, 1982. He received the B.E., M.E. and D.E. degrees in electrical and electronic engineering from Tokyo Institute of Technology, Japan, in 2006, 2008 and 2010 respectively. He became a faculty member of the Department of Electrical and Electronic Engineering, Tokyo Institute of Technology since 2012, and now he is working as Associate Professor. He received IEEE VTS Japan 2006 Young Researcher's Encouragement Award from IEEE VTS Japan Chapter in 2006 and the Best Paper Awards in Software Radio from IEICE SR technical committee in 2009 and 2012. His research interests are MIMO transmission algorithms, multiuser MIMO, MIMO mesh network, wireless power transmission, cooperative cellular networks, sensor networks, digital predistortion RF and mm-waves. He is a member of IEEE and IEICE.

Emeritus Professor Kiyomichi Araki

Emeritus Prof. Kiyomichi Araki was born in 1949. He received the B.S. degree in electrical engineering from Saitama University, in 1971, and the M.S. and Ph.D. degrees in physical electronics both from Tokyo Institute of Technology in 1973 and 1978 respectively. In 1973-1975, and 1978-1985, he was a Research Associate at Tokyo Institute of Technology, and in 1985-1995 he was an Associate Professor at Saitama University. In 1979-1980 and 1993-1994 he was a visiting research scholar at University of Texas, Austin and University of Illinois, Urbana, respectively. From 1995 to 2014 he was a Professor at Tokyo Institute of Technology. His research interests are in information security, coding theory, communication theory, ferrite devices, RF circuit theory, electromagnetic theory, software defined radio, array signal processing, UWB technologies, wireless channel modeling and so on. Prof. Araki is a member of IEEE, IEE of Japan, Information Society of Japan and fellow of IEICE.

Specially Appointed Associate Professor Tao YU

Specially Appointed Assoc. Prof. Tao Yu received his M.E. degree from the Communication University of China (CUC), Beijing, China in 2010, and the Dr.Eng. degree from the Tokyo Institute of Technology (Tokyo Tech), Tokyo, Japan in 2017. From 2014 to 2015, he was a visiting student in Osaka University. From 2017 to 2022, he worked as a postdoctoral researcher in Sakaguchi Lab, Dept. Electr. Electron. Eng., Tokyo Tech. From 2022, he joined the Tokyo Tech Academy for Super Smart Society where he is working as a specially appointed associate professor. His research interests include UAV communication, V2X, sensor networks, localization, antenna, smart mobility, and building energy management. He is member of IEEE and IEICE.

Assistant Professor Zongdian Li

Assist. Prof. Zongdian Li was born in Yunnan, China, in 1996. He received the B.E. degree in communication engineering from Beijing University of Posts and Telecommunications (BUPT), Beijing, China, in 2018, and the M.E. and Ph.D. degrees in electrical and electronic engineering from Tokyo Institute of Technology (Tokyo Tech), Tokyo, Japan, in 2020 and 2023, respectively. Since October 2023, he has been an Assistant Professor with the Department of Electrical and Electronic Engineering, School of Engineering, Tokyo Tech. His research interests include software-defined networking (SDN), vehicle-to-everything (V2X) communications, digital twins, and autonomous driving. He is a member of IEEE and IEICE.

Tokyo Tech Beyond 5G Cellular Networks

MmWave coverage expansion by Repeaters

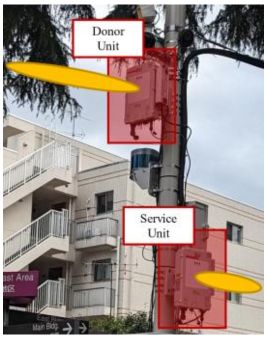


Fig. 1 mmWave repeater units

The millimeter wave (mmWave) band is expected to be a key technology for high-speed, large-capacity communications in the 5G generation and beyond due to its wide bandwidth capability and has already begun to be utilized. However, mmWave operates at a higher frequency band compared to conventional ones, which presents challenges such as increased propagation loss and straightness. These issues result in narrower coverage at individual base stations. Therefore, as a solution to the mmWave coverage problem, we have been evaluating the performance of mmWave repeaters using the 5G environment we have built on the Ookayama campus. In this fiscal year, we have permanently installed mmWave repeaters (Fig. 1) and have been building an environment that enables high-speed use of applications specialized for the Tokyo Tech Beyond 5G (B5G) PoC field in a wider area. As shown in Fig. 2, the LOS area covered by the repeater realizes high-speed data transmissions.

Fig. 2 DL throughput measurement result (LoS-Area, w/ repeater)

MEC/RSU-empowered AR system for Improving Traffic Safety

We have been working on the implementation of a digital twin utilizing multiple roadside units (RSUs) installed at the Ookayama Campus. The RSU is equipped with LiDAR, cameras, and edge computers. In this fiscal year, we built and implemented an AR application that detects vehicles, predicts collisions, and visualizes them as an effort to improve traffic safety by utilizing this digital twin (Fig. 3). The server-side system of this application runs on the MEC built on the B5G PoC field at Tokyo Tech, so data can be sent and received between user equipment (UE) and the server via the MQTT protocol with low latency, making it a highly real-time application.

(a) (b) (c)

Fig. 3 PoC results of AR-based collision-avoidance application. Fig. (a) displays the car-detection alert, fig. (b) presents the car location as AR objects, and fig. (c) indicates the alert suggesting the user

MIMO system

Multi-user mmWave Massive Relay MIMO System with User Scheduling

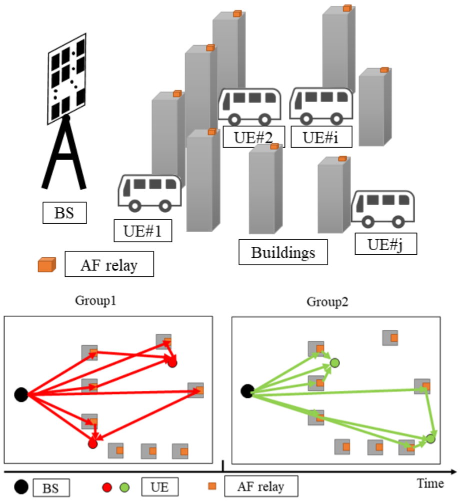


Fig. 4 System model

We proposed a system that explores the potential of using relay stations towards 6G, offering a possibility of addressing the challenges such as limited coverage associated with the next generation of wireless networks. Fig. 4 shows the system model for the multi-user MIMO communication system with user scheduling. This system includes one base station with mmWave antenna, a massive number of AF relay stations (RS), and several users (UE). In addition, we proposed a user scheduling method to divide users with less interference into different groups to improve resource utilization. In the same group, data is transmitted and received from base stations to multiple users by using spatial multiplexing techniques among multiple antennas at the same time and frequency resource. In numerical simulation (Fig.5), it showed that massive relay MIMO system can enlarge the coverage and enhance the channel capacity. Furthermore, user scheduling can group users with less interference and improve the system throughput.

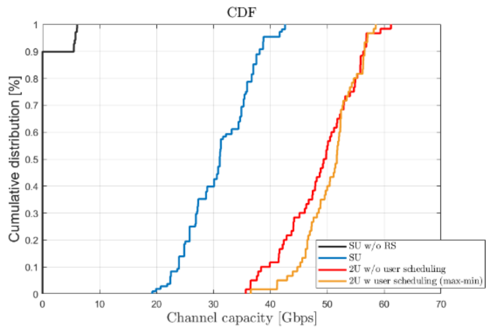


Fig. 5 System model

Highly reliable mmWave communications in blockage environment

While the broad bandwidth of the millimeter-wave band enables high datarate, its susceptibility to path blockage reduces system reliability. To construct a reliable system even in a blockage environment, a system that combines multi-beam communication and fountain code-based cross-layer coding is proposed (Fig. 6). The proposed system assumes a vehicle equipped with multi-element antennas and performs multi-beam transmission utilizing both LoS and NLoS waves. By using cross-layered codes that combine packet-level loss correction codes and bit-level bit error correction codes as error correction codes, packet loss caused by blocking and decoding errors, which are problems in the millimeter wave band, can be corrected by loss correction codes, making retransmissions of lost packets unnecessary. This eliminates the need for retransmission of lost packets. In addition, by combining cross-layered codes with multi-beam transmission, even if some beams are blocked, the original data can be decoded from the data transmitted on the unblocked beams, thus creating a system that is robust against blockage.

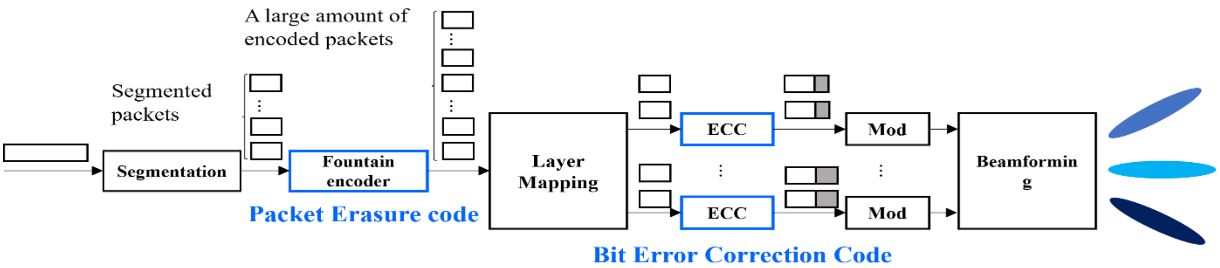


Fig. 6 Transceiver architecture

Sakaguchi-Tran Laboratory

Smart Mobility Digital Twin for Autonomous Driving

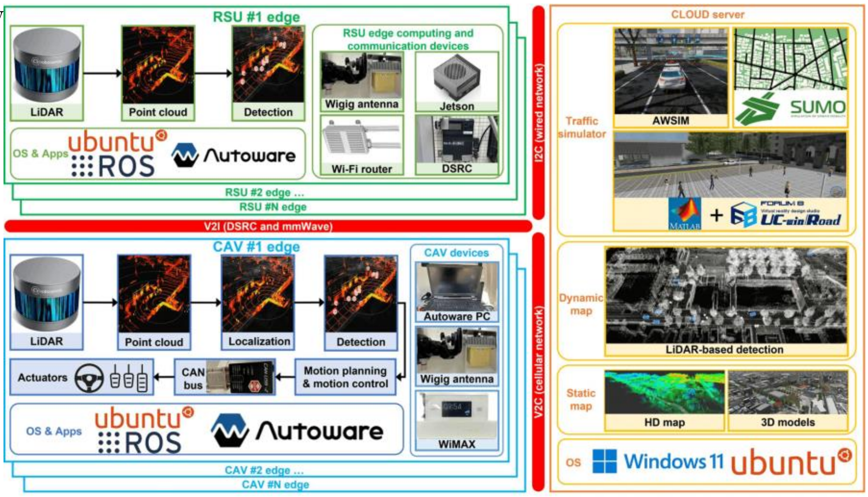


Fig. 7 System architecture of Smart Mobility R&E Field

Based on the Smart Mobility R&E Field (Fig. 7), Sakaguchi-Tran Lab establishes a new smart mobility DT (SMDT) platform for the control of connected and automated vehicles (CAVs) over next-generation wireless networks. In particular, the proposed platform enables cloud services to leverage the abilities of DTs to promote the autonomous driving experience. To enhance traffic efficiency and road safety measures, a novel navigation system that exploits available DT information is designed. The SMDT platform and navigation system are implemented with state-of-the-art products, e.g., CAVs and roadside units (RSUs), and emerging technologies, e.g., cloud and cellular V2X (C-V2X). In addition, proof-of-concept (PoC) experiments are conducted to validate system performance. The performance of SMDT is evaluated from two standpoints: (i) the rewards of the proposed navigation system on traffic efficiency and safety and, (ii) the latency and reliability of the SMDT platform. Our experimental results using SUMO-based large-scale traffic simulations show that the proposed SMDT can reduce the average travel time and the blocking probability due to unexpected traffic incidents. Furthermore, the results record a peak overall latency for DT modeling and route planning services to be 155.15 ms and 810.59 ms, respectively, which validates that our proposed design aligns with the 3GPP requirements for emerging V2X use cases and fulfills the targets of the proposed design. Our demonstration video can be found at https://youtu.be/3waQwlaHQkk.

Real-time Digital Twin Application

We implemented a V2X-enabled real-time digital twin application to realize the cooperative autonomous driving system. In this cyberspace, dynamic information regarding vehicles, pedestrians, and bicycles is recreated based on object detection from the distributed sensors in our campus. The real-time digital twin with the negligible gap between physical space and cyberspace facilitates the real-time optimization of the entire mobility system.

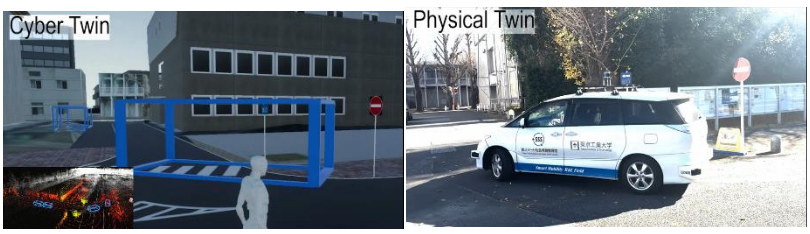


Fig. 8 Cyber-physical synchronization

Smart Mobility application for collision avoidance

Regarding a new intersection system that incorporates a collision avoidance system, we demonstrated the efficiency improvement through simulation and the feasibility of the system using a real machine and emulation. Furthermore, by using machine learning to predict the movement of objects used in collision avoidance systems, we achieved more accurate predictions than conventional methods.

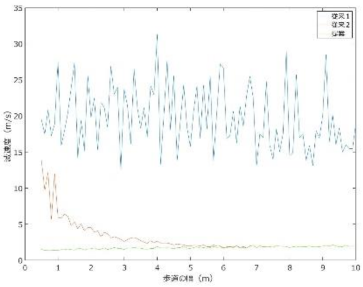


Fig. 9 Simulation

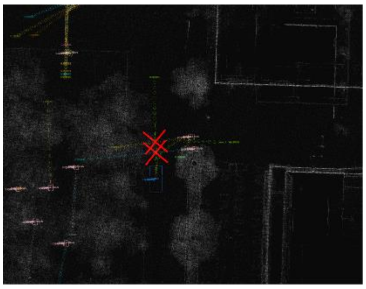


Fig. 10 Collision prediction

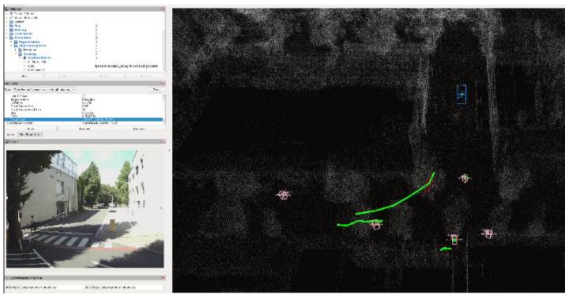


Fig. 11 Movement prediction with machine learning

IoFDT(Internet of Federated Digital Twin) Platform

We built a platform to share the information accumulated by the digital twin to different digital twins and users. We studied the requirements for the platform, designed the architecture, and implemented it. In addition, we ran an application on the platform and confirmed its effectiveness.

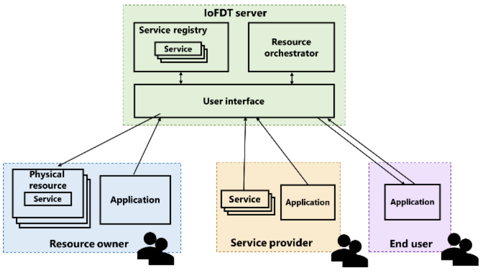


Fig. 12 Architecture

Fig. 13 Demonstration of platform with AR application

Interference control based on coloring mechanism for 802.11ax compliant wireless LAN systems

Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) is used as a collision avoidance protocol in WLANs. However, since CSMA/CA is not specified for each wireless AP (Access Point), if the UE terminal receives a radio wave on the same channel from another nearby wireless AP, the communication with the desired AP may be suppressed, that reduces the spectral usage efficiency. In response to this problem, Wi-Fi6 provides the Basic Service Set (BSS) color space reuse technique. This technique is expected to improve system performance and spectrum resource utilization in densely deployed environments, since it allows multiple wireless APs to cover an area with minimal contention. We designed a system of interference control based on the ratio of the BSS coloring to the BSS coloring, and clarified situations in which the BSS coloring functions effectively through simulations and empirical experiments.

