MCRG Tokyo Tech

Mobile Communications Research Group
Tokyo Institute of Technology

2017

ANNUAL REPORT

Contents

MCRG Tokyo Tech

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.

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 5 cooperate laboratories. Totally 9 professors, 5 associate professors, and 5 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. Kentaro Saito, Assist. Prof. Takuichi Hirano, and
  Specially Appointed Assoc. Prof. (Lect.) Azril Haniz
- Sakaguchi Laboratory (System Lab.):
  Prof. Kei Sakaguchi, Assist. Prof. Gia Khanh Tran, and Emeritus Prof. Kiyomichi Araki
- Hirokawa Laboratory (Antenna Lab.):
  Prof. Jiro Hirokawa, and Specially Appointed Assist. Prof. Takashi Tomura
- Fukawa Laboratory (Signal Processing Lab.):
  Prof. Kazuhiko Fukawa, and Assist. Prof. Yuyuan Chang
- Matsuzawa and Okada Laboratory (Device Lab.):
  Prof. Akira Matsuzawa, and Assoc. Prof. Kenichi Okada

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
- Watanabe Laboratory:
  Visiting Prof. Fumio Watanabe
- 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. From 1992 to 1994, he was a Research Associate at Chiba University. From 1994 to 2006, he was an Associate Professor at Tokyo Institute of Technology, where he has been a Professor since 2006. He is currently the Chair of the Department of Transdisciplinary Science and Engineering, School of Environment and Society. He was also 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 fellow of IEICE, senior member of IEEE, and member of Japan Society for International Development (JASID).

Assistant Professor Kentaro Saito

Assist. Prof. Kentaro Saito was born in Kanagawa, Japan, in 1977. He received his B.S. and Ph.D. degrees from the University of Tokyo, Japan, in 2002 and 2008, respectively. He joined NTT DOCOMO, Kanagawa, Japan, in 2002. Since then, he has been engaged in the research of IP networks, transport technologies, MAC technologies, and radio propagation for mobile communication systems. He has been engaged in the development of the LTE base station. He joined Tokyo Institute of Technology, Japan in 2015. Since then, he has been engaged in research of radio propagation measurements and MIMO channel modeling. He is a senior member of IEICE and a member of IEEE.

Assistant Professor Takuichi Hirano

Assist. Prof. Takuichi Hirano received a B.S. in electrical and information engineering from Nagoya Institute of Technology, Nagoya, Japan in 1998. He received his M.S. and D.E. degrees from the Tokyo Institute of Technology, Tokyo, Japan, in 2000 and 2008, respectively. He is currently an Assistant Professor with the Tokyo Institute of Technology. He has been involved with electromagnetic theory, numerical analysis for EM problems and antenna engineering such as slotted waveguide arrays. He received the Young Engineer Award from IEICE Japan in 2004, IEEE AP-S Japan Chapter Young Engineer Award in 2004 and IEEE MTT-S Japan Chapter Young Engineer Award in 2011. He is a member of IEICE, IEEJ and IEEE.

Specially Appointed Associate Professor (Lecturer) Azril Haniz

Dr. Azril Haniz received the B.E. degree in electrical and electronic engineering in 2010, and the M.Eng and Dr.Eng. degrees from the Dept. of International Development Engineering in Tokyo Institute of Technology, Japan in 2012 and 2016, respectively. He is currently working as a specially appointed associate professor in the same university. He won the best student paper award in the Singapore-Japan International Workshop on Smart Wireless Communications (SmartCom) in 2014, and is a recipient of the 2016 Tejima Seiichi Doctoral Dissertation Award. His research interests include localization, cognitive radio, sensor networks and signal processing. He is currently a member of IEEE and IEICE.

Recent Research Topics

- Dolph-Chebyshev Beamforming for SHF bands Channel Characterization in Indoor Environment
- Development of SIMO Channel Sounding System in 12GHz by Utilizing Radio-on-Fiber Technology
- Shadowing Effect of Obstacles on Millimeter-wave Band Propagation Channel in Indoor Environment
- 11 GHz Urban Microcell Radio Channel Prediction Using Software Based Visual Inspection for An Automatic Clustering Algorithm
- Propagation Delay Analysis for VHF Band Broadband Mobile Communication Systems
- Radio Propagation Measurement and Channel Modeling in Outdoor Agriculture Environment for Wireless Sensor Network
- Building Entry Loss Measurement in High-Rise Environment by Unmanned Aerial Vehicle
- GPSDO based Synchronization Method for Channel Sounders using SDR Platform
- Localization of Unknown Radios in Urban Environments
- Pattern Recognition based Hand Motion Tracking System using Channel State Information from Commodity Wi-Fi Devices
- Utilizing Cluster Computing for Generative Adversarial Networks of Deep Learning Model to Extract and Reconstruct Signal Features
- Device-free Localization utilizing low-cost devices in Indoor Environments
- Path Loss Prediction by using Machine Learning for Wireless LAN Site Planning
- Equivalence Between Orbital Angular Momentum (OAM) and Multiple-Input Multiple-Output (MIMO) in Uniform Circular Arrays
- Representation Method of Wireless Network Area Quality by Augmented Reality Technology
- Education in Asia (Internationalization of Higher Education through a Study Abroad Program)