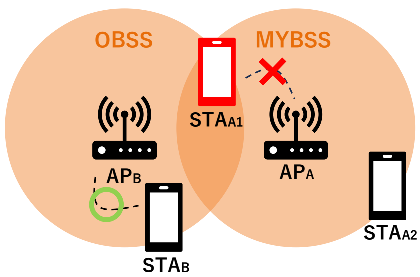


Fig. 14 CSMA/CA

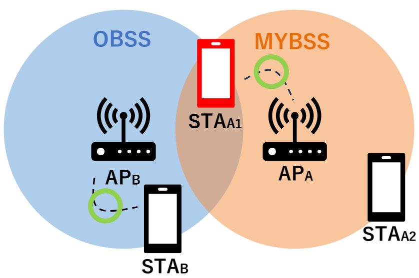


Fig. 15 BSS Coloring

Sakaguchi-Tran Laboratory

Estimation using HAPS

In recent years, there has been an increase in the number of illegal radio stations that use radio waves with power exceeding the limits or on illegal frequencies. Today, a radio monitoring system called the DEURAS system exists to crack down on them. However, the system may not work well if the illegal radio stations have no line of sight or generate a lot of reflected waves, depending on the surrounding environment. To solve this problem, we proposed a radio wave source estimation system using HAPS, an unmanned aerial vehicle flying at high altitude. We have succeeded in obtaining highly accurate position estimation using only one HAPS and are still working to improve it.

Fig. 16 Estimation using a HAPS

Estimation using UAVs

Recently, there has been an increasing trend in illegal radio transmissions, posing a serious risk of significant radio interference with legitimate transmissions. This study aims to estimate the positions of radio transmitters, using UAVs as receiving antennas. Compared to the DEURAS method using fixed sensors, UAVs can ensure line-of-sight with the transmitter by adjusting their flight paths, allowing for precise position estimation. We found that utilizing AOA (Angle of Arrival) instead of RSSI (Received Signal Strength Indication) for radio information further enhances estimation accuracy with multiple.

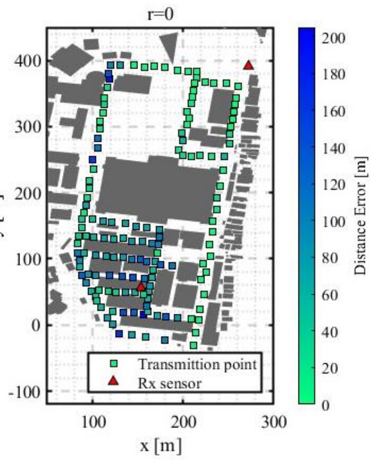


Fig. 17 Estimation using UAVs

Estimation using LEO and WLAN signal

Japan has repeatedly suffered from damages caused by earthquakes. Furthermore, it is said that there is a 90% probability of a disaster occurring within the next 40 years that will surpass the scale of the Great East Japan Earthquake, known as the Nankai Trough. Establishing defense measures against such imminent large-scale disasters is an urgent task. Rapid rescue efforts are crucial when a disaster strikes. However, both material and human resources for rescue are limited. Therefore, if it is possible to estimate the population within the affected area, it would be beneficial for allocating appropriate resources based on the number of victims seeking aid. This can potentially facilitate and accelerate rescue operations, leading to a reduction in casualties. In this research, we proposed the feasibility of a population estimation method using Low Earth Orbit (LEO) and WLAN signals emitters from smartphone users located inside the disaster area. We are still improving simulation to show the potential feasibility of our proposed system.

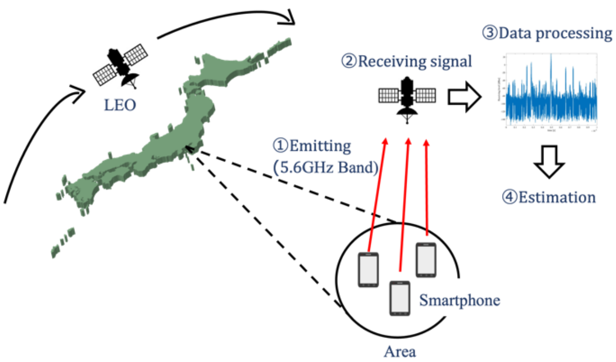


Fig. 18 Estimation using LEO and WLAN signal

Construction of a UAV Base Station Network

System Architecture

When disasters occur, wireless communication may become unavailable, necessitating the establishment of high-capacity temporary networks. We proposed the construction of a UAV-BS network. The network operates by relaying radio waves from the base stations through backhaul UAVs and access UAVs, enabling communication to end-user devices.

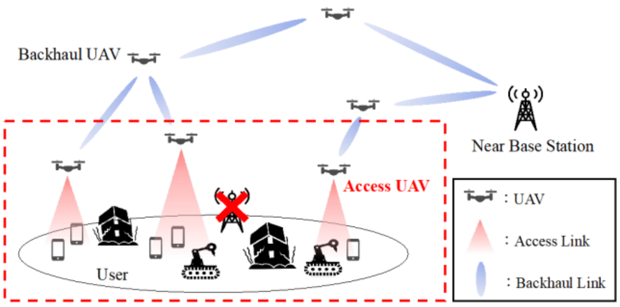


Fig. 19 Overall Architecture of the UAV-BS network

Numerical Analysis Using Demonstration Experiment Data

Beamforming technology is required in this system, but the UAV's position may shift due to wind, position correction etc. Therefore, a numerical analysis model was created based on demonstration experiment data to confirm the effects of positional errors. In this way, the factors that must be considered in a millimeter-wave UAV network are examined using a numerical analysis model based on demonstration experiment data.

IRS Integration to UAV-BS Networks for Coverage Extension

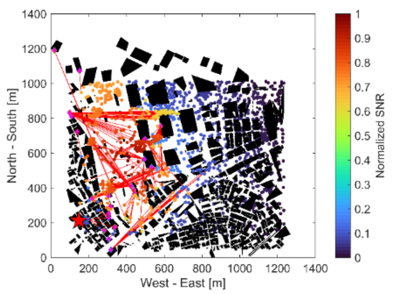


Fig. 20 IRS-UE pairing for SNR improvement

To transmit detailed damage information to victims and rescue workers, access UAVs should be capable of high-capacity communications to all UEs. mmWave has the potential for it due to wide bandwidth but suffers from severe propagation attenuation due to blocking. Therefore, we considered reflecting and delivering radio waves by IRS, and then created a virtual LoS for improvement the received SNR even for UEs with NLoS.

Trajectory Optimization for UAV-Based Data Collection

UAVs with high mobility is suitable for data collection when the base stations are unavailable. To minimize the completion time of data collection through UAV trajectory optimization, we proposed a 3-Dimentional UAV trajectory considering the flight altitude. The coverage area of each hovering point is optimized according to the distribution of UEs and is realized by adjustment of the flight altitude.

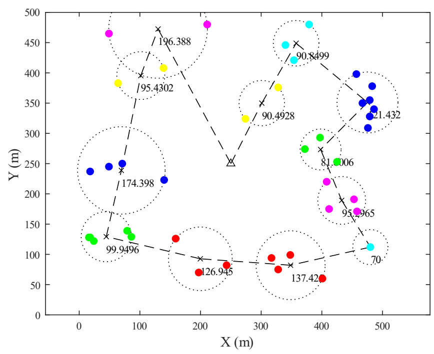


Fig. 21 Proposed 3-D UAV Trajectory

Hirokawa-Tomura Laboratory

Home page: http://www-antenna.ee.titech.ac.jp

Professor Jiro Hirokawa

received the B.S., M.S. and D.E. degrees in electrical and electronic engineering from Tokyo Institute of Technology (Tokyo Tech), Tokyo, Japan in 1988, 1990 and 1994, respectively. He was a Research Associate from 1990 to 1996 and an Associate Professor from 1996 to 2015 at Tokyo Tech. He is currently a Professor there. He was with the antenna group of Chalmers University of Technology, Gothenburg, Sweden, as a Postdoctoral Fellow from 1994 to 1995. His research area has been in slotted waveguide array antennas and millimeter-wave antennas.

He received IEEE AP-S Tokyo Chapter Young Engineer Award in 1991, Young Engineer Award from IEICE in 1996, Tokyo Tech Award for Challenging Research in 2003, Young Scientists' Prize from the Minister of Education, Cultures, Sports, Science and Technology in Japan in 2005, Best Paper Award in 2007 and a Best Letter Award in 2009 from IEICE Communications Society, and IEICE Best Paper Award in 2016 and 2018. He is a Fellow of IEEE and IEICE.

Assistant Professor Takashi Tomura

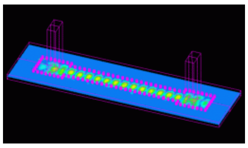
received the B.S., M.S. and D.E. degrees in electrical and electronic engineering from the Tokyo Institute of Technology, Tokyo, Japan, in 2008, 2011 and 2014, respectively. He was a Research Fellow of the Japan Society for the Promotion of Science (JSPS) in 2013. From 2014 to 2017, he worked at Mitsubishi Electric Corporation, Tokyo and was engaged in research and development of aperture antennas for satellite communications and radar systems. From 2017 to 2019, He was a Specially Appointed Assistant Professor at the Tokyo Institute of Technology, Tokyo. He is currently an Assistant Professor there. His research interests include electromagnetic analysis, aperture antennas and planar waveguide slot array antennas.

Dr. Tomura received the Best Student Award from Ericsson Japan in 2012 and the IEEE AP-S Tokyo Chapter Young Engineer Award in 2015 and Young Researcher Award from IEICE technical committee on antennas and propagation in 2018. He is a member of IEEE and IEICE.

Our Research Interests

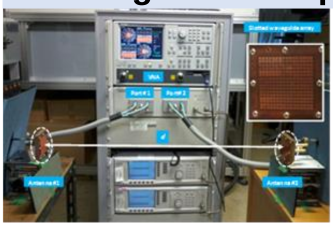
Hirokawa laboratory have researched antennas, feeding circuits, electromagnetic analysis theory and wireless communication systems. Main target frequency band is millimeter wave band and higher band such as 120 GHz and 350 GHz. The features of our antennas are planar, high gain, high efficiency and wide bandwidth, which have been realized by new fabrication method such as diffusion bonding of thin laminated metal plates and 3d-printer. Not only components but also wireless communication system has been studied such as 60-GHz band gigabit access transponder equipment (GATE) and rectangular coordinate orthogonal multiplexing (ROM), a multiplex communication system.

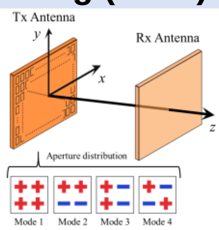
Post-wall waveguide



- Known as Substrate Integrated Waveguide (SIW)
- Published in the IEEE transaction in 1998 (Total citation: 308, Web of Science, 2017/6)
- Used as microwave and millimeter-wave band low-loss waveguide

Rectangular coordinate orthogonal multiplexing (ROM)

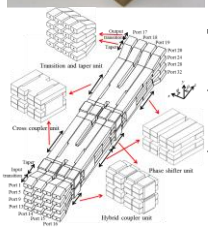




- Published in the IEEE transaction in 2017
- Equivalent to OAM transmission in the optical communication system, and apply to microwave and millimeter-wave applications

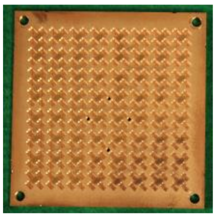
2-D beam-switching one-body Butler matrix

- Published in the IEEE transaction in 2016.
- Combined E and H-plane short-slot coupler into one body.
- Components of the Butler matrix (Hybrid and Cross coupler)

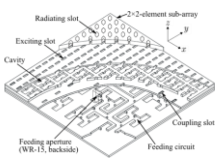


- $4^2 \times 4^2$-way one-body 2-D beam-switching waveguide Butler matrix
- Reduced its length and conduction losses by half.
- Reduced the number of components and volume.

Corporate-feed Slot Array Antenna with Plate-laminated Waveguide

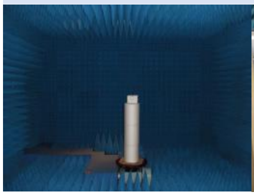


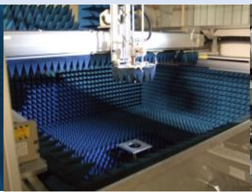
- Published in the IEEE transaction in 2011.
- After that, research is also started in Sweden, Singapore, China, etc.
- Designed in various frequency bands like 38-GHz band, 60-GHz band, and 120-GHz band, etc.



✓ Large number of elements
⇒ High gain
✓ Made with metal only
⇒ High efficiency
✓ Composed of the corporate-feed circuit
⇒ Wide band

Measurement Facility


Anechoic Chamber


Near Field Measurement


Vector Network Analyzer

- Antennas are made and measured in the practically used frequency band.
- Specialized to planar antenna.(by 110GHz)

○Anechoic Chamber : Gain, Radiation Pattern
○Near Field Measurement :
Aperture Distribution (AM, PH)
Directivity, Radiation Pattern
○Network Analyzer : Reflection

Hirokawa-Tomura Laboratory

Design of Best Assignment for Post-wall 1-D Parallel Switching Matrices with Five Beams

In order to overcome some shortcomings of conventional switching matrices, general configurations of 1-D parallel switching matrices with an arbitrary number of beams have been proposed [1]. For the general configurations, the number of beams can be arbitrary, and the imbalance among outputs can be reduced due to the similar number of beams and number of layers from input ports to output ports.

The original block diagram and the compensated block diagram of the general configuration with five beams are shown in Fig. 1. The original structure is composed of ten couplers and ten phase shifters. There are 120 phase difference assignments. A total of 19 different couplers having different transmission phases are used in these 120 assignments. The phase shifters and the straight waveguides need to be adjusted according to the transmission phases of the couplers so that the compensated block diagram can be obtained. The phase shifters in blue colors are long phase shifters having two-layer length. The others are all short phase shifters having one-layer length. Phase difference from straight waveguide is defined as the difference between the transmission phase of a straight waveguide and the value of phase shift. A smaller phase difference can make the phase shift easier to achieve. Therefore, the best assignment is selected by choosing the assignment having the smallest absolute sum of phase differences from straight waveguide. The best assignment uses six types of couplers having θ values of 0.176π, 0.250π, 0.309π, 0.314π, 0.328π, and 0.346π. It has the smallest sum of 420.29°, which should lead to the widest bandwidth among 120 assignments. Fig. 2 shows the realized structure of the configuration. The configuration is realized by post-walls over the frequency band from 20 GHz to 24 GHz, and uses a PTFE substrate, which has a thickness of 3.2 mm and a dielectric constant of 2.17.

According to the simulation results, the bandwidth of reflection less than -10 dB for five input ports is more than 17.82%, 18.18%, 16.18%, 15.55%, and 17.73%, respectively. The average phase differences between adjacent output ports at the center frequency are $-69.47°$, $-141.58°$, 146.58°, 72.67°, and 0.19°, compared with the theoretical values of $-72°$, $-144°$, 144°, 72°, and 0°.

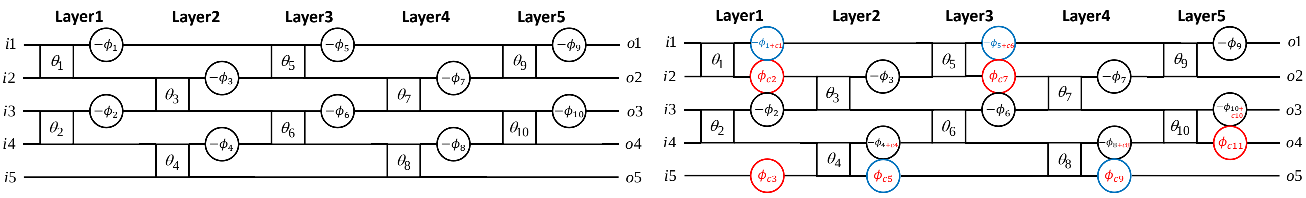


Fig. 1. Original Block Diagram and Compensated Block Diagram

Fig. 2. Realized Structure of Matrix

Reference

[1] J. Hirokawa and N. J. G. Fonseca, "Generalized one-dimensional parallel switching matrices with an arbitrary number of beams," *IEEE J. Microw.*, vol. 1, no. 4, pp. 975–988, Oct. 2021. DOI: 10.1109/JMW.2021.3106871

Design of post-wall waveguide stacked E-plane cruciform cross couplers for 120-GHz band

A waveguide two-dimensional beam switching integrated Butler matrix has been proposed as a power supply circuit for beamforming. The two-dimensional integrated Butler matrix has input and output ports arranged two-dimensionally, and can scan the emitted beam two-dimensionally by switching the input ports to excite. In addition to being able to form multiple beams at the same time, it has the advantage of low loss due to its waveguide structure.

Figure 1 shows the structure of the coupler. As shown in figure (c), three waveguides with the tube axis direction of the x-axis are stacked in the z-axis direction, with slot 1 between waveguides 1 and 2, and slot 1 between waveguides 2 and 3. Slot 2 is placed between waveguides 3 and 4, and slot 3 is placed between waveguides 3 and 4. Let one end of waveguide 1 be port 4, both ends of waveguide 2 be ports 1 and 5, both ends of waveguide 3 be ports 2 and 6, and one end of waveguide 4 be port 3. The ends of waveguides 1 and 4 are short-circuited. As shown in figure (b), the center axes of waveguides 1 and 4 are offset by p in the y direction with respect to waveguides 2 and 3. The slot is placed at the center of the wide walls of waveguides 2 and 3, and is offset by p in the y direction when viewed from waveguides 1 and 4.

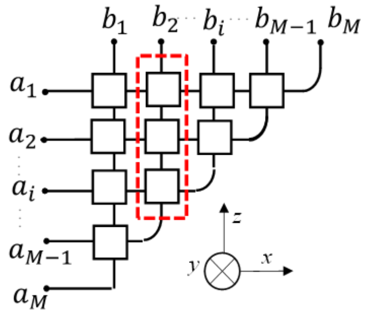


Fig. 1. Original Block Diagram and Compensated Block Diagram

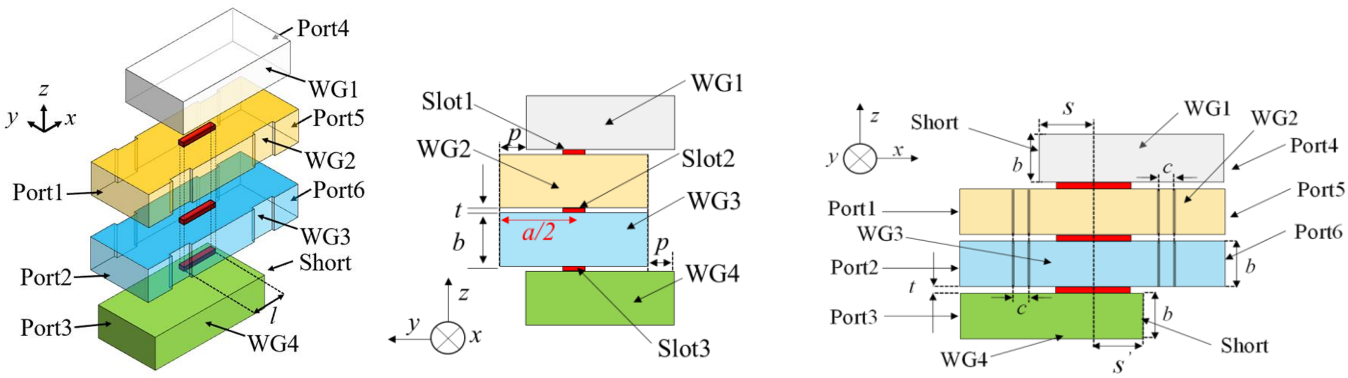


Fig. 2. Realized Structure of Matrix

Reference

[1] Y. Mitsumoto, T. Tomura, J. Hirokawa, D. Yamanaka, N. Kidera, and O. Kagaya, "Design of post-wall waveguide stacked e-plane cruciform cross couplers for 120-GHz band," Int. Symp. Antennas Propag. (ISAP), RS28.3, Oct. 2023.

Hirokawa-Tomura Laboratory

Wideband Design of 2×2-element Post-Wall Waveguide Slot Subarray for 350-GHz band

Due to the increasing demand for wireless communications, the use of the 300-GHz band is being considered. As a previous study of 300-GHz band planar antennas, a hollow waveguide has been used in [1]. The antenna achieved a gain of 38 dBi and a specific bandwidth of 80 GHz (22%) in actual measurements, showing good characteristics. On the other hand, it is expensive to manufacture because it uses a silicon process. To solve this problem, we investigated the possibility of reproducing the structure of [1] using a post-wall waveguide that can be produced using printed circuit board processing technology. The center frequency of this antenna is 340 GHz.

Figure 1 shows the overall structure of the antenna. Two types of dielectrics are used, and the antenna is manufactured by layering them. Power is supplied from the back of the antenna, and all radiating sections are supplied with power at the same phase and amplitude using a corporate feed circuit. Figure2 shows a 2 × 2-element subarray, which is the radiating part. From the top to the bottom, it consists of a radiation slot, a radiation cavity, an exciting slot, a cavity, a coupling slot, and a feeding waveguide.

Moving on to the results. In [2], the antenna geometry was optimized using GA. However, among the results obtained, there was a problem with the extremely close distance between the cavity and the exciting slot (Figure 3). Since this antenna is manufactured by etching, a distance of at least 0.05 mm is required between the post and the slot. When the characteristics are investigated at a distance from the current structure, the reflection characteristics deteriorate significantly. Next, we describe a method to solve this problem. Figure4 shows the newly adopted cavity shape. The adopted magnetic field distribution was changed from TM210 mode to TM410 mode. By changing the magnetic field distribution from TM210 mode to TM410 mode, the distance between the exciting slot and the post can be increased while maintaining a strong magnetic field near the exciting slot. The antenna bandwidth was increased from 8.0% to 14.5% [3]. Since there is a problem that the antenna bandwidth decreases when the antenna is post-walled, we plan to study the antenna radiation element in the future.

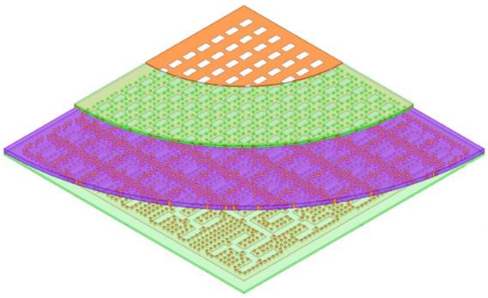


Fig.1

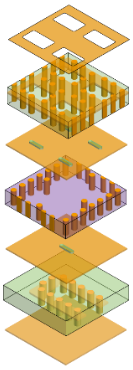


Fig.2

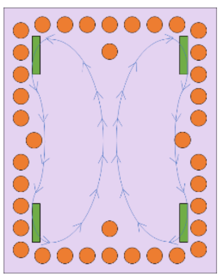


Fig.3

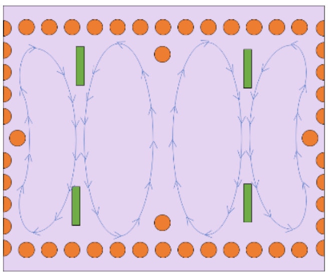


Fig.4

Reference

[1] A. Gomez-Torrent et al., "A 38 dB Gain, Low-Loss, Flat Array Antenna for 320–400 GHz Enabled by Silicon-on-Insulator Micromachining," IEEE Trans Antennas Propag, vol. 68, no. 6, pp. 4450-4458, Jun.2020.

[2] 小倉彰平，戸村崇，林琳，“340GHz 帯 2×2 素子誘電体充填導波管スロットサブアレーの広帯域設計,”信学総大, B1-90,Mar.2022

[3] S. Ogura, T. Tomura, L Lin, " Wideband Design of 2×2-element Post-Wall Waveguide Slot Subarray for 350-GHz band," Int. Symp. Antennas Propag., Kuala Lumpur, Malaysia, Nov. 2023

Feeding design of a full-corporate radial line slot antenna with isoflux radiation pattern

In the system for observing Earth from satellites, efficient technology for downlinking satellite observation data to ground stations is indispensable. Research on isoflux antennas, as satellite-mounted antennas for downlinking observation data, is actively conducted. isoflux radiation pattern is an antenna characteristic that allows the satellite to cover the visible surface of the Earth with the same power, maintaining stable communication links as long as ground stations exist on the visible surface from the satellite. Previous studies on isoflux antennas have been designed for frequencies below the X-band, making them insufficient to cover the Ka-band frequencies, which are the widest bandwidth frequencies allocated for satellite observation satellite downlinks, ranging from 37.5 to 40.5 GHz. Our objective is to design an isoflux antenna capable of covering this frequency band as a planar antenna manufacturable on PCBs. We are conducting designs using radial line slot antennas.

Recent research reports suggest that structuring radial lines into two layers for corporate feeding enhances the bandwidth. We propose further multilayering of radial lines using this structure to enable corporate feeding for each radiating element perimeter.

The structure for delivering power to the radial lines from the lower to upper layers is illustrated. The electromagnetic fields entering the corporate feeding structure flow into the upper layer via ring slots backed by short walls. Additionally, iris structures are installed on the upper layer to adjust the power distribution ratio to the inner and outer sides. In this paper, assuming five radiating elements, we designed a fully corporate-fed radial line.

To achieve isoflux radiation pattern, it is necessary to supply 68.0% of the total power to the innermost radiating element perimeter, 17.4% to the second, 7.8% to the third, 4.2% to the fourth, and 2.5% to the fifth. Through analysis using HFSS, we were able to create a feeding circuit with a power distribution ratio error of -2.7% to 1.5% for this target.

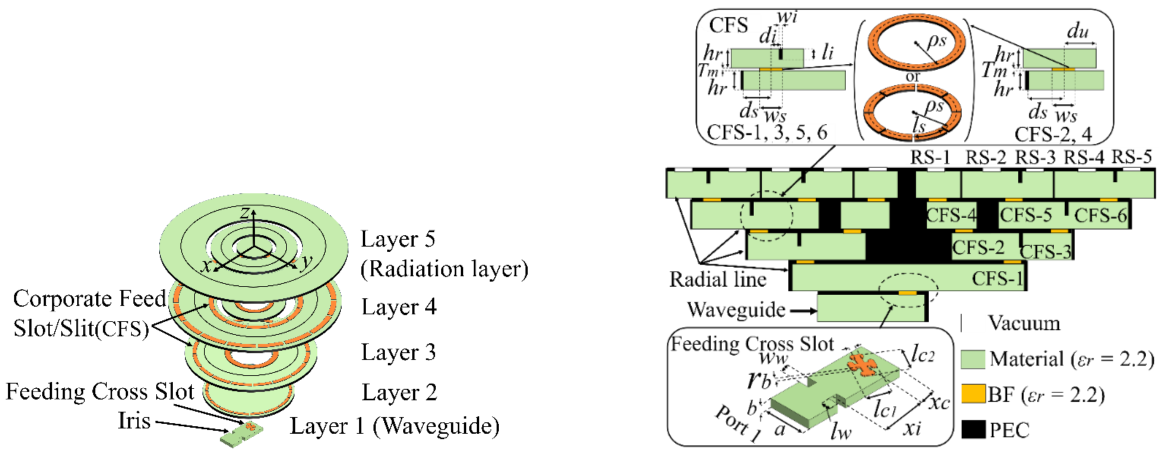


Fig. 1. Full-corporate feed radial line (Number of radiation lap: 5)

Reference

[1] M. Bertrand, et al. , “A broadband low-profile circularly polarized radial line slot antenna”, IEEE Trans. on Antennas and Propag., vol. 71, no. 1, pp. 140-150, Jan. 2023.

[2] 中山 弦, 戸村 崇, “アイソフラックス放射指向性を有する完全並列給電ラジアルラインスロットアンテナの給電部設計,” 信学技報, Vol. 123, No.262, pp. 27-30, Nov. 2023

Hirokawa-Tomura Laboratory

Design of Reconfigurable Reflectarray Antennas on Flexible Substrate with Varactor Diodes Mounted on Slot-Coupled Microstrip Lines

Compact deployable antennas are suitable for small satellites that require strict payload constraints. In particular, reflectarray antennas on flexible substrate[1] are expected to be used as large antennas for small satellites because they can be combined with a large deployable membrane structure[2] to improve storage efficiency dramatically. On the other hand, flexible substrates with low flatness can be deformed relatively easily due to creases for storage or external forces, which causes radiation phase error between array elements and gain reduction. Therefore, it is necessary to dynamically control the radiation phase. In this study, we design a reconfigurable reflectarray antenna with varactor diodes on flexible substrate[3]. Fig. 1 shows the proposed antenna structure. The first layer consists of radiation slots and slot-coupled microstrip lines with diodes mounted on it. The second layer is a ground plane to prevent the transmission of the incident wave to the backside of the reflector. In this structure, reconfigurability is realized by controlling the reverse bias voltages applied to diodes on the first layer. In the design process, periodic boundary conditions in the x and y-axis directions and x-polarized normal incident wave are assumed, and the voltage characteristics of the reflection coefficient S_{11} are analyzed by finite element method. For modeling the diode(Macom, MA46603-276), measured S-parameters for each reverse bias voltage are used. As a result, it is confirmed that a variable reflection phase range of 343 deg. could be obtained with a reflection loss of 0.53 dB or less.

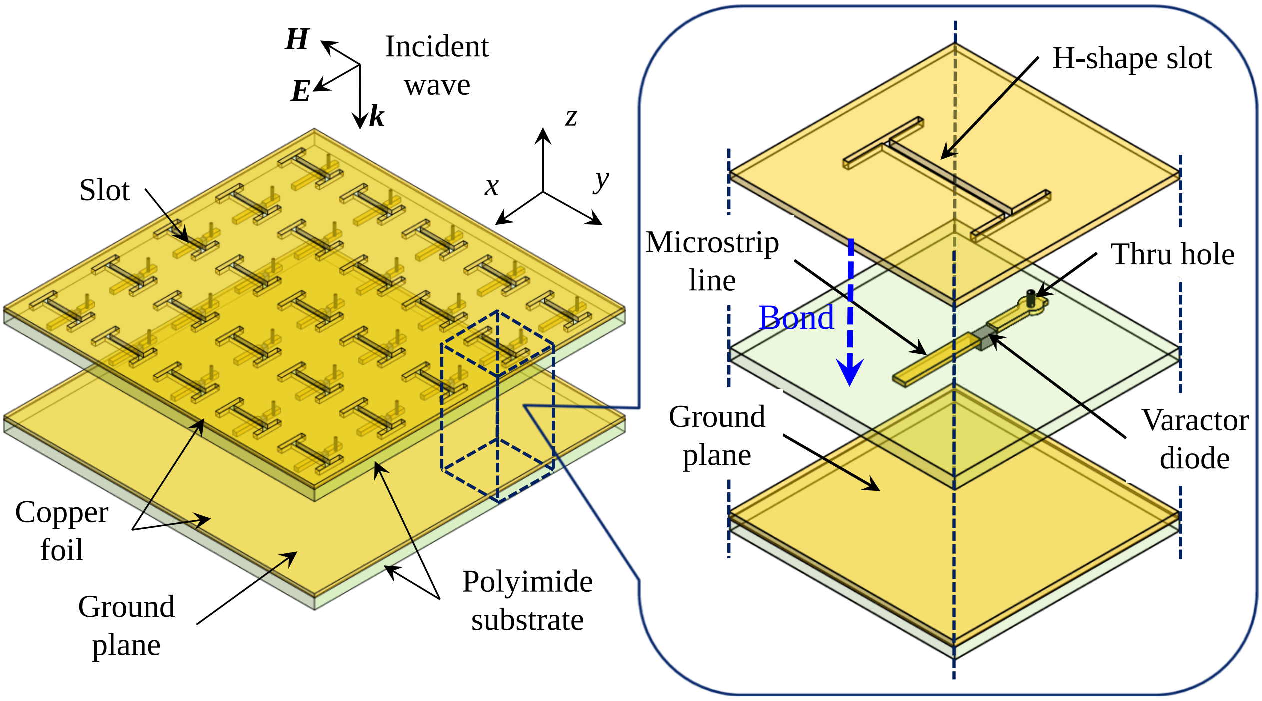


Fig. 1 Antenna structure

Reference

[1] T. Tomura et al, “Simulation results of a foldable reflectarray composed of four triangular notched patches,” Int. Symp. Antennas Propag., pp.1-2, 220358, 2021.

[2] K. Ikeya, et al., “Significance of 3U CubeSat OrigamiSat-1 for space demonstration of multifunctional deployable membrane,” Acta Astronautica, vol.173, pp.363-377, 2020.

[3] 武田裕貴，戸村崇，坂本啓，“スロット結合線路にバラクタダイオードを実装した反射位相可変フレキシブル基板リフレクトアレーの設計”，信学技報，vol. 122, no. 441, AP2022-250, pp. 93-96, Mar. 2023.

Design of a Planar Beam-Tilt Array for Primary Radiators of CubeSat-Onboard Reflectarray [1], [2]

Reflectarray antennas are used as high-gain antennas for cube-satellites because these can achieve high gain with a flat panel [1]. The conventional primary radiator for reflectarray on the cube-satellite, MarCO, uses a deployment mechanism to mechanically adjust the main beam direction toward the reflectarray antenna, but this method results in reducing gain due to blocking and in low reliability of the deployment mechanism [2]. In order to eliminate the deployment mechanism, a planar beam-tilt array primary radiator is required. This research presents the design of a beam-tilt array antenna on a printed circuit board as a primary radiator for 3U cube-sat onboard reflectarray.

The configuration of the planar beam tilt-array antenna is shown in Fig. 1 . The feeding lines are microstrip lines embedded within the substrate and the array element is fed by eight-way power divider with uniform amplitude and a phase difference to tilt main beam direction. The structure of the array element is shown in Fig. 2 . The antenna structure consists of an 18um thick copper foil on a PTFE substrate with a relative permittivity of 10.7. The array element is a microstrip antenna with three shorted sides, and the remaining non-short-circuited side is operated as a slot. The H-plane beamwidth is adjusted by the slot length p_x and the E-plane beamwidth by the number of elements and the element spacing *a*.