Takada Laboratory

Dolph-Chebyshev Beamforming for SHF bands Channel Characterization in Indoor Environment (A collaborative research with Aalborg University)

Due to increasing demand for higher data rate systems, 5G wireless systems utilizing a wide range of frequency bands and massive number of antenna arrays have been considered. Because the performance of the system depends on the environment, the accurate characterization of spatial-temporal multipath channels becomes inevitable. However, by using massive number of antennas with omni-directional elements, the sidelobe level (SLL) becomes very high, which degrades the characterization accuracy. Thus, this study extends the Dolph-Chebyshev Beamforming (DCBF) for Uniform Circular Array (UCA) to reduce the sidelobes in the actual measurement data, which is measured at three SHF bands: 3, 10 and 28 GHz. Figure 1 shows the DCF in comparison with conventional beamforming (CBF). It can be observed that the extended DCBF can significantly reduce the SLL compared with CBF.

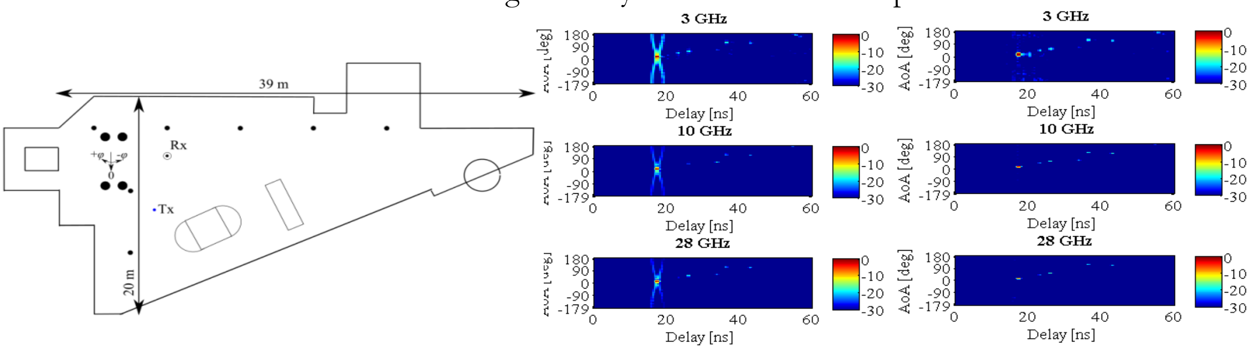


Fig 1. (Left) Measurement Environment, (Middle) CBF Results, (Right) DCBF Results

Development of SIMO Channel Sounding System in 12GHz by Utilizing Radio-on-Fiber Technology

(Supported by JSPS KAKENHI No. 15H04003 and No. 16K18102)

From the channel sounding system point of view, cabling loss owing to coaxial cable in high frequency bands is not negligible since it often limits propagation measurement distance. Also, as the number of antennas increases, measurement set up such as calibration procedure becomes troublesome. In order to solve these issues, Radio-on-Fiber (RoF) technology has been introduced to our Single Input Multiple Output (SIMO) channel sounding system. Our sounding system utilizes VNA and switched array scheme so that quasi-dynamic measurements can be conducted. In this work, stability of parameters such as phase and amplitude against ambient temperature shift are verified since RoF is susceptible to such change. Unlike most literature which investigate these impacts for antenna pattern measurement, impact on AoA estimation result is revealed. As shown in Fig. 1, strong relationship between phase and temperature is confirmed. Fig. 2 shows the AoA estimation result before/after the temperature change. Despite of strong relationship between phase and temperature, its impact on AoA estimation is acceptably small due to similar characteristics of phase shift among antenna elements.

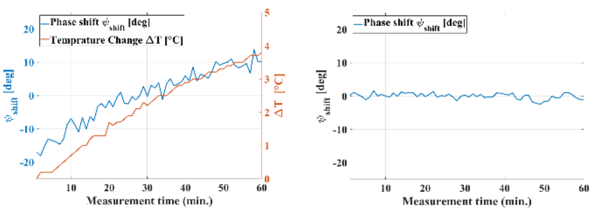


Fig 1. Phase shift with temperature change(left) and without the change(right)

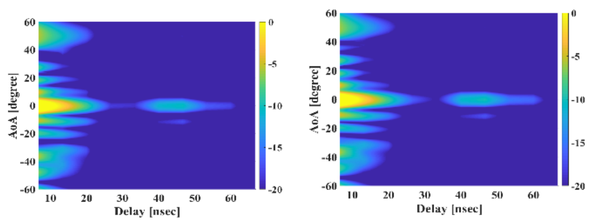


Fig.2 AoA estimation result before temperature change(left) and after the change(right)

Shadowing Effect of Obstacles on Millimeter-wave Band Propagation Channel in Indoor Environment (A collaborative research with NTT)

In next generation 5G systems, millimeter wave bands (24GHz – 86GHz) can provide the additional bandwidth to meet these data traffic demands. However, at higher frequency bands, since beam width is narrower, huge shadowing loss will result from object blockage. In this work, the shadowing loss caused by multiple obstacles in different places at 26GHz and 66GHz frequency bands in an indoor environment was measured and evaluated. This experiment focused on the characteristics of the direct wave. On the Rx side, a directional antenna was rotated to measure the directional characteristics of channel. With the rotating Rx antenna, power delay profile (PDP) was measured in all directions, and merged to obtain the angle delay power spectrum (ADPS). From the ADPS, path gain of the direct wave could be analyzed. The shadowing quantity was calculated by comparing the path gain of direct wave with and without the existence of the obstacle. Results show the shadowing characteristics for several frequencies and obstacles. Results from this work is expected to be useful in designing wireless systems and cells.

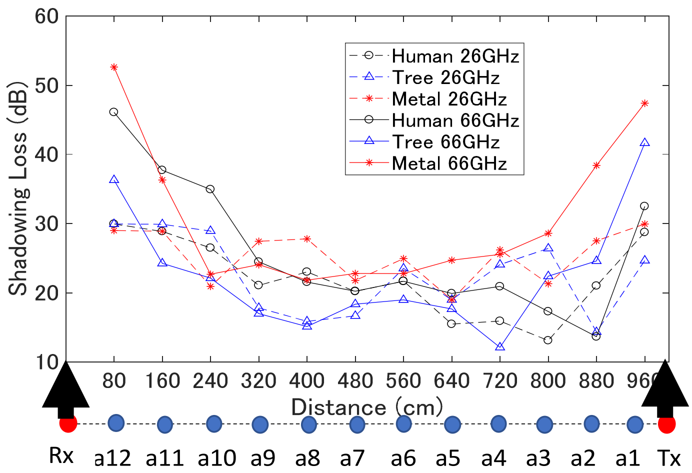


Fig.: Shadowing Loss in indoor environment

11 GHz Urban Microcell Radio Channel Prediction Using Software Based Visual Inspection for An Automatic Clustering Algorithm

The accuracy of the model is necessary for the design of the wireless system, as the performance of the wireless communication depends on the propagation environment. In the physical channel model, the characterization of the propagation environment relies the electromagnetic wave propagation. The path parameters of the radio waves that are the direction-of-depart (DOD), the direction-of-arrival (DOA), and delay for each MPC are determined using the SAGE algorithm. The geometry based stochastic channel model (GSCM) characterizes the propagation channel model by placing typical scatterers randomly to the simulation environment. Accurate description of the environment including the geometry, material characteristic becomes necessary to identify the dominant propagation paths and scattering objects of the multipath components. The geometry based stochastic channel model (GSCM) characterizes the propagation channel by placing typical scatterers randomly to the simulation environment.

The visual inspection of the scattering objects using the S2-lite as extension of the ArcGIS software is performed. The S2-Lite takes as it inputs the radio channel parameters provided by the SAGE algorithm. This tool is being used, as an alternative of the measurement based ray tracing, to create accurate cluster based channel model which contributes to the development of the GSCMs.