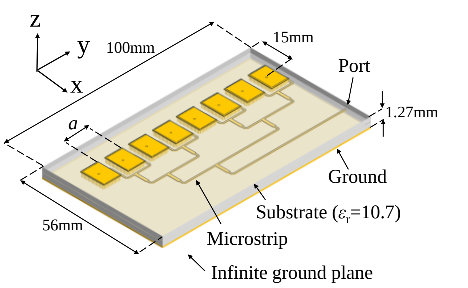


Fig. 1. All structure of slot array antenna.

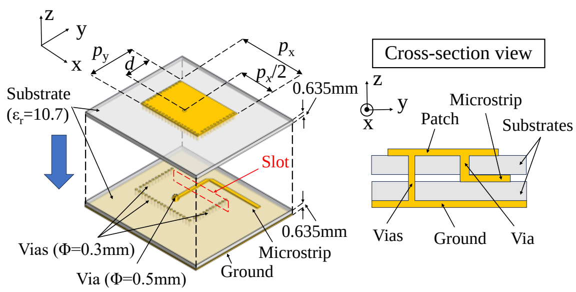


Fig. 2. Antenna element of slot array antenna

The design frequency is 5.84 GHz with 20 MHz bandwidth, the target beam direction is $\theta = 51.4°$, $\phi = 90°$, and the 10-dB beamwidth is 51.2° in the E plane and 103.1° in the H plane. The number of array element is determined as eight to realize the E-plane beamwidth.

Based on these results, the parameters are determined as p_x=10.64mm p_y=8.07mm *d*=4.52mm *a*=10.93mm and the 10-dB beamwidth is 60.0° in the E plane and 102.0° in the H plane, and they are close to the desired radiation pattern.

[1] R. E. Hodges, et al. , "Novel deployable reflectarray antennas for CubeSat communications," in Proc. 2015 IEEE MTT-S Int. Microw. Symp. , 2015, pp. 1-4.
[2] R. E. Hodges, et al. , "A Deployable High-Gain Antenna Bound for Mars: Developing a new folded-panel reflectarray for the first CubeSat mission to Mars," IEEE Antennas Propag. Mag. , vol. 59, no. 2, pp. 39-49, April 2017.

Fukawa Laboratory

Home page: http://www.radio.ce.titech.ac.jp

Professor Kazuhiko Fukawa

received the B.S. and M.S. degrees in physics, and the Dr. Eng. degree in electrical and electronics engineering, all from Tokyo Institute of Technology, Tokyo, Japan, in 1985, 1987, and 1998 respectively. He joined Nippon Telegraph and Telephone Corporation (NTT), Japan, in 1987. Since then, he has been engaged in research on digital mobile radio communication systems and applications of the adaptive signal processing, including adaptive equalization, interference cancellation, and adaptive arrays. He was a Senior Research Engineer at NTT Mobile Communications Network Inc. (NTT DoCoMo), from 1994 to 2000, and an Associate Professor at the Tokyo Institute of Technology, from 2000 to 2014. Since 2014 March, he has been a Professor at the Tokyo Institute of Technology. Prof. Fukawa is a senior member of IEEE. He received the Paper Award from IEICE in 1995, 2007, 2009, and 2012, the Best Paper Prize from the European Wireless Technology Conference (EuWiT), and the Achievement Award from IEICE in 2009.

Assistant Professor Yuyuan Chang

He received the B.E. degree from Department of Control Engineering and the M.E. degree from Department of Electrical Control Engineering, National Chiao Tung University, Hsinchu, R.O.C. (Taiwan), in 1997 and 1999, respectively, and another M.E. and the D.E. degree from Electrical and Electronic Engineering Department, Tokyo Institute of Technology, Tokyo, Japan, in 2007 and 2011, respectively. He served in Industrial Technology Research Institute (ITRI), Hsinchu, R.O.C. (Taiwan), from 2000 to 2005. He has been with Tokyo Institute of Technology from 2011 as a research fellow. Since April of 2016, he has been an Assistant Professor of Tokyo Institute of Technology. His research interests include multi-user MIMO systems, user scheduling algorithm, MIMO sounder, wireless sensor networks, and millimeter wave wireless systems. He is a member of IEICE and received the Best Paper Award of IEICE Communications Society in 2013

Our Research Interests

At Fukawa laboratory, we have been conducting both fundamental and applied researches involving signal processing techniques for mobile communications. Recently, we have focused on transmission systems, especially MIMO-OFDM, multiple access, modulation and demodulation schemes for cognitive radio, super high-bit rate mobile communications, and millimeter wave. Below is a detailed list of our research topics in recent five years.

Research Topics in Recent Five Years

Transmission System

MIMO detection & CSI estimation

- Suboptimal MLD
  - ✓ EM algorithm
  - ✓ Factor graph
  - ✓ MMSE detection avoiding noise enhancement
- Adaptive blind method for heterogeneous streams
- Soft decision-directed channel estimation (SDCE)
- Channel estimation exploiting sparsity

MIMO-OFDM system optimization

- BER improvement
  - ✓ Minimum BER (MBER) precoding
- PAPR reduction
  - ✓ Block diagonalization with selected mapping (BD-SLM)
  - ✓ Partial transmit sequence (PTS)
- Joint BER and PAPR improvement
  - ✓ Eigen-mode transmission with PAPR reduction
- Relaying system improvement
  - ✓ Amplify-and-Forward (AF) / Decode- and-Forward (DF) switching

Super high rate mobile communications

- 8×16 MIMO multi-Gbps systems

Multiple Access

Collision detection

Interference mitigation

- Spatial filtering
- MBER precoding for co-channel interference environment
- Neural network based power and beamforming controls
- Linear interference suppression for multiple relay systems

Access scheme

- IDMA with iterative detection
- Random packet collision solution

Wireless Security

Random phases based physical layer security

Millimeter Wave Communications

Phase noise compensation

I/Q imbalance compensation

Real zero coherent detection

Others

Constant Amplitude OFDM

Machine Learning Schemes for Wireless Communications

In this report, we will present some of the above research topics that have been recently presented at international conferences or accepted for publication in international journals.

Fukawa Laboratory

Reinforcement Learning-Based Cognitive Radio Transmission Scheduling in Vehicular Systems [3]

Stable and reliable wireless communications are absolutely essential in achieving safe, efficient, and comfortable autonomous driving systems, and require more channel resources. Cognitive radio (CR) alleviates the spectrum shortage by exploiting spectrum resources that are not used by primary users (PUs). Conventional CR-based vehicle-to-everything (V2X) communications still suffer from spectrum scarcity when the demands for wireless resources are excessive. Most previous analyses of this problem have adopted too simple models for V2X that assume constant vehicle velocity and that coarsely discretize vehicle positions. More realistic models for V2X are too topologically complex and too dynamically variant to find stable solutions of optimization problems by using conventional off-policy-based reinforcement learning (RL) algorithms such as Q-learning and deep Q-network (DQN) based on reply memories.

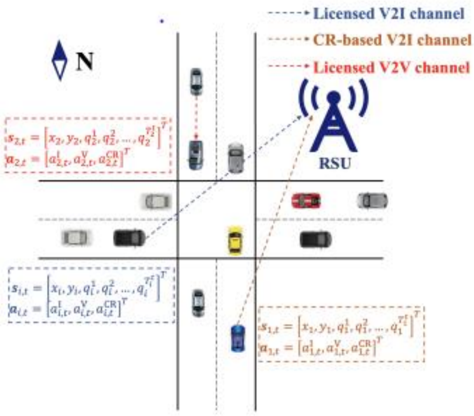


Fig. 1. A V2X communication model.

Considering the above situation, this paper firstly builds a precise and realistic autonomous driving testbed by 3D engine. In the testbed, all vehicles move in an autopilot mode with random velocity and direction, which can provide more realistic traffic flow, positions, and motion for all vehicles. As shown in **Fig. 1**, the testbed implemented a system model with CR-based V2X communication, which consists of N vehicles and one Road Side Units (RSU). The channel resources contain Licensed Vehicle-to-Infrastructure (V2I) channel, Licensed Vehicle-to-Vehicle (V2V) channel, or Unlicensed CR channel. While the conventional work used too simple testbeds to represent the autonomous driving environment, in this paper, we employed a more realistic simulator CARLA to provide CR-based autonomous driving scenarios as shown in **Fig. 2**.

Due to the constrain of Kullback-Leibler (KL) divergence between updated and previous policies, on-policy RL algorithms such as proximal policy optimization (PPO) can find stable solutions to complex optimization problems. Inspired by this property, in this paper, we expand the single-agent RL algorithm PPO into a multi-agent algorithm multi-action proximal policy optimization (MA-PPO), which is obtained via further increasing the action dimension to a predetermined number by using MultiDiscreate class provided by OpenAI gym. For comparison, we expand DQN to a multi-action deep Q-network (MA-DQN) algorithm by reusing parameters, in which DQN can select not one but multiple actions with very high dimension.

Fig. 2. An autonomous driving environment built in CARLA.

Computer simulations using the new testbed show the MA-PPO algorithm can gradually converge to more stable solutions and can achieve more steady and efficient data transmission than DQN. **Figs. 3** and **4** show the mean reward and amounts of lost data, respectively, for the RL algorithms. It can be seen that MA-PPO (blue line) can grow the reward with increase in iterations while decreasing an amount of lost data with increase in iterations. The constraints of KL divergence between two adjacent policies can be considered to bring about this superiority. Although the MA-DQN algorithm (orange line) can achieve the highest reward and the smallest amount of lost data at about 150 iterations, its performance is severely deteriorated at about 300 iterations, while causing very large deviations. This behavior is unacceptable in autonomous driving wireless communication scenarios. It is also noteworthy that the performance of MA-DQN with linearly decaying learning rate (violet line) is severely deteriorated at about 300 iterations and cannot recover from the worst level later.

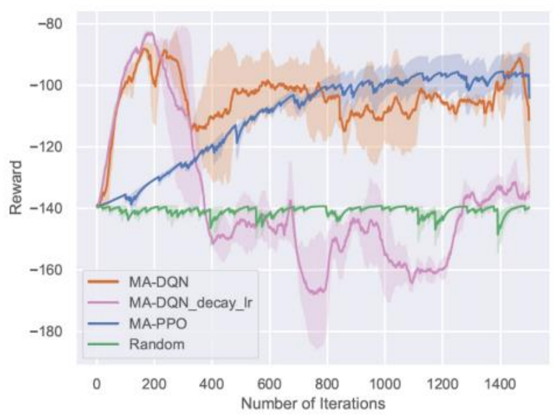


Fig. 3. An example of average throughput.

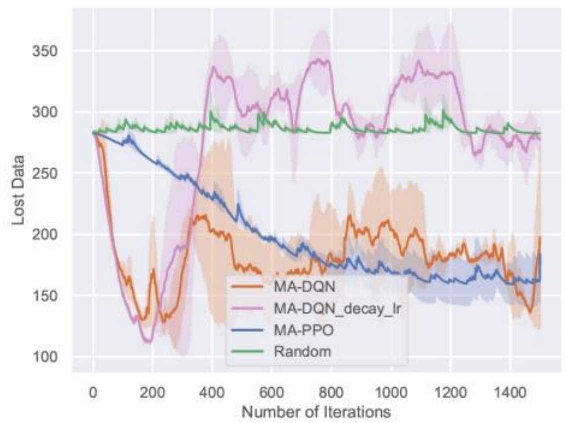


Fig. 4. Transmission delay time.

A CSI-Based Construction Scheme for G_N-Coset Codes over Frequency Selective Fading Channels [4]

Polar codes were invented by Erdal Arıkan in 2009 , and has been adopted as the control channel coding scheme of 5G mobile communications, because it is demonstrated that polar codes can approach Shannon's capacity on symmetric binary-input memoryless channels as the block length goes to infinity. Since polar codes can be classified into G_N -coset codes, the other G_N -coset codes have provoked great interest due to the constructive similarity. As such a code, the old but classic Reed-Muller (RM) codes, which were introduced in 1954 , have been expected to achieve Shannon's capacity on symmetric channels for a long time. Recently, it has been proved that RM codes can also polarize, which can be regarded as a partial proof of the expectation.

The aim of this paper is to design GN -based codes that are suitable for orthogonal frequency-division multiplexing (OFDM) transmission over wireless frequency selective fading channels and that can solve the following two problems; i) it is hard to construct proper polar codes, and ii) the performance of RM codes is severely degraded with an increase in the code rate, because the minimum Hamming distance between codewords decreases exponentially. **Fig. 5** shows OFDM transmission over frequency selective fading channels with the proposed feedback system, which operates as the following three steps. A pilot signal sequence is sent and used to estimate the channel frequency response of each subcarrier H_k, as CSI. Note that this paper assumes perfect channel estimation. Using the estimated channel frequency response and G_N, the criterion for the row vector selection is calculated. The row vectors with the largest K criteria are selected from G_N and used to encode the K information bits. To reduce an amount of feedback information, not indices of the selected or deleted row vectors, but differences from those by RM codes are fed back to the encoder on the transmitter side. Note that setting $|H_k|$ to 1 results in the row vector selection by RM codes, which can be predetermined. Using the feedback information, the encoder can estimate which row vectors are selected or deleted for the encoding, and then provides encoded bits for the OFDM modulator.

The computer simulation shows the block error rate (BLER) performance comparisons among RM codes, polar codes of the 5G standard, the conventional scheme of and the proposed code construction scheme. **Fig.6** and **7** show the BLER performance for different code rates of 0.25, 0.5, 0.75, 0.875, it is evident that the proposed code construction scheme outperforms traditional codes across all code rates. Importantly, regardless of the code rate, the proposed scheme achieves over a 5 dB average E_b/N_0 gain compared to the conventional scheme. In the case of the proposed scheme, only 30 indices need to be fed back (15 indices are added to and 15 indices are removed from the RM selection for information bits), which can reduce the amount of feedback indices to 53.1%.

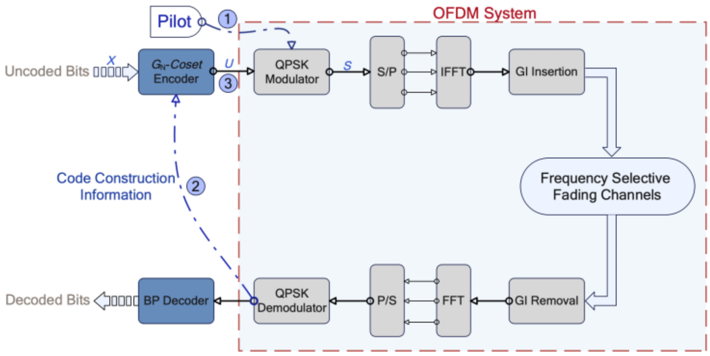


Fig. 5. OFDM transmission with the proposed feedback system.

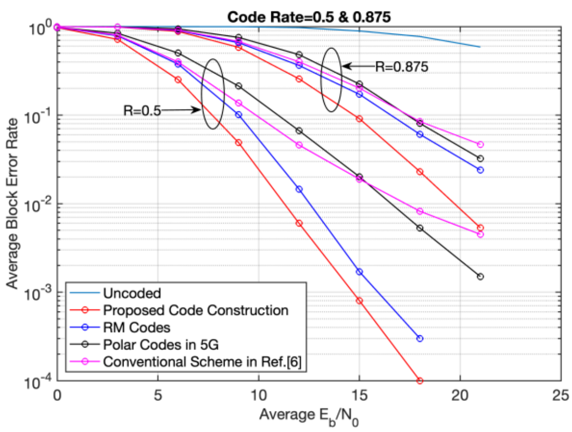


Fig. 6. BLER performance with the code rates of 0.25 & 0.75.

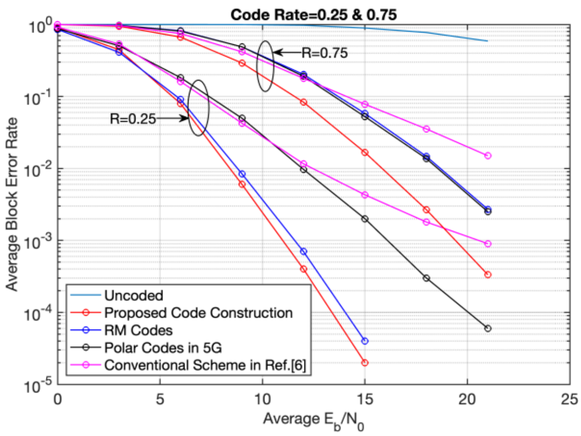


Fig. 7. BLER performance with the code rates of 0.5 & 0.875.