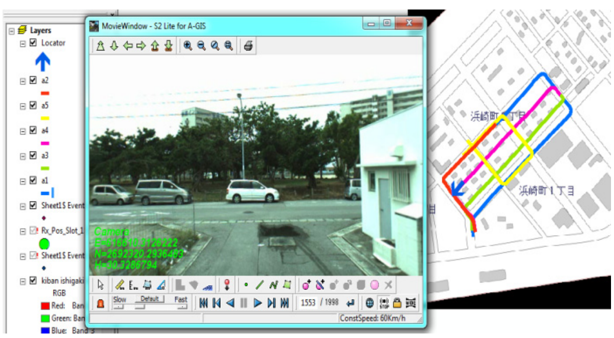


Fig.: Visualization of the measurement path

Takada Laboratory

Propagation Delay Analysis for VHF Band Broadband Mobile Communication Systems (A collaborative research with National Institute of Information and Communications Technology (NICT))

The public broadband mobile communication (PBB) system in the VHF band is expected to be a flexible wireless communication system suitable to share critical information using real time video streaming for disaster relief purpose. Recently, the PBB system has been developed and the performance was evaluated. For the improvement of the current system and developing future PBB systems, the characterization of delay profiles in various environments are important for system design. Figure 1 shows an example of a measured channel impulse response (CIR) in an urban environment and multiple delay paths were observed. Figure 2 shows the measured fading characteristics in both frequency and excess time domain and frequency selectivity was observed. However, its varies slowly with time. From these delay properties we are trying to develop a more accurate statistical channel model.

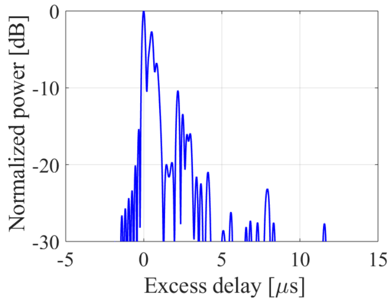


Fig. 1 Channel Impulse Response

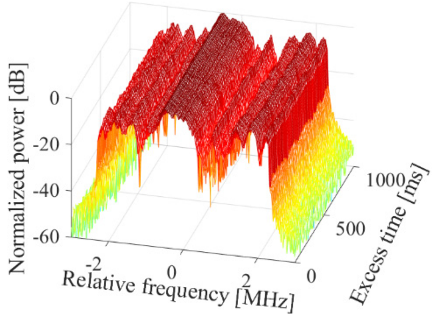


Fig. 2 Fading characteristics

Radio Propagation Measurement and Channel Modeling in Outdoor Agriculture Environment for Wireless Sensor Network

(A collaborative research with National Electronics and Computer Technology Center, Thailand. The work is partly supported by Fujikura Foundation)

A measurement campaign in two common types of tropical agriculture environments, which have the forest characteristic (vegetation dominated by tree with a single trunk: jackfruit orchard) and not (a tall food grass: sugarcane field) was conducted by using a developed channel sounder [24] having a bandwidth of 45.6 MHz at 2.45 GHz. The location of Tx was fixed and then the Rx was moved over the vegetation depth and angular direction as shown in Fig 1. The results reveal that the number of trees/ridges which exist between Tx and Rx is the reason behind of the variation of the excess loss caused by the vegetation over angular direction. Therefore, the modified maximum attenuation (MA) model, which is a function of number of ridges, is proposed to better represent the vegetation attenuation regardless of the angular parameter shown as Fig 2. Utilizing such proposed model, the procedure of predicting the received power at any point in the agriculture field by using a few measurement data is proposed.

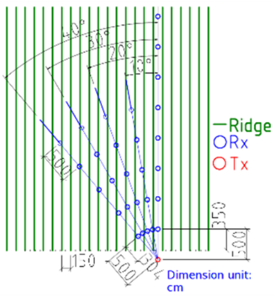


Fig. 1. A part of the measurements in sugarcane field.

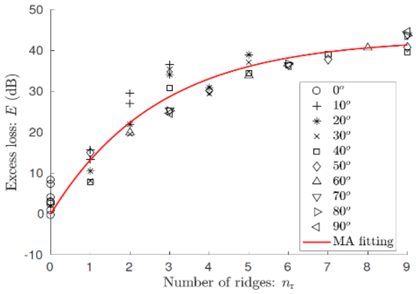


Fig. 2. The excess loss over the number of ridges between Tx and Rx.

Building Entry Loss Measurement in High-Rise Environment by Unmanned Aerial Vehicle

(Supported by Support Center for Advanced Telecommunications (SCAT) Foundation.)

Since the user traffic in the mobile wireless communication is rapidly increasing, and the more optimized service area planning is needed to solve the issue. Especially in the high-rise environments, the knowledge of the outdoor-to-indoor radio propagation characteristics is indispensable to optimize the service area, because radio waves enter the indoor from many directions from outside in those areas.

In this research, we propose the radio measurement method by using the Unmanned Aerial Vehicle (UAV). The lightweight radio equipment was implemented on the commercial software-defined radio platform. The building entry loss (BLE) characteristics were measured in the university's campus. And the results showed that the BLE ranged from 15 dB to 20 dB in the research building. The results are expected to be utilized for the improvement of BLE model.