Time-Varying Channel Prediction for Pilot Contamination Mitigation in Hybrid Massive MIMO Communications [5]

Recently, massive multiple-input multiple-output (MIMO) has attracted much attention and been introduced into the 5th generation mobile communications system (5G). Hybrid beamforming (HB), which consists of analog beam-forming (AB) and digital beamforming (DB), can be regarded as one of the most feasible massive MIMO techniques, because it can significantly reduce the number of baseband and radio frequency (RF) circuits. However, HB cannot accurately estimate channel impulse responses of all antenna elements because the degrees of freedom of the received (Rx) signal are reduced by AB and are too small for the accurate channel estimation. To solve this problem, a previous scheme assumed that incident angles of propagation paths (cluster) in the uplink (UL) are narrowly distributed and can estimate time-invariant channel frequency responses of all the elements from those of HB by using information on angle of arrival (AoA) for the cluster. The estimated channel frequency responses are used to control both phase rotation of AB and a precoding matrix of DB so that HB can approximately perform block diagonalization in the downlink (DL). However, hybrid massive MIMO still suffers from the following pilot contamination: When the number of user terminals (UTs) using the same channel simultaneously exceeds the number of orthogonal pilot signals, the same pilot signal needs to be shared among multiple UTs [8]. The channel estimation using the shared pilot signal obtains an estimate of combined channel frequency responses of the multiple UTs, which can cause significant degradation of transmission performance.

To cope with the pilot contamination under time-varying channel conditions, this paper proposes a method for adaptively predicting DL channels while mitigating the pilot contamination. Considering time division duplex (TDD) multiuser MIMO communications, the proposed scheme firstly estimates an AoA for each user's cluster by applying multiple signal classification (MUSIC) to the Rx pilot signals, which can reconstruct the channel frequency responses of the interfering users and then extracts the desired channel frequency responses from the combined ones. Since the desired channel frequency responses can be considerably extracted, the proposed scheme coarsely compensates for time-variation of the Rx signal by predicting the Doppler effect of each cluster. The residual time-variation can be tracked and removed using detected signals of all the streams in a decision-directed manner. Finally, the estimated total time-variation is used to predict the DL channel frequency response.

Computer simulations under conditions of time-varying fading channels, two desired UTs with multiple antennas, two interfering UTs with multiple antennas, and one base station (BS) equipped with a 256-element array antenna demonstrate that the proposed scheme can sufficiently track time-varying channels and mitigate the pilot contamination.

Consider the massive MU-MIMO system shown in **Fig. 8**, where the base station (BS) and user terminals (UTs) are assumed to perform HB and full digital beamforming (FDB), respectively. Suppose that the BS with $\boldsymbol{N_{\mathrm{RF}}}$ antennas communicates with $\boldsymbol{K}$ UTs having $\boldsymbol{N_{\mathrm{UT}}}$ antennas. Furthermore, let us assume that $\boldsymbol{K'}$ interfering UTs are located near the cell boundary, and that $(\boldsymbol{K}+\boldsymbol{K'})$ UTs share the same frequency channel simultaneously. Let $\boldsymbol{M_{\mathrm{BS}}}$ denote the number of RF circuits (sub-arrays) in the BS and $\boldsymbol{N_{\mathrm{RF}}/M_{\mathrm{BS}}=N_{\mathrm{BS}}}$ be an integer equal to the number of antenna elements per RF circuit. The number of data streams for each UT is set equal to that of antennas of each UT, $\boldsymbol{N_{\mathrm{UT}}}$. In addition, since a TDD system is assumed, both the uplink (UL) and DL use the same frequency channel. Since channel frequency responses of UL agree with those of DL, the BS can control phase rotation of AB and a precoding matrix of DB for HB using estimated or predicted channel frequency responses of DL. What's more, since orthogonal frequency-division multiplexing (OFDM) is assumed as the transmission scheme, subcarrier signals of OFDM follow frequency flat fading even under frequency selective fading conditions. In this paper, we focus on one OFDM subcarrier that experiences the Rayleigh fading.

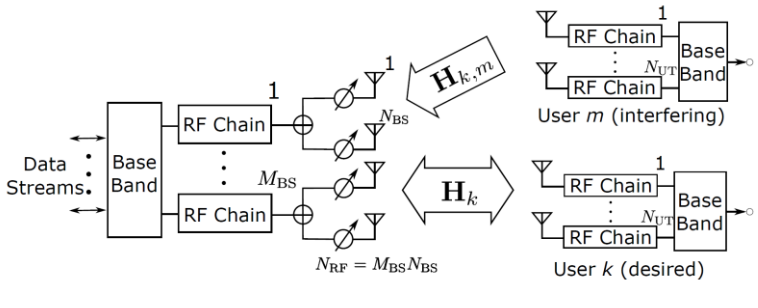


Fig. 8. Block diagram of the massive MU-MIMO system.

BS and UTs were assumed to be located as shown in **Fig. 9**. The central azimuth angles of the clusters arriving from the desired UTs were set to 15° and −15°, respectively. The central azimuth angles of the clusters arriving from the interfering UTs were assumed to be uniformly distributed in the range from −75° to 75° with an angular difference from the central azimuth angle of the desired UT being 45° or more. The central elevation angles of the clusters were assumed to be normally distributed with 0° mean and standard deviation 15°. The direction of the movement of the UTs was assumed to follow the uniform distribution.

Fig. 10 shows the mean squared error (MSE) of the predicted channel at the center of the DL packet. The error floor can be seen when the pilot contamination (PC) occurs but PC mitigation (PCM) is not conducted, whereas PCM can make the error floor much lower and near to that without PC. In addition, PCM can reduce differences in required $\boldsymbol{E_\mathrm{b}/N_0}$ between PC and non-PC to less than 3 dB. Especially, when the channel is time-variant, the difference can get close to 0 dB. It can be also seen that the proposed scheme can accurately predict the time-varying channels up to $\boldsymbol{f_\mathrm{D}} =$ 150 Hz.

Fig. 11 shows the average packet error rate (PER) of DL, when HB approximately performs block diagonalization by using the predicted DL channel. It can be seen that PCM can alleviate degradation of PER in the DL from PC, as effectively as that of MSE. Note that the simulation results of the second stream (the smaller eigenvalue) without PCM were not plotted because the PER is very close to 1.0 regardless of both the Doppler frequency and $\boldsymbol{E_\mathrm{b}/N_0}$.

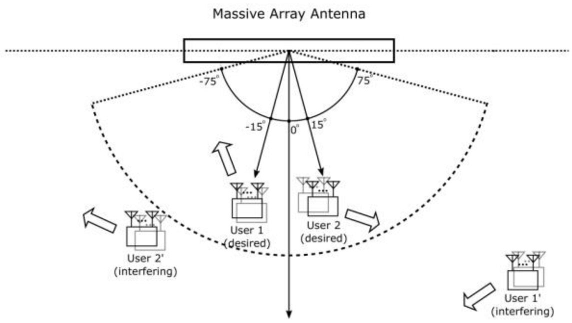


Fig. 9. The positions of BS and UTs.

The proposed scheme estimates the average AoA of each UT's cluster and uses the information to remove channels of the interfering UTs from pilot based channel estimates. After predicting and compensating for the overall Doppler effect of each desired UT's cluster, the residual time-variation can be further tracked using the detected signals of all the Tx streams. Finally, the estimated total time-variation is exploited to predict the DL channel. Computer simulations under TDD-OFDM transmission with two desired UTs, two interfering UTs, and one BS with HB have shown that the proposed scheme is very robust against the pilot contamination and can accurately predict time-varying channels up to $\boldsymbol{f_\mathrm{D}} =$ 150 Hz.

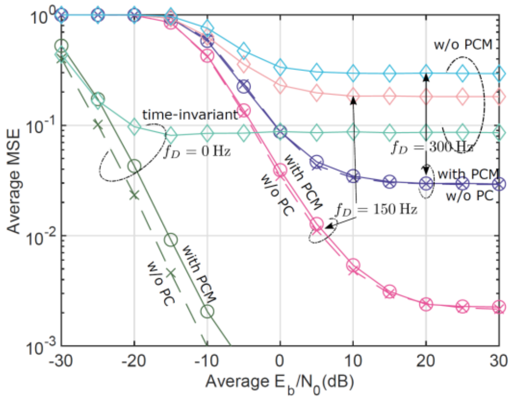


Fig. 10. MSE of channel prediction in DL.

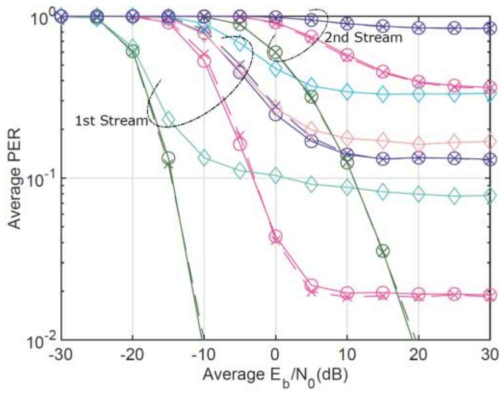


Fig. 11. Average DL PER of each stream.

A Slotted Polar Random Spreading Scheme for Massive MIMO Unsourced Random Access [6]

Recently, machine-type communication (MTC) has been motivated by Internet of Things (IoT) applications. As a practical solution for IoT networks, MTC is effective in low power consumption, ultra-low latency and high reliability data transmission. In the fifth generation (5G) mobile network, massive MTC (mMTC) is one of the most significant usage scenarios, which will be evolved into massive communication in 6G. In general, MTC meanly focuses on short packet transmission. At any given transmission frame, only a small fraction of users is active while others keep silent to save power. Unsourced random access (URA) proposed in 2017 is one of the most promising techniques to realize the massive connectivity in MTC. In URA, all users share a same codebook and the base station (BS) only has to detect the received codewords without identifying the senders. The problems of the existing URA scheme includes, i) Multi-user interference caused by non-orthogonal signals. Such interference becomes severe with the increase of user number. ii) The computational complexity of some schemes is extremely high.

To solve the afore-mentioned problems, we propose a slot-based random spreading URA scheme using polar code. With the same manner of most of the URA works, a single cell consists of multiple single antenna users and one multiple input multiple output (MIMO) BS is considered. Also, the transmission frame is partitioned into several slots. Each active user selects one slot for message transmission according to index modulation (IM). **Fig. 12** depicts the transmitter in the proposed scheme. The message sent by each active user is divided into three parts: The first part indicates which slot is selected based on IM principle while the second one corresponds to pilot and spreading sequence selection. The remaining part is polar encoded and spread over the selected slot. **Fig. 13** shows the receiver of the proposed scheme. First, the activity detection (AD) aims to detect the transmitted pilots and is completed in a two-stage manner where energy detector (ED) is performed to cover as many as potential transmitted pilots while covariance-based maximum likelihood detection (CB-MLD) is to decrease the false alarm. Once a message is successfully decoded, the receiver performs successive interference cancellation (SIC), which can subtract replicas of correctly decoded signals from received signals. Then the residual received signals are fed into AD again. Multiple iterations of successive interference cancellation (SIC) can improve the PUPE performance and alleviate the thresholds requirement.

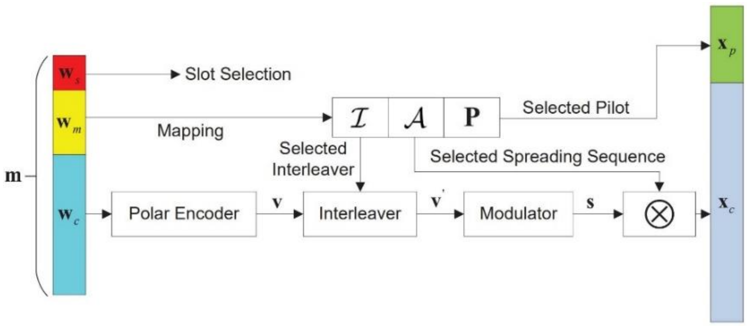


Fig. 12. A block diagram of the transmitter in the proposed scheme.

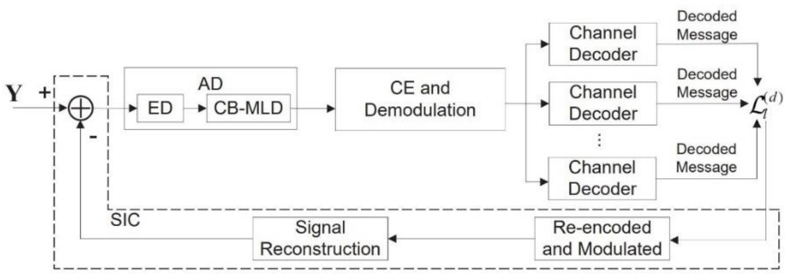


Fig. 13. Block diagram of the massive MU-MIMO system.

Fig. 14 shows how the number of

active users in the proposed scheme affects the signal-noise ratio (SNR) required to ensure the per user probability of error (PUPE) equaling to 0.05. For comparison, the results of both the multiple orthogonal pilots scheme and non-slotted FASURA scheme proposed before were also plotted in the figure. Each active user transmits 100-bit message. It can be seen from the figure that when the number of active users per slot, $K_a > 700$, the proposed scheme is superior to FASURA. As K_a increases, the superiority of the proposed scheme becomes more significant in terms of the required SNR. The reason is as follows: when K_a increases and exceeds a threshold, the multiuser interference becomes severer. The slotted structure in the proposed scheme can reduce the amount of such interference drastically, which brings about the superiority of the proposed scheme to FASURA under the large K_a condition. **Fig. 15** shows how the number of iterations affects PUPE of the proposed scheme per slot with various settings of number of antennas (M) and K_a. It can be seen from this figure that PUPE converges fast with iterations. For example, when $M = 50$ and $K_a' = 250$, it requires only 4 iterations for the convergence, which demonstrates the effectiveness of the SIC process.

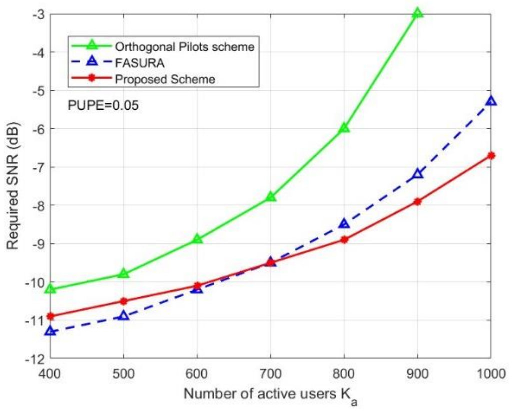


Fig. 14. SNR required to ensure PUPE = 0.05 versus the number of active users when the number of antennas, M = 50.

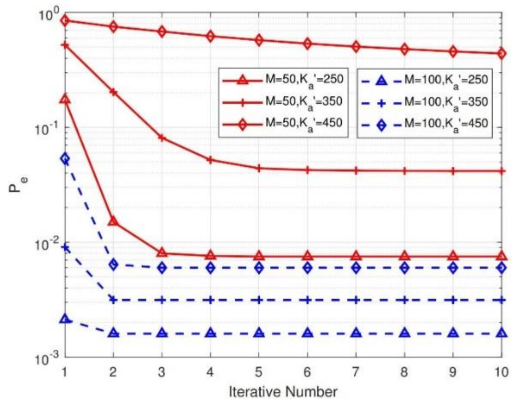


Fig. 15. PUPE versus the iterative number per slot with the numbers of antennas and active users being parameters.

This page intentionally left blank.

Okada Laboratory

Home page: https://www.ssc.pe.titech.ac.jp

Professor Kenichi Okada

received the B.E., M.E., and Ph.D. degrees in communications and computer engineering from Kyoto University, Kyoto, Japan, in 1998, 2000, and 2003, respectively. From 2000 to 2003, he was a Research Fellow of the Japan Society for the Promotion of Science in Kyoto University. In 2003, he joined Tokyo Institute of Technology as an Assistant Professor, where he is currently a Professor of electrical and electronic engineering in Institute of Science Tokyo. He has authored or co-authored more than 500 journal and conference papers. His current research interests include millimeter-wave and terahertz CMOS wireless transceivers for 20/28/39/60/77/79/100/300GHz for 5G, WiGig, satellite and future wireless systems, digital PLL, synthesizable PLL, atomic clock, and ultra-low-power wireless transceivers for Bluetooth Low-Energy, and sub-GHz applications.
Prof. Okada is a member of the Institute of Electrical and Electronics Engineers (IEEE), the Institute of Electronics, Information and Communication Engineers (IEICE), the Information Processing Society of Japan (IPSJ), and the Japan Society of Applied Physics (JSAP). He was a recipient or co-recipient of the Ericsson Young Scientist Award in 2004, the A-SSCC Outstanding Design Award in 2006 and 2011, the ASP-DAC Special Feature Award in 2011 and Best Design Award in 2014 and 2015, the MEXT Young Scientists' Prize in 2011, the JSPS Prize in 2014, the Suematsu Yasuharu Award in 2015, the MEXT Prizes for Science and Technology in 2017, the RFIT Best Paper Award in 2017, the IEICE Best Paper Award in 2018, the RFIC Symposium Best Student Paper Award in 2019, the IEICE Achievement Award in 2019, the DOCOMO Mobile Science Award in 2019, the IEEE/ACM ASP-DAC Prolific Author Award in 2020, the Kenjiro Takayanagi Achievement Award in 2020, the KDDI Foundation Award in 2020, the IEEE CICC, Best Paper Award in 2020, the IEEE ISSCC Author-Recognition Award in 2023, and more than 50 other international and domestic awards. He is a Fellow of IEEE. He is/was a member of the technical program committees of IEEE International Solid-State Circuits Conference (ISSCC), VLSI Circuits Symposium, European Solid-State Circuits Conference (ESSCIRC), Radio Frequency Integrated Circuits Symposium (RFIC), Asian Solid-State Circuits Conference (A-SSCC), and he is/was also Guest Editors and an Associate Editor of IEEE Journal of Solid-State Circuits (JSSC), an Associate Editor of IEEE Transactions on Microwave Theory and Techniques (T-MTT), a Distinguished Lecturer of the IEEE Solid-State Circuits Society (SSCS).

Our Research Interests

- Phased-array transceiver for 5G, 6G, 7G
- Terahertz Wireless Communication, Terahertz Imaging
- 1Tb/s Millimeter-wave Wireless Communication
- Satellite Communication
- All-Digital PLL, Synthesizable PLL, Injection-Locked PLL
- Millimeter-wave Antenna, High-frequency PCB design
- Quantum computing/sensing, Cryo-CMOS, Atomic Clock
- IoT battery-less transceiver
- Reconfigurable analog RF circuits
- Modeling and Optimization of On-chip Spiral Inductor

Details can be found here
https://x.gd/RVxqz

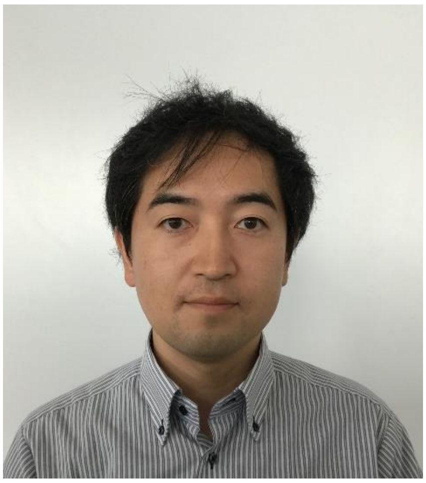
This page intentionally left blank.

Fujii and Ohta Laboratory

Specially Appointed Professor Teruya Fujii

He received the B.E. degree from Kyushu Institute of Technology in 1981 and M.S. and Ph.D. degrees from Kyushu University in 1983 and 1995, respectively. In 1983, he joined NTT Yokosuka Lab. He involved in R&D activities of mobile communications and mobile radio propagations. In 2000, he moved to Japan Telecom (Softbank Corp.). After he successfully completed his Softbank R&D department head term, he became the first R&D fellow of Softbank in 2016. In 2017, he became a specially appointed professor of Tokyo Institute of Technology as an additional position.

Specially Appointed Associate Professor Yoshichika Ohta



He received the B.E. and M.E. degrees from Muroran Institute of Technology, Japan, in 2000 and 2002, respectively. In 2002, he joined Japan Telecom Co., LTD., which is now known as SoftBank Corp. Since then, he has been engaged in the research of mobile communication systems and mobile radio propagation. He is now a director of system design R&D department in technology research laboratory at SoftBank Corp., Tokyo, Japan. In 2023, he was concurrently appointed as a specially appointed associate professor at Tokyo Institute of Technology. His current research interests include mobile communication systems, mobile radio propagation, HAPS (High altitude platform station) communication systems, and Wireless power transfer.

Recent Research Topics

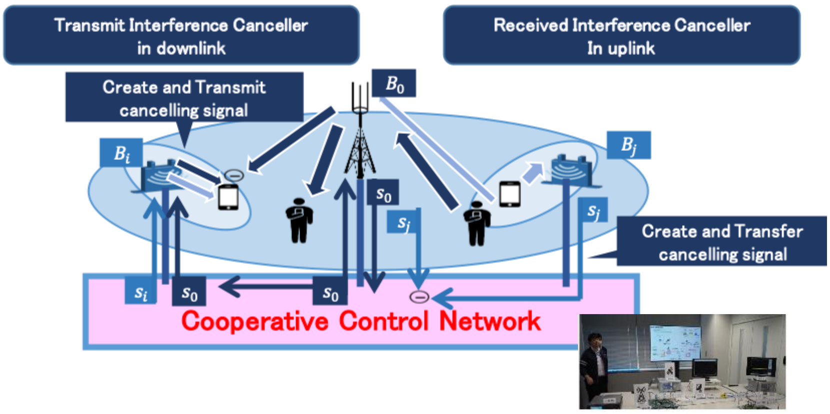
- **3D Layered Cell Construction in Broadband Mobile Communication**
  - Transmit and Receive Interference Canceller for 3D Layered Cell Construction in Broadband Mobile Communication.
  - Frequency Sharing in 3D Cell Structure consisting of Ground and Sky Cells by using Beamforming.

A Study on Transmit and Receive Interference Canceller for 3D Layered Cell Construction in Broadband Mobile Communication

[2]~[4] [6] [8]~[10] [14] [18] [20] [22] [23]

In the three-dimensional(3D) layered cell construction in same frequency bands are used in both macro and small cells, we pioneered interference cancellation technology using "cooperation control network" where each cell cooperates through a network ahead, for LTE and 5th generation mobile communications. We propose "transmit interference canceller in small cells extended to MIMO and SIMO" that cancels the macro cell signal received at terminal in each small cell through cooperative control network in downlink and "received interference canceller in macro cell" that cancels the small cell signal received at base station in macro cell through cooperative control network in uplink.

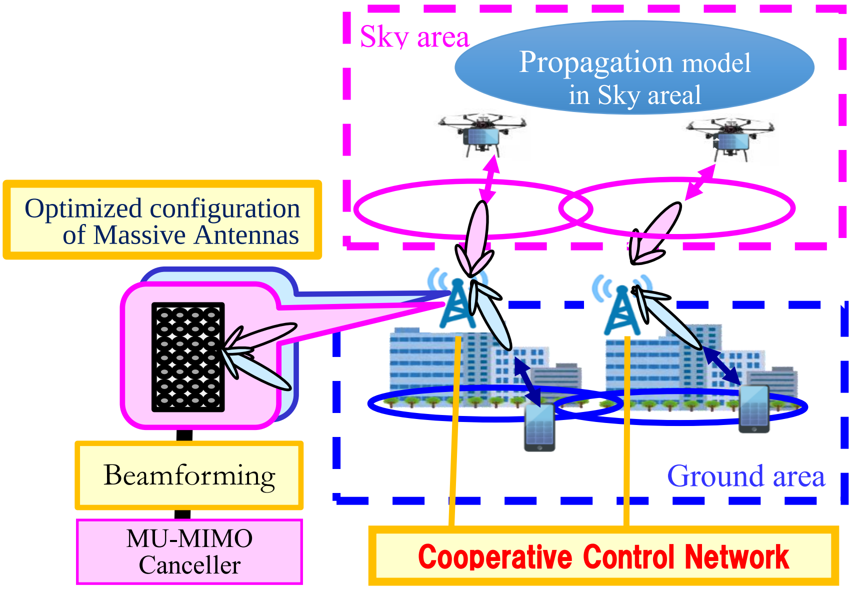
By using these proposed interference cancellers, we showed that the communication quality such as SINR (Signal power to Noise and Interference power Ratio) and communication capacity in small cells can be improved remarkably.



A Study on Frequency Sharing in 3D Cell Structure consisting of Ground and Sky Cells by using Beamforming

[1] [5] [7] [11]~[13] [15]~[17] [19] [21] [24] [25]

It is being expected to control the flight of drones and transmit video data taken with drones using cellular network. When the mobile terminal on the drone communicates in the sky using current cellular network, it interferes with a wide range and the radio quality of the mobile terminals on the ground is deteriorated. We proposed "3D Cell Structure" which shares the same frequency by spatially separating the ground cell and sky cell by using 5G antenna beamforming for the base station antenna. We evaluate the communication characteristics when mobile terminal on the drone communicates in a conventional cellular system and evaluate its effectiveness in comparison with the proposed system. We are working on the optimization design of "Massive Antennas" that take into account the arrival angular spread, and on the modeling of the fading characteristic of radio waves in the sky, which is indispensable for wireless communications.



Publications

Takada Laboratory

Transactions and Letters

[1] Nopphon Keerativoranan, Kentaro Saito, and Jun-Ichi Takada, "Grid-Based Channel Modeling Technique with Path Parameters Interpolation for Site- and Scenario-Specific Wireless Channel Emulator," IEEE Open Journal of the Communications Society, vol. 5, pp. 1724-1739, Mar. 2024.
doi: 10.1109/OJCOMS.2024.3373538

[2] Siraphop Saisa-Ard, Nopphon Keerativoranan, and Jun-Ichi Takada, "Knife-edge Diffraction Model for Vehicle Shadowing Estimation in Site- and Scenario-specific Wireless Channel Emulator," IEICE ComEx, vol. 13, No. 4, pp. 97-100, Feb. 2024.
doi: 10.23919/comex.2023XBL0177

[3] Hang Song, Shinsuke Sasada, Takayuki Kadoya, Koji Arihiro, Morihito Okada, Xia Xiao, Tomomi Ishikawa, Declan O'Loughlin, Jun-ichi Takada, and Takamaro Kikkawa, "Cross-Correlation of Confocal Images for Excised Breast Tissues of Total Mastectomy," IEEE Transactions on Biomedical Engineering, early access, 2024.
doi: 10.1109/TBME.2023.3348480

[4] Xin Du and Jun-ichi Takada, "UTD-type Solution of Physical Optics Approximation for Reconfigurable Intelligent Surface Modeled by A Continuous Planar Surface," IEEE Open Journal of Antennas and Propagation, vol. 4, pp. 1103-1115, 2023.
doi: 10.1109/OJAP.2023.3329767

[5] Kentaro Saito, Nopphon Keerativoranan, and Jun-ichi Takada, "Scenario-specific Radio Propagation Simulation from LiDAR Point Cloud Data for Smart Office Scenario," IEICE ComEx, vol. 12, No. 7, pp. 379-384, July. 2023.
doi: 10.1587/comex.2023XBL0054

[6] Xin Du and Jun-ichi Takada, "Equivalence of knife-edge diffraction model and uniform geometrical theory of diffraction applying Fresnel approximation for an absorbing screen," Electronic Letters, vol. 59 no. 22, article no. e13014, 2023.
doi:10.1049/ell2.13014

[7] Xin Du and Jun-ichi Takada, "A Uniform Additional Term Using Fock-type Integral to Unify Edge Diffraction, Creeping Diffraction, and Reflection in Lit and Shadowed Regions," Progress In Electromagnetics Research B, vol. 101, no. 6, pp. 101-117, 2023.
doi:10.2528/PIERB23041703

[8] Xin Du and Jun-ichi Takada, "Design of Parameters of Fast Fourier Transform for Three-Dimensional Split Step Parabolic Equations and Mirror Kirchhoff Approximation," IEEE Access, vol. 11, pp. 44964-44976, 2023.
doi: 10.1109/ACCESS.2023.3273783

[9] Xin Du and Jun-ichi Takada, "Structure of the Field behind a Dielectric Circular Cylinder in the Lit Side of the Transition Region," Progress In Electromagnetics Research M, vol. 116, no. 9, pp. 103-118, 2023.
doi:10.2528/PIERM23022307

[10] Noawanit Songkram, Suparoek Chootongchai, Sawaros Thanapornsangsuth, Hathaiphat Osuwan, Krerk Piromsopa, Yootthana Chuppunnarat, and Nutthakorn Songkram, "Success factors to promote digital learning platforms: An empirical study from an instructor's perspective," International Journal of Emerging Technologies in Learning, vol. 18, no. 9, pp. 32–48, 2023.
doi:10.3991/ijet.v18i09.38375

[11] Naotake Yamamoto, Taichi Sasaki, Atsushi Yamamoto, Tetsuya Hishikawa, and Jun-ichi Takada, "Simple Calculation Method for Radio Propagation of a Concrete Beam on a Concrete Ceiling in the 920-MHz Band," IEEE Access, vol. 11, pp. 93551-93559, 2023.
doi:10.1109/ACCESS.2023.3310571

[12] Bo Wei, Hang Song, Makoto Nakamura, Koichi Kimura, Nozomu Togawa, and Jiro Katto, "QuDASH: Quantum-Inspired Rate Adaptation Approach for DASH Video Streaming," IEEE Access, vol. 11, pp. 118462-118473, 2023.
doi: 10.1109/ACCESS.2023.3326326

International Conference

[13] Nopphon Keerativoranan, Siraphop Saisa-Ard, and Jun-Ichi Takada, “Grid-based Shadowing Gain Modeling for Handling Dynamic Objects in Wireless Channel Emulation,” 2024 18th European Conference on Antennas and Propagation (EuCAP), pp.1-5, Mar. 2024 (Glasgow, Scotland).

[14] Nopphon Keerativoranan, Yikai Wang, and Jun-ichi Takada, “Utilization of Wi-Fi Signal for Validation of Micro-Doppler Model in a Person Falling Scenario,” 2024 18th European Conference on Antennas and Propagation (EuCAP), pp.1-5, Mar. 2024 (Glasgow, Scotland).

[15] Cries Avian, Jenq-Shiou Leu, Erfansyah Ali, Nur Achmad Sulistyo Putro, Hang Song, Jun-Ichi Takada, Setya Widyawan Prakosa, Ariana Tulus Purnomo, “Non-contact Breathing Patterns Recognition with FMCW Radar by Processing Temporal Information using Transformer Network,” 2023 Asia-Pacific Microwave Conference (APMC), pp. 420-422, Dec. 2023 (Taipei, Taiwan).

[16] Nopphon Keerativoranan, Siraphop Saisa-Ard, and Jun-Ichi Takada, “Modelling the Shadowing Gain from Obstacle in Wireless Channel Emulator with Grid-based Channel Interpolation Technique,” 2023 International Conference on Emerging Technologies for Communications (ICETC 2023), P2-2, pp. 1-1, Nov. 2023 (Sapporo, Japan).

[17] Lei Jiang, Nopphon Keerativoranan, Tad Matsumoto, and Jun-ichi Takada, “A 2-Dimensional Smoothing Technique in Non-stationary Environments,” 2023 International Conference on Emerging Technologies for Communications (ICETC 2023), P1-14, pp. 1-1, Nov. 2023 (Sapporo, Japan).

[18] Nopphon Keerativoranan and Jun-Ichi Takada, “Study on Rician K-factor Estimation from Time-Variant Channel Frequency Response for Performance Evaluation of Deterministic Wireless Channel Emulator”, XXXVth URSI General Assembly and Scientific Symposium, pp. 1-1, Aug. 2023 (Sapporo, Japan).

[19] Siraphop Saisa-Ard, Nopphon Keerativoranan, and Jun-Ichi Takada, “Vehicle Shadowing Modeling for Deterministic Channel Emulator and Electromagnetic Simulation-Based Validation”, XXXVth URSI General Assembly and Scientific Symposium, pp. 1-1, Aug. 2023 (Sapporo, Japan).

[20] CheChia Kang, Xin Du, and Jun-ichi Takada, “Measurement of the Dynamic Radio Channel at Sub-THz Band Affected by Human Body Shadowing,” XXXVth URSI General Assembly and Scientific Symposium, pp. 1-1, Aug. 2023 (Sapporo, Japan).

[21] Xin Du and Jun-ichi Takada, “Design of Simulation Parameters in Angular-spectrum Domain for Two-dimensional Mirror Kirchhoff Approximation and Split Step Parabolic Equation,” XXXVth URSI General Assembly and Scientific Symposium, pp. 1-4, Aug. 2023 (Sapporo, Japan).

[22] Hang. Song, Mingxia Wan, and Jun-ichi Takada, “Measurement of complex permittivity by FMCW radar: investigating the influence of distance on the reflected signal,” XXXVth URSI General Assembly and Scientific Symposium, pp. 1-1, Aug. 2023 (Sapporo, Japan).

[23] Ek-amorn Shinwasusin, Nopphon Keerativoranan, Panawit Hanpinitsak, Xin Du, and Jun-ichi Takada, “Comparison of Physical Optics and Ray Tracing in Non-Planar Serration Object at Millimeter-Wave Band,” XXXVth URSI General Assembly and Scientific Symposium (URSI GASS 2023), Aug. 2023 (Sapporo, Japan).

[24] Xin Du, CheChia Kang, and Jun-ichi Takada, “Comparison Between the Fields Modeled by a Circular Cylinder and a Screen in the Transition Region,” 2023 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting, pp. 845-846, Jul. 2023 (Portland, USA).

[25] Sawaros Thanapornsangsuth, and Jonghwi Park, “Using Human-centered Design for Local Sustainable Development Challenges,” 2023 American Educational Research Association Annual Meeting (AERA), May 2023 (Chicago, IL, USA).

Publications

Domestic Conference

[26] Fumihide Kojima, Shinsuke Miwa, Toshiyuki Miyachi, Takeshi Matsumura, Hirokazu Sawada, Hiroaki Harai, Jun-ichi Takada, and Hiroshi Harada, "Construction of the evaluation environment employed for the wireless emulator -- Configuration and basic tests for the large-scale virtual evaluation environment --," IEICE Technical Report, vol. 123, no. 436, SRW2023-73, pp. 100-105, Mar. 2024 (Tokyo, in Japanese).