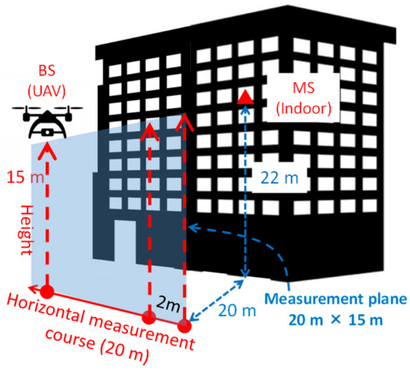


Fig. 1 Measurement method

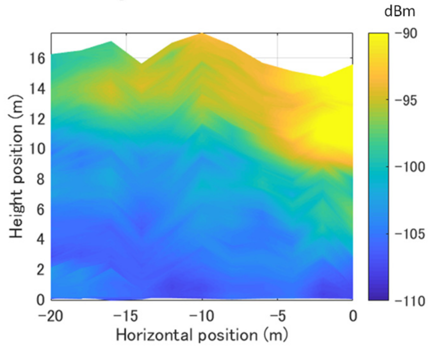


Fig. 2 Horizontal-Height profile of Received power

GPSDO based Synchronization Method for Channel Sounders using SDR Platform

Accuracy of channel characteristics measured by the channel sounder depends on accuracy of time and phase synchronization between transmitter (Tx) and receive (Rx). In this work, GPSDO based synchronization is considered because of its cheaper price and flexibility compared to conventional channel sounders. Carrier synchronization of 4.85 GHz signal in the indoor environment using GPS signals is examined by installing a GPS antenna on the roof top and extending it to an indoor room using a low loss coaxial cable. Experiment was conducted with back to back connection between Tx and Rx in a SDR platform using USRP and GNU Radio and a 10 MHz output signal from two GPSDOs disciplined with same 1PPS GPS signal are fed to Tx and Rx. It is found that the phase follows as predictable behavior when measured for 8 seconds. Also, from the calculation of auto correlation, phase is found to be highly correlated within 4 seconds. In the future, phase synchronization will be tested using two GPS antennas feeding to the GPSDO separately and for longer time to find out the exact coherence time.

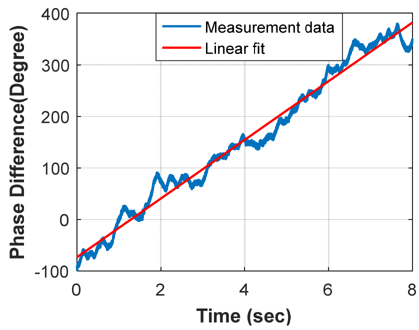


Fig. 1 Phase coherency of 4.85 GHz signal

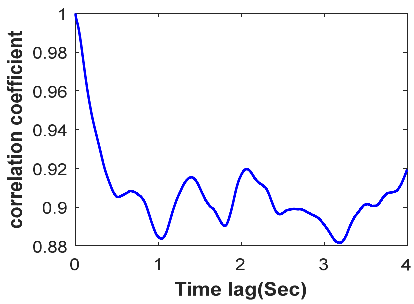


Fig. 2 Autocorrelation of received signal

Takada Laboratory

Localization of Unknown Radios in Urban Environments

(A collaborative research with Koden Electronics)

Unknown radios have the potential to cause harmful interference to existing radio systems, thus it is crucial to localize these radios in order to stop their transmission and prevent service disruption. In this research, a novel algorithm to localize unknown radios in urban environments is proposed. The fingerprinting technique is employed, which is expected to perform better than conventional localization techniques such as triangulation in urban environments where there may be many obstacles obstructing the direct line-of-sight path between the unknown radio and the receiver sensor.

The phase-difference between two antenna elements on an array is utilized as the location fingerprint. One advantage of using this fingerprint is that it contains information regarding the dominant multipath's AOA (angle-of-arrival) without explicitly estimating the unknown radio's AOA. This enables the system to localize radios at a wide range of frequencies without changing the array geometry. The training fingerprints in the database are interpolated in the frequency and spatial domains before performing pattern matching. Simulation results indicated that it could achieve much higher localization accuracy compared to conventional techniques.

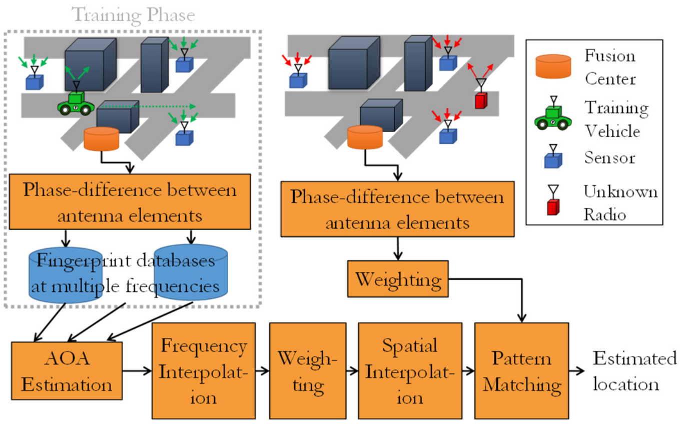


Fig. 1 Flowchart of proposed algorithm

Pattern Recognition based Hand Motion Tracking System using Channel State Information from Commodity Wi-Fi Devices

Device-free hand motion tracking in the air becomes an essential tool for today's human-computing interaction applications such as smart home, virtual and augmented reality. Typical tracking systems, mostly camera-based, have some limitations; small tracking coverage, surrounding light dependency, privacy issue, and requirement of obstacle-free area. Because RF is not affected by the limitations of the conventional system, an alternative hand motion tracking system using commercial Wi-Fi devices is proposed.

Although it is very challenging to directly trace hand motion trajectory with Wi-Fi systems, utilizing channel characteristics provided by Wi-Fi channel state information (CSI) allows us indirectly to perceive motion via the Doppler frequency shift. Our proposed technique arises from the concept that any motion is a combination of hand moving in different angles. Therefore, by recognizing these motions consecutively as Doppler shifts, trajectory of hand motion could be implicitly inferred. Currently, our experiment shows that after applying Wavelet transform to calibrated CSI, 1D hand motion when moving toward and away from the Wi-Fi receiver are detected.

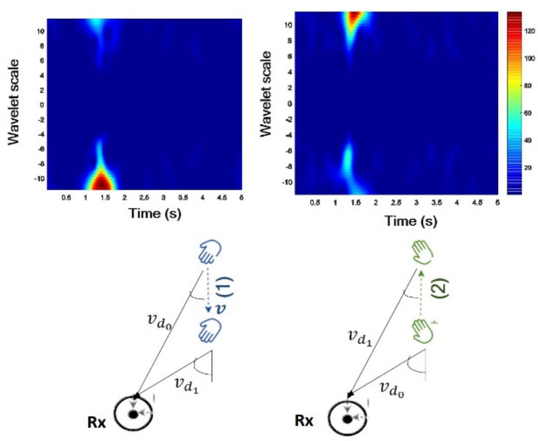


Fig: 1D hand motion reflected as power concentration in Doppler shift domain during 1 – 1.5 sec

Utilizing Cluster Computing for Generative Adversarial Networks of Deep Learning Model to Extract and Reconstruct Signal Features

(Part of the joint research projects between Tokyo Institute of Technology and National Taiwan University of Science and Technology)

Deep learning is a branch of machine learning with rising popularity in recent years. It performs exceptionally well in visual recognition tasks, and in finding complex patterns directly from raw data. One applicable problem is reconstructing sensing data gathered sparsely in a complex environment which is usually difficult to extract features for further processing. By treating signal compositions as spatial patterns, the strength of deep learning can be applied to reconstruct signal maps given conditions and environment setups, similar to the task of applying colors to sketches. Conditional Generative Adversarial Network, one of the recent deep learning models, is applied to generate realistic signal maps. And since neural networks are embarrassingly parallel in nature, cluster computing such as TSUBAME 3.0 of Tokyo Tech, can be used to dramatically speed up its training phase.

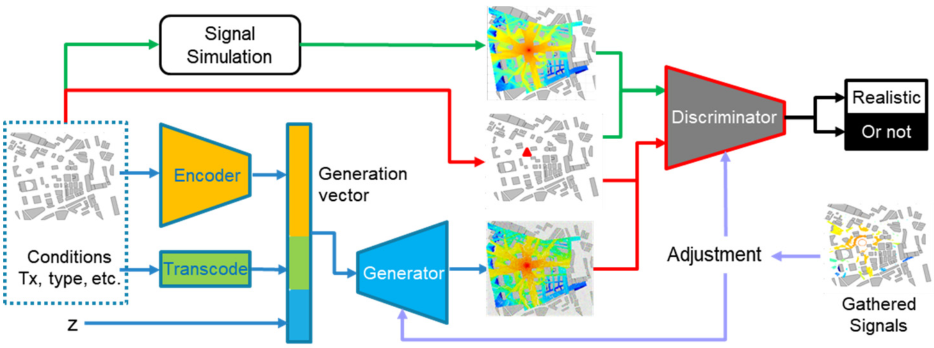


Fig. Adversarial Model of Generator and Discriminator for Automatic Signal Reconstruction