[27] Takeshi Matsumura, Fumihide Kojima, Hiroaki Harai, Jun-ichi Takada, and Hiroshi Harada, "Development and Verification of Radio Link Emulator for Evaluation of Radio Devices using Wireless Emulator," IEICE Techinical Report, vol. 123, no. 436, SRW2023-75, pp. 112-117, Mar. 2024 (Tokyo, in Japanese).

[28] Fumihide Kojima, Masahiro Takagi, Takeshi Matsumura, Hirokazu Sawada, Hiroaki Harai, Jun-ichi Takada, and Hiroshi Harada, "Development of virtual nodes and reconfigurable radio devices for the IEEE 802.11 based wireless emulation --- Implementations of IEEE 802.11g/ax protocol stacks and interoperability tests," IEICE Technical Report, vol. 123, no. 436, SRW2023-76, pp.118-123, Mar. 2024 (Tokyo, in Japanese).

[29] Jun-Ichi Takada and Nopphon Keerativoranan, "Implementation of Radio Propagation Model in Cyber-Physical Wireless Emulator," 2024 IEICE General Conference, BS-1-04, Mar. 2024 (Higashi-hiroshima, Hiroshima).

[30] Nopphon Keerativoranan and Jun-ichi Takada, "Concept of Double-layered Grid-based Channel Emulation for Enabling Wireless Channel Emulator in Device-to-Device Scenario," 2024 IEICE General Conference, BS-1-05, Mar. 2024 (Higashi-hiroshima, Hiroshima).

[31] Auksarapak Kietkajornrit, Nopphon Keerativoranan, and Jun-ichi Takada, "Angular-Domain Parameter Matching Utilizing Clustering Technique for Grid-Based Wireless Channel Emulation," 2024 IEICE General Conference, BS-1-06, Mar. 2024 (Higashi-hiroshima, Hiroshima).

[32] Kaito Ichijo, Hang Song, Xin Du, and Jun-ichi Takada, "Radio propagation simulation by hybrid physical and geometrical optics approximation for target imaging under the presence of dielectric shielding," 2024 IEICE General Conference, B-1A-28, BS-1-06, Mar. 2024 (Higashi-hiroshima, Hiroshima).

[33] Derun Zhou, Xin Du, Hang Song, and Jun-ichi Takada, "Low Computational Cost Unequal Interval Mirror Kirchhoff Approximation for Predicting Shadowing Effect," 2024 IEICE General Conference, C-1-18, Mar. 2024 (Higashi-hiroshima, Hiroshima).

[34] Jun-ichi Takada, Nopphon Keerativoranan, Tatsuya Nagao, Takahiro Hayashi, Minseok Kim, Yukiko Kishiki, Kenshi Horihata, Gilbert Sih Ching, Kento Sugiyama, Kentaro Saito, Tetsuro Imai, Miyuki Hirose, Azril Haniz, Hirokazu Sawada, and Takeshi Matsumura, "Radio Channel Emulation in Cyber-Physical Wireless Emulator," IEICE Technical Report, vol. 123, no. 436, SRW2023-74, pp. 106-111, Mar. 2024 (Tokyo).

[35] Jerome Silla, Jun-ichi Takada, Shinobu Yamaguchi, Sengthong Lueyang, Souvalith Phompadith, and Xaykone Phonesavath, "Assessment of community ICT access and connectivity for development of an intangible cultural heritage digital repository in Luang Prabang," 34th JASID Annual Conference, Nov. 2023 (Tokyo).

[36] Xin Du, CheChia Kang, and Jun-ichi Takada, "Novel Aperture Field Integration Method for Predicting Scattering from Reflector," 2023 IEICE Society Conference, C-1-7, Sep. 2023 (Nagoya).

[37] CheChia Kang, Xin Du, and Jun-ichi Takada, "Synchronized Dynamic Channel Measurement and Motion Capture for Sub-THz Radio Channel Affected by Human Presence," 2023 IEICE Society Conference, B-1-17, Sep. 2023 (Nagoya).

[38] Yang Miao, Minseok Kim, CheChia Kang, Naoya Suzuki, and Jun-ichi Takada, "MmWave Human Body Scattering and Blockage Measurement Using Dual-Band Distributed Beamforming," IEICE Tecchnical Report, vol. 123, no. 173, AP2023-73, pp. 37-42, Sept. 2023 (Tokyo).

[39] Takeshi Matsumura, Fumihide Kojima, Hiroaki Harai, Jun-ichi Takada, and Hiroshi Harada, "R&D of Wireless Emulator for Wireless System Evaluation in Cyberspace," IEICE Technical Report, vol. 123, no. 106, RCC2023-14, pp. 2-7 / no. 107, NS2023-32, pp. 2-7 / no. 108, RCS2023-84, pp. 26-31 / no. 109, SR2023-31, pp. 26-31 / no. 110, SeMI2023-25, pp. 20-25, July 2023 (Osaka, in Japanese).

[40] Kentaro Saito, CheChia Kang, and Jun-ichi Takada, "Estimation Method of Building Material and Structure Parameters based on Free-Space Method," IEICE Technical Report, vol. 123, no. 121, SRW2023-13, pp. 13-13, Jul. 2023 (Niigata, in Japanese).

Oral Presentation

[41] Nopphon Keerativoranan and Jun-ichi Takada, "Enabling Wireless Channel Emulator in Site-specific Device-to-Device Scenario with Grid-based Channel Modeling", 7th Management Committee and 7th Technical Meeting of COST CA20120, TD(24)07073, Jan. 2024 (Lisbon, Portugal).

[42] CheChia Kang, Xin Du, and Jun-ichi Takada, "Point Cloud-based Diffraction Path Extraction for Dynamic Human Body Shadowing Channel at 300 GHz Band in Corridor Scenario," 7th MC and 7th Technical Meeting of COST CA20120, CA20120 TD(24)07088, Jan. 2024 (Lisbon, Portugal).

[43] CheChia Kang, Xin Du, and Jun-ichi Takada, "Equivelent Edge Currents based Forward Scattering Prediction for Complex Circumference of the Cross-section of Human Body at 300 GHz Band," 6th MC and 6th Technical Meeting of COST CA20120, CA20120 TD(23)06022, Sept. 2023 (Poznan, Poland).

[44] Nopphon Keerativornan, Kentaro Saito, and Jun-ichi Takada, "Non-Stationary Site-Specific to Standard Channel Parameter Mapping for Performance Evaluation of Wireless Channel Emulator," 5th Management Committee and 5th Technical Meeting of COST CA20120, TD(23)05005, May, 2023 (Barcellona, Spain).

[45] CheChia Kang, Xin Du, and Jun-ichi Takada, "Synchronized Dynamic Channel Measurement and Motion Capture for Sub-THz Radio Channel Affected by Human Presence," 5th Management Committee and 5th Technical Meeting of COST CA20120, TD(23)05063, May 2023 (Barcelona, Spain).

Other Publications

[46] CheChia Kang, Xin Du, and Jun-ichi Takada, "Selected Scientific Topic: Synchronized Dynamic Channel Sounder and Posture Capture for Millimeter Wave Radio Channel Suffering from Human Body Shadowing," COST INTERACT Newsletter, no. 4, Apr. 2023.

[47] Sawaros Thanapornsangsuth, "Empowering Youth to Become Sustainability Leaders," Diplomatic Courier, Nov. 23, 2023.

Sakaguchi-Tran Laboratory

Transactions and Letters

[1] Z. Li, K. Wang, T. Yu, and K. Sakaguchi, "Het-SDVN: SDN Based Radio Resource Management of Heterogeneous V2X for Cooperative Perception," IEEE Access, 2023.Ryunosuke Masaoka, Gia Khanh Tran, Jin Nakazato, and Kei Sakaguchi. "The Future of Flying Base Stations: Empirical and Numerical Investigations of mmWave-Enabled UAVs." Future Internet 16.1 (2023): 5.

[2] R. Masaoka, G. K. Tran, J. Nakazato, and K. Sakaguchi, "The Future of Flying Base Stations: Empirical and Numerical Investigations of mmWave-Enabled UAVs," Future Internet, vol. 16, no. 1, p. 5, 2023.

[3] K. Wang, Z. Li, K. Nonomura, T. Yu, K. Sakaguchi, O. Hashash, and W. Saad, "Smart Mobility Digital Twin Based Automated Vehicle Navigation System: A Proof of Concept," IEEE Transactions on Intelligent Vehicles, early access article, 2024.

[4] G. K. Tran and T. Okada, "Design of Antenna Polarization Plane for Concurrent Uplink/Downlink Drone Networks," Electronics, vol. 12, no. 14, p. 3045, 2023.

[5] G. K. Tran, T. Kamei, and S. Tanaka, "Route Optimization of Unmanned Aerial Vehicle Sensors for Localization of Wireless Emitters in Outdoor Environments," Network, vol. 3, no. 3, pp. 326–342, 2023.

International Conference

[6] K. Wang, Z. Li, T. Yu, and K. Sakaguchi, "Smart mobility digital twin for automated driving: Design and proof-of-concept," in 2023 IEEE 97th Vehicular Technology Conference (VTC2023-Spring), pp. 1–6, IEEE, 2023.

[7] S. Ke, K. Sakaguchi, G. K. Tran, M. Iwabuchi, and T. Murakami, "Multi-User MIMO Based on Millimeter Wave Massive Analog Relay Stations," in 2023 IEEE 34th Annual International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC), pp. 1–6, IEEE, 2023.

[8] N. Okubo, J. Nakazato, and K. Sakaguchi, "Field Trial of AR-based Radio Signal Visualization for Better Deployment of mmWave 5G and Beyond," in 2023 IEEE 98th Vehicular Technology Conference (VTC2023-Fall), pp. 1–5, IEEE, 2023.

[9] S. Habu, K. Sakaguchi, and G. K. Tran, "MmWave Multi-beam V2X with Fountain Code for Joint Ultra-Broadband, Reliable, and Low Latency Communication," in 2023 IEEE 98th Vehicular Technology Conference (VTC2023-Fall), pp. 1–5, IEEE, 2023.

[10] R. Masaoka and G. K. Tran, "Construction and Demonstration of Access Link for Millimeter Wave UAV Base Station Network," in 2023 Fourteenth International Conference on Ubiquitous and Future Networks (ICUFN), pp. 163–167, IEEE, 2023.

[11] M. Lagahit, Z. Li, K. Sakaguchi, and M. Matsuoka, "Exploring Ground Segmentation from LIDAR Scanning-Derived Images Using Convolutional Neural Networks," The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, vol. 48, pp. 221–226, 2023.

[12] K. Wang, Z. Li, T. Yu, K. Sakaguchi, O. Hashash, and W. Saad, "Digital Twins for Autonomous Driving: A Comprehensive Implementation and Demonstration," 2024 International Conference on Information Networking (ICOIN), Ho Chi Minh City, Vietnam, 2024.

[13] K. Nonomura, K. Wang, G. Cho; H. Matsuo; J. Nakazato, Z. Li, T. Yu; and K. Sakaguchi, "Proof-of-Concept of Digital Twin for Road Safety

Assisted by B5G Heterogeneous MEC Network," 2024 IEEE Consumer Communications and Networking Conference (CCNC), Las Vegas, NV, USA, 2024.

[14] F. Noda, G. K. Tran, "Proposal of LEO based Population Estimation System using Smartphone Emitted WLAN signals," 2024 IEEE 21st Consumer Communications & Networking Conference (CCNC), Las Vegas, NV, USA, 2024

[15] S. Yamamoto, J. Nakazato, G. K. Tran, "Study on the Coverage Extension of Millimeter Wave UAV BS Networks by Using IRS," 2024 IEEE 21st Consumer Communications & Networking Conference (CCNC), Las Vegas, NV, USA, 2024

Domestic Conference

[16] J. Nakazato, K. Maruta, G. K. Tran, N. Okubo, K. Sakaguchi, "[Invited Lecture] Beyond 5G Open RAN Platform through Cross-Domain Collaboration," IEICE Tech. Rep., vol. 123, no. 436, SRW2023-51, pp. 33-38, March 2024.

[17] G. K. Tran, "[Invited Lecture] Research on UAV based smart wireless system," IEICE Technical Report; IEICE Tech. Rep., vol. 123, no. 109, pp. 25–25, 2023.

[18] N. Okubo, J. Nakazato, and K. Sakaguchi, "AR-based Radio Propagation Visualization System to Assist Area Deployment of mmWave B5G," IEICE Technical Report; IEICE Tech. Rep., vol. 123, no. 3, pp. 44–49, 2023.

[19] K. Nonomura, Y. Tao, and K. Sakaguchi, "Delivery System Optimization for Multiple Autonomous Vehicles: A DigitalTwin-Based Method and Implementation," IEICE Technical Report; IEICE Tech. Rep., vol. 123, no. 76, pp. 69–74, 2023.

[20] T. Kamei, G. K. Tran, and S. Tanaka, "Measurement to evaluate the effectiveness of fingerprint-based localization using high-altitude sensors," IEICE Technical Report; IEICE Tech. Rep., vol. 122, no. 400, pp. 47–49, 2023.

[21] Y. Furuse, G. K. Tran, and T. Shoma, "A study on a radio source location estimation system using HAPS," IEICE Technical Report; IEICE Tech. Rep., vol. 123, no. 19, pp. 55–57, 2023.

[22] R. Miura, G. K. Tran, Y. Yamamoto, K. Fukuda, M. Kishida, T. Nii, et al., "System design and evaluation of interference control based on BSS coloring mechanism in WLAN," IEICE Technical Report; IEICE Tech. Rep., vol. 123, no. 76, pp. 59–62, 2023.

[23] N. Okubo, J. Nakazato and K. Sakaguchi., "AR-based Radio Propagation Visualization System for mmWave Cellular Systems Using Analog Relay Stations," IPSJ DICOMO, pp.413-419, Jul. 2023.

[24] 王 魁, 李 宗典, 于 韜, 阪口 啓, 自動運転に向けのスマートモビリティデジタルツイン: 設計と実装, 信学技報, vol. 123, no. 76, RCS2023-39, pp. 63-68, 2023 年 6 月.

[25] 土生晋太郎, 阪口啓, タン ザカン, 複数ビームと噴水符号を用いた車載向け大容量・高信頼・低遅延 V2X 通信に関する検討, 信学技報, vol. 123, no. 172, RCS2023-126, pp. 125-130, 2023 年 8 月.

[26] 古瀬佑太, タン ザカン, HAPS 搭載アンテナを用いた電波発信源の位置推定システムの特性評価, 信学技報, vol. 123, no. 369, SR2023-74, pp. 28-30, 2024 年 1 月.

[27] 松尾大樹, ウ トウ, 阪口啓, 自動運転社会における安全性確保のための高度交差点システムの設計と実装, 信学技報, vol. 123, no. 380, ITS2023-57, pp. 62-67, 2024 年 2 月.

[28] 竹中優, 松尾大樹, ウ トウ, 阪口啓, 分散コンピューティングリソースの協調利用を支援する IoFDT(Internet of Federated Digital Twin), 信学技報, vol. 123, no. 380, ITS2023-56, pp. 56-61, 2024 年 2 月.

[29] 杉元友哉, タン ザカン, 交差点環境の V2X 通信における受信電力の遮蔽予測, 電子情報通信学会 2024 年総合大会, 2024 年 3 月.

[30] 大岡叡, 李宗典, 阪口啓, チェング ケルビン, デジタルツインを活用したデジタルサイネージ広告のコンテンツ切り替えアーキテクチャの提案, 電子情報通信学会 2024 年総合大会, 2024 年 3 月.

[31] Supat Roongpraiwan, 李宗典, 阪口啓, デジタルツインと機械学習を用いた協働ロボット

Publications

システム, 電子情報通信学会 2024 年総合大会, 2024 年 3 月.

[32] 大塚シエル, 宇都有昭, 高橋秀治, 阪口啓, 川本忠, LEO 衛星およびオフグリッド PV システムを用いた自律型農業インフラシステムの設計, 電子情報通信学会 2024 年総合大会, 2024 年 3 月.

[33] 趙 仁楷, タン ザカン, UAV を用いた災害時情報収集に関する基礎検討, 電子情報通信学会 2024 年総合大会, 2024 年 3 月.

Paten

[34] P. S. H. Leather, R. Askar, K. Sakaguchi, T. Haustein, and L. Raschkowski, "Methods and measurement systems for precisely evaluating a device under test," June 22 2023. US Patent App. 17/935,039.

[35] P. S. H. Leather, T. Haustein, K. Sakaguchi, and R. Askar, "Network device for use in a wireless communication network and an end-to-end over-the-air test and measurement system for one or more network devices," Aug. 29 2023. US Patent 11,742,961.