Device-free Localization utilizing low-cost devices in Indoor Environments

Due to the increasing demand for the localization Based Service (LBS), wireless localization technologies have become very popular. Because GPS does not work well in indoor environments, indoor localization has become a focus of research and development recently. In this research, a low-cost device-free indoor localization system by using Raspberry Pi is established. And now we are trying to realize it with high accuracy. The fingerprinting technique is employed. In our proposed system, the Received Signal Strength (RSS) of Bluetooth Low Energy (BLE) is used as fingerprints. Raspberry Pi is utilized as BLE beacons to implement the indoor localization system. Raspberry Pi is a low-cost small single-board computer. It can transmit and receive BLE signals by mounting BLE USB dongle. Using this property, we can make algorithm of Indoor Localization more flexible. We also constructed the automatic measuring system to make indoor localization experiment more smoothly.

Fig. Photo of Raspberry Pi

Takada Laboratory

Path Loss Prediction by using Machine Learning for Wireless LAN Site Planning

Wireless local area networks (WLAN) draw growing interests due to the demand for ubiquity and better quality of services (QoS) with lower costs. WLAN site planning, to determine the location of access point (AP) so as to cover the designated areas with the sufficient QoS, has been an important topic. Many research works as well as the commercial planning tools are already available. Most of such tools rely on the propagation simulation, but there are two challenges, i.e. the accuracy of the simulation, and the availability of detailed building. This study proposes a propagation path loss model based on a small amount of measurements and machine learning to improve the accuracy of propagation prediction.

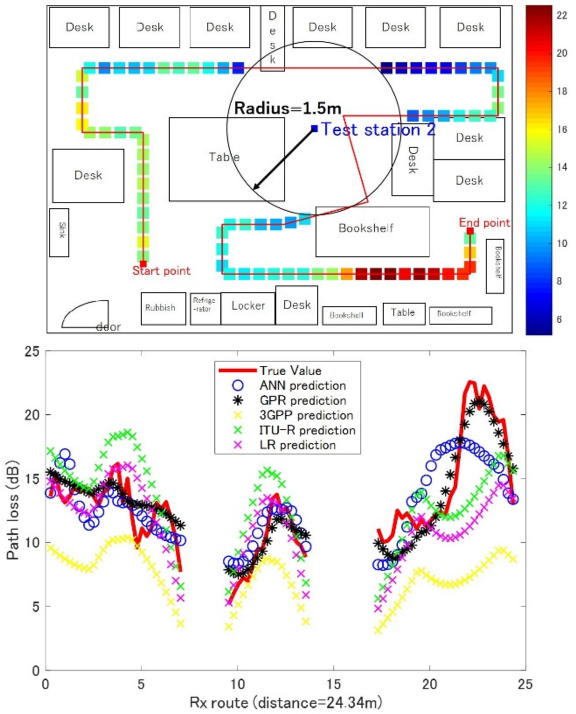


Fig. Path loss prediction by machine learning

Equivalence Between Orbital Angular Momentum (OAM) and Multiple-Input Multiple-Output (MIMO) in Uniform Circular Arrays

- Investigation by Eigenvalues -

Communication using orbital angular momentum (OAM) was demonstrated in the optical field using fiber. In the OAM, Gaussian beam with linear phase taper $2n\pi$ (n: integer; the OAM state) around the beam axis is used. Different OAM states can carry independent signals simultaneously. The OAM is analogy to the state of electrons in quantum theory. Equivalence between the OAM and MIMO was investigated by UCAs.s It was found that the array excitation vectors in the MIMO become helical phase distribution used in the OAM, and equivalence between the OAM and MIMO was proved for UCAs. The radius and distance characteristics of eigenvalues were also investigated. It was found that MIMO and/or OAM performance improves in the near-field region. It was also found that the performance improves when radius of UCAs becomes large.

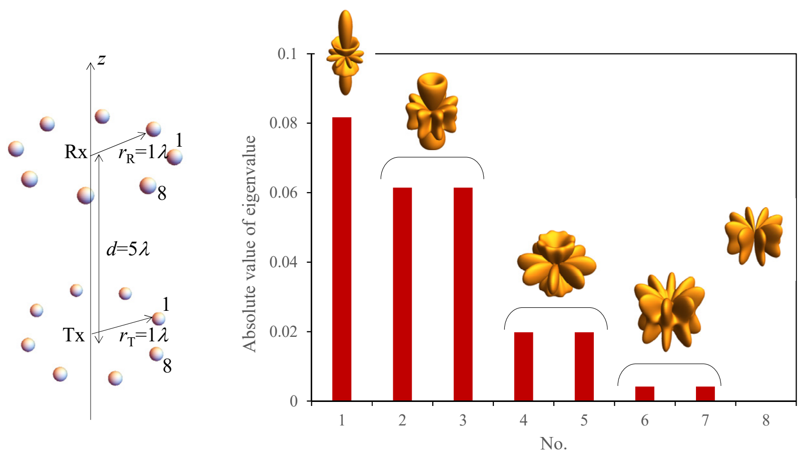


Fig: Two uniform circular arrays and eigenvalues of MIMO

Representation Method of Wireless Network Area Quality by Augmented Reality Technology