[36] K. Sakaguchi, K. Mahler, T. Haustein, and W. Keusgen, "Positioning of unmanned aerial vehicles using millimeter-wave beam infrastructure," Sept. 12 2023. US Patent 11,755,037.

[37] P. S. H. Leather, T. Haustein, K. Sakaguchi, L. Thiele, and T. Wirth, "Apparatus, measurement system for testing an apparatus and methods for operating the same," Sept. 26 2023. US Patent 11,770,195.

[38] P. S. H. Leather, T. Haustein, K. Sakaguchi, and R. Askar, "Network device for use in a wireless communication network and an end-to-end over-the-air test and measurement system for one or more network devices," Aug. 29 2023. US Patent 11,742,961.

[39] K. Mahler, T. Haustein, M. Grossmann, and K. Sakaguchi, "Generation and use of HD maps," Nov. 14 2023. US Patent 11,815,617.

Hirokawa-Tomura Laboratory

Transactions and Letters

[1] A. Mahmoud, T. Tomura, M. Ettorre, D. Gonz´alez-Ovejero, R. Sauleau, and J. Hirokawa, "High-gaintapered monopulse antenna based on octuple excitation method in diffusion bonding technology at W-band," IET Microw. Antennas Propag., vol.18, no.5, pp.317–330, Mar. 2024.

[2] Y. Wu, J. Hirokawa, and T. Tomura, "A perpendicular-corporate-feed parallel-plate slot array antenna by H-plane groove gap waveguides with interlaced triangular pins," IEEE Trans. Antennas Propag., vol.72, no.1, pp.1033–1038, Jan. 2024.

[3] Q. Li, J. Hirokawa, T. Tomura, and N. Fonseca, "Two-dimensional one-body 3 × 3-way hollow-waveguide nolen matrix using a two-plane unequal division coupler," IEEE Trans. Microw. Theory Techn., vol.72, no.1, pp.376-390, Jan. 2024.

[4] X. Fu, D. You, X. Wang, Y. Wang, C.J. Mayeda, Y. Gao, M. Ide, Y. Zhang, J. Sakamaki, A.A. Fadila, Z. Li, J. Sudo, M. Higaki, S. Inoue, T. Eishima, T. Tomura, J. Pang, H. Sakai, K. Okada, and A. Shirane, "A low-power 256-element Ka-band CMOS phased-array receiver with on-chip distributed radiation sensors for small satellite constellations," IEEE J. Solid-State Circuits, vol.58, no.12, pp.3380–3395, Dec. 2023.

[5] S. WU, J. Hirokawa, T. Tomura, and N. Fonseca, "Optimal adjacent output phase difference assignments in one-dimensional parallel switching matrices with four beams," IEEE J. Microw., vol.3, no.4, pp.1199–1211, Oct. 2023.

[6] H. Xiong, J. Hirokawa, and T. Tomura, "A center-fed dual-polarized parallel-plate waveguide slot array antenna based on a feeding waveguide with centered longitudinal feeding slots," IEEE Access, vol.11, pp.93793–93803, Aug. 2023.

[7] M.K. Emara, T. Tomura, J. Hirokawa, and S. Gupta, "Metallo-dielectric millimeter-wave Huygens' quarter-wave and half-wave plates," IEEE Trans. Antennas Propag., vol.71, no.8, pp.6678–6687, Aug. 2023.

[8] Q. Li, J. Hirokawa, and T. Tomura, "Two-plane waveguide coupler with arbitrary coupling ratios in the H-plane and E-plane directions," IET Microw. Antennas Propag., vol.17, no.10, pp.818–826, Aug. 2023.

[9] T. Wang, T. Tomura, J. Hirokawa, B. Pyne, P.R. Akbar, and H. Saito, "A feeding network with collinearly centered longitudinal coupling slots for a rectangular parallel-plate slot array antenna," IEEE Trans. Antennas Propag., vol.71, no.7, pp.5838–5849, July 2023.

[10] Q. Li, J. Hirokawa, T. Tomura, Y. Takahashi, N. Kita, and N.J.G. Fonseca, "A two-dimensional 6 × 4-way hollow waveguide beam-switching matrix," IEEE Access, vol.11, pp.74239-74249, July 2023.

[11] Y. Wu, T. Tomura, J. Hirokawa, and M. Zhang, "A wideband full-metal sidewall-loaded magnetoelectric dipole array based on combined ridge and groove gap waveguide in the Q band," IEEE Trans. Antennas Propag., vol.71, no.7, pp.6156–6161, July 2023.

[12] Y. Akamine, T. Tomura, and J. Hirokawa, "Single-cut scattered field transformation applicable for differences in the radar ranges of transmitter and receiver," IEEE Trans. Antennas Propag., vol.71, no.6, pp.5310–5321, June 2023.

[13] J. Shuang, J. Hirokawa, T. Tomura, and H. Saito, "X-band grating-loaded parallel-plate slot array antenna with low reflection," IEICE Commun. Express, vol.12, no.6, pp.277–281, June 2023.

Publications

Fukawa Laboratory

Transactions and Letters

[1] Yuyuan Chang and Kazuhiko Fukawa, "Non-orthogonal multiple access based on orthogonal space-time block codes for mobile communications," IEICE Transactions on Communications, vol. E106.B, no. 10, pp. 1024-1033, Oct. 2023.

[2] Binu Shrestha, Yuyuan Chang, and Kazuhiko Fukawa, "Device-to-device communications employing fog nodes using parallel and serial interference cancelers," IEICE Transactions on Communications, vol. E107.B, no. 1, pp. 223-231, Jan. 2024.

International Conference

[3] Yun Li, Yuyuan Chang, Kazuhiko Fukawa, and Naoki Kodama, "Reinforcement learning-based cognitive radio transmission scheduling in vehicular systems," 2023 IEEE 97th Vehicular Technology Conference (VTC2023-Spring), Florence, Italy, Jun. 2023, pp. 1-5.

[4] Huiying Song, Yuyuan Chang, and Kazuhiko Fukawa, "A CSI-based construction scheme for GN-Coset codes over frequency selective fading channels," 2023 IEEE 97th Vehicular Technology Conference (VTC2023-Spring), Florence, Italy, Jun. 2023, pp. 1-5.

[5] Yuki Ono, Yuyuan Chang, Kazuhiko Fukawa, Satoshi Suyama, and Takahiro Asai, "Time-varying channel prediction for pilot contamination mitigation in hybrid massive MIMO communications," 2023 IEEE 97th Vehicular Technology Conference (VTC2023-Spring), Florence, Italy, Jun. 2023, pp. 1-5.

[6] Zijie Liang, Yiwei Su, Huiying Song, Kazuhiko Fukawa, and Yuyuan Chang, "A slotted polar random spreading scheme for massive MIMO unsourced random access," 2023 IEEE 98th Vehicular Technology Conference (VTC2023-Fall), Hong Kong, Hong Kong, Oct. 2023, pp. 1-5.

Domestic Conference

[7] Kohei Nozaki, Yuyuan Chang, Kazuhiko Fukawa, and Daichi Hirahara, "Low-complexity multiuser detection of multiple collided packets in space-based AIS experiments," IEICE Tech. Report, vol.122, no. 409, SAT2022-71, pp. 87-92, Mar. 2023 (in Japanese).

[8] Yuki Ono, Yuyuan Chang, Kazuhiko Fukawa, Satoshi Suyama, and Takahiro Asai, "Time-varying channel prediction for pilot contamination alleviation in hybrid massive MIMO communications," IEICE Tech. Report, vol.122, no. 399, RCS2022-296, pp. 255-260, Mar. 2023 (in Japanese).

[9] Kohei Nozaki, Yuyuan Chang, Kazuhiko Fukawa, "Low-complexity signal detection for more than two collided packets in space-based AIS," IEICE Society Conf., B-5-58, Mar. 2023 (in Japanese).

[10] Yuki Ono, Yuyuan Chang, Kazuhiko Fukawa, Satoshi Suyama, and Takahiro Asai, "Channel prediction of time-varying channels to mitigate pilot contamination for hybrid beamforming massive MIMO systems," IEICE Society Conf., B-5-103, Mar. 2023 (in Japanese).

[11] Zhengjun Qian, Yuyuan Chang, and Kazuhiko Fukawa, "Iterative maximum likelihood detection schemes for faster-than-Nyquist signals," IEICE Tech. Report, vol. 123, no. 172, RCS2023-114, pp. 61-66, Aug. 2023.

[12] Yun Li, Yuyuan Chang, and Kazuhiko Fukawa, "Resource management using reinforcement learning for V2X communications to support autonomous driving," IEICE Tech. Report, vol. 123, no. 172, RCS2023-115, pp. 67-72, Aug. 2023.

[13] Zhengjun Qian, Yuyuan Chang, and Kazuhiko Fukawa, "Iterative MLD receiver for faster-than-Nyquist signals," IEICE Society Conf., B-5-23, Sept. 2023.

[14] Yun Li, Yuyuan Chang, and Kazuhiko Fukawa, "Optimized channel selection in vehicular systems using reinforcement learning techniques," IEICE Society Conf., B-5-2, Sept. 2023.

[15] Yuki Ono, Yuyuan Chang, Kazuhiko Fukawa, Satoshi Suyama, and Takahiro Asai, "Time-varying channel prediction based on angle variation model for analog-digital-hybrid massive MIMO communications," IEICE Society Conf., B-5A-54, Mar. 2024 (in Japanese).

[16] Keigo Shimada, Kazuhiko Fukawa, Yuyuan Chang, "Machine learning based compensation for IQ imbalance and nonlinear amplification of wireless communications circuits," IEICE General Conf., B-5A-78, Mar 2024 (in Japanese).

[17] Yuyuan Chang and Kazuhiko Fukawa, "Theoretical analysis of linear compensation for IQ Imbalance in mobile communications circuits," IEICE Society Conf., B-5A-79, Mar. 2024 (in Japanese).

[18] Yuki Ono, Yuyuan Chang, Kazuhiko Fukawa, Satoshi Suyama, and Takahiro Asai, "Time-varying channel prediction considering angle-of-arrival variation for hybrid massive MIMO communications," IEICE Tech. Report, vol. 123, no. 434, RCS2023-287, pp. 146-151, Mar. 2024 (in Japanese).

[19] Yuyuan Chang and Kazuhiko Fukawa, "Predistortion Exploiting Linear Estimation and Its Residual Errors for IQ Imbalance and Nonlinear Amplification in Wireless Communications Circuits," IEICE Tech. Report, vol. 123, no. 434, RCS2023-290, pp. 164-169, Mar. 2024 (in Japanese).

[20] Keigo Shimada, Kazuhiko Fukawa, Yuyuan Chang, "Compensation schemes for IQ imbalance and nonlinear amplification using machine learning techniques," IEICE Tech. Report, vol. 123, no. 434, RCS2023-291, pp. 170-175, Mar. 2024 (in Japanese).

Publications

Fujii-Ohta Laboratory

Transactions and Letters

[14] Hikari Tsuhama, and Teruya Fujii, "Theoretical Analysis of 3D Spatial Autocorrelation Characteristics of Nakagami-Rice Fading in Sky Radio Propagation," IEICE Transactions on Communications, Vol.J106-B, no.9, pp631-636, Sep. 2023

International Conference

[15] Takafumi Fujii, and Teruya Fujii, "A Basic Study on Cancelling Same Frequency Interference from 5G Systems to Other Systems by a Cooperative Control Network," 2023 IEEE 97th Vehicular Technology Conference (VTC2023-Spring), Jun. 2023

[16] Takuya Kaneda, Takafumi Fujii, and Teruya Fujii, "Uplink Interference Canceller and Processing Amount Reduction Method of Macrocell in 3Dimension Spatial HetNet Construction," 2023 IEEE 97th Vehicular Technology Conference (VTC2023-Spring), Jun. 2023

[17] Takafumi Fujii, and Teruya Fujii, "Prototype Development of Same-frequency Interference Canceller from 5G Base Stations to Satellite Ground Stations," 2023 IEEE 98th Vehicular Technology Conference(VTC2023-Fall), Oct. 2023

Domestic Conference

[18] Kohei Mitsumoto, Ryohei Maeda, Hikari Tsuhama, and Teruya Fujii, "A Study on Optimal Configuration of Massive Antenna for MU-MIMO Base Station Considering 3D Spatial Radio Arrival Angle Characteristics," IEICE Technical Report, RCS2023-1, Apr. 2023

[19] Takashi Fujii, and Teruya Fujii, "A Prototype of Equipment that cancels Interference from 5G Base Stations to Satellite Ground Stations", IEICE Technical Report, RCS2023-112, Aug. 2023

[20] Takuya Kaneda, Takashi Fujii, and Teruya Fujii, "A Study on Channel Response Estimation of Neighboring Cell Terminals using SRS in 3D Spatial Cell Configuration for Mobile Communications," IEICE Technical Report, RCS2023-117, Sep. 2023

[21] Ryohei Maeda, Takashi Fujii, and Teruya Fujii, "Virtual Cell MU-MIMO Canceller Coordinating Base Stations in TDD Transmission －Eigenmode Transmission without Feedback of Transmit and Receive Weights－," IEICE Technical Report, RCS2023-118, Sep. 2023

[22] Takashi Fujii, and Teruya Fujii, "Prototype of Equipment that cancels Interference from 5G Base Stations to Satellite Ground Stations," IEICE Society Conf., B-5-20, Sep. 2023

[23] Ryohei Maeda, Takashi Fujii, and Teruya Fujii, "A Basic Study of MU-MIMO Canceller without Feedback of Transmit and Receive Weights in TDD Transmission," IEICE Society Conf., B-5-22, Sep. 2023

[24] Takuya Kaneda, Takashi Fujii, and Teruya Fujii, "A Study on Channel Response Estimation of Neighboring Cell Terminals using SRS in 3D Spatial Cell Configuration for Mobile Communications," IEICE Society Conf., B-5-12, Sep. 2023"

[25] Kohei Mitsumoto, Ryohei Maeda, and Teruya Fujii, "A Study on Optimized Configuration of Massive Antennas for MU-MIMO Base Stations," IEICE Society Conf., B-5-33, Sep. 2023

[26] Teruya Fujii, and Takashi Fujii, "Proposal of 3D spatial cell configuration integrated HAPS and Beyond 5G in mobile communication," IEICE Society Conf., BI-5-6, Sep. 2023

[27] Takashi Fujii, Takuya Kaneda, Ryohei Maeda, and Teruya Fujii, "Construction of Coordinated Base Stations for Network Coordination Interference Canceller," IEICE Technical Report, RCS2023-176, Nov. 2023

[28] Teruya Fujii, and Takashi Fujii, "The same

frequency sharing by coordinating between UAV/HAPS and terrestrial cellular,"
IEICE Technical Report, RCS2023-177, Nov. 2023
[29] Teruya Fujii, "High-accuracy 3D Spatial Measurement of Nakagami-Rice Variation K-Factor in Sky Cells," IEICE Technical Report, RCS2023-202, Dec. 2023
[30] Takuya Kaneda, Takashi Fujii, and Teruya Fujii, "A Study on Channel Response Estimation of Neighboring Cell Terminals using SRS in 3D Spatial Cell Configuration for Mobile Communications - Considering Frequency Offset in SRS -,"
IEICE Technical Report, RCS2023-203, Dec. 2023
[31] Ryohei Maeda, Takashi Fujii, and Teruya Fujii, " Optimization of Base Station Coordinated Virtualized Cell MU-MIMO Canceller according to the Accuracy of Channel Estimation,"
IEICE Technical Report, RCS2023-204, Dec. 2023"
[32] Makoto Sugisawa, and Teruya Fujii, "Sharing the same frequency between UAV temporary relay system and terrestrial cellular system during disasters," IEICE General Conf., B-5A-13, Mar. 2024
[33] Takashi Fujii, Takuya Kaneda, Ryohei Maeda, and Teruya Fujii, " System Configuration of Base Stations to Realize Network Coordinated Interference Canceller," IEICE General Conf., B-5A-14, Mar. 2024
[34] Teruya Fujii, Kouichi Kawai, Susumu Yoneda, and Ito Takeshi, "Measurement Accuracy of K factor in the sky cell," IEICE General Conf., B-1A-21, Mar. 2024
[35] Toshihisa Tsuji, and Teruya Fujii, " Frequency sharing between ground and sky cells by applying beamforming and MU-MIMO canceller,"
IEICE General Conf., B-5A-55, Mar. 2024
[36] Ryohei Maeda, Takashi Fujii, and Teruya Fujii, "Optimization of Base Station Coordinated MU-MIMO Canceller according to the Accuracy of Channel Estimation," IEICE General Conf., B-5A-56, Mar. 2024
[37] Takuya Kaneda, Takashi Fujii, and Teruya Fujii, "A Study on Channel Response Estimation of Terminals in Neighboring Cells using SRS,"
IEICE General Conf., B-5A-60, Mar. 2024
[38] Teruya Fujii, Susumu Yoneda, Kouichi Kawai, and Ito Takeshi, "Measurement accuracy of K factor in the sky cell for 3D spatial cell construction,"
IEICE Technical Report, A・P2023-216, Mar. 2024