Wireless networks are expected to be utilized in variety of scenes and by users in the future Internet of Things (IoT) systems. In case of the service area planning of wireless networks, it is necessary to place base stations (BSs) densely to satisfy the user traffic demands while suppressing the unnecessary radio interferences. However, it is difficult for the users who are not familiar with the radio communication system. We propose the managing method of wireless network area planning instinctively by the augmented reality (AR) technology. In the proposal, the area quality is predicted by the raytracing simulation which is calculated. And then the service area and that quality information are displayed in the user camera view. By presenting the area quality with the physical view of user, the problems of the service area are grasped more clearly and instinctively. The system is expected to improve the service area planning.

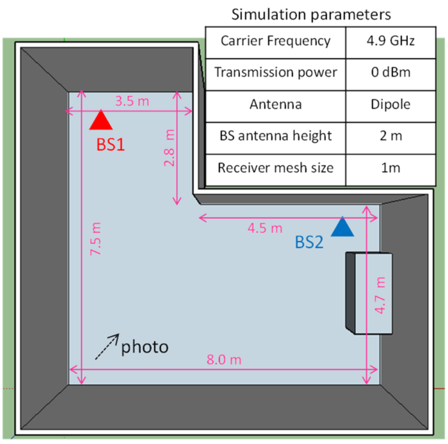


Fig. 1 Raytracing simulation condition

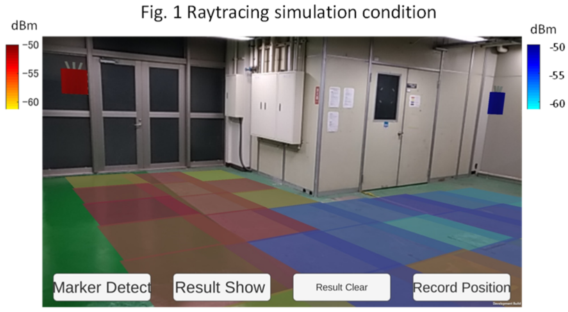


Fig. 2 User's camera view

Education in Asia

(Internationalization of Higher Education through a Study Abroad Program)

Internationalization of higher education through a student mobility/study abroad program in the Southeast Asian region is expected to be the major component to facilitate the development of the common space of higher education within the region, and thus supporting the development of the Association of Southeast Asian Nations (ASEAN). However, due to the lack of systematic studies and literature on the effects of the study abroad program in ASEAN on students, it is difficult to indicate if the program is successful in fostering ASEAN students and graduates with ASEAN awareness and appreciation for cultural and religious differences within the region.

This research aims to explore the relationship and influence between different experiences and learning environment of students at ASEAN host institutions and students' attitude towards ASEAN, friendship formation, as well as their future careers related with ASEAN. Online questionnaire and in-depth interview will be utilized for data collection.

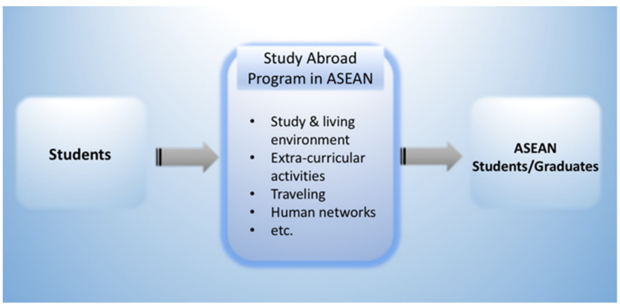


Fig. The study abroad program to fostering ASEAN students/graduates

Results and findings from this study are hoped to be policy recommendations for ASEAN governments and higher education institutions to provide appropriate and favorable learning environment for participants during their study abroad in an ASEAN country. This, if appropriately adopted, will help equip students/graduates with an ASEAN-oriented awareness so that they will become the future human resource of ASEAN economically and socio-culturally.

Sakaguchi Laboratory

Home page: http://www.sakaguchi-lab.net/ja/index

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 Professor and at the same time he is a Senior Scientist at Fraunhofer HHI in Germany. 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. He served as a TPC co-chair in the IEEE 5G Summit in 2016, a General co-chair in the IEEE WDN-5G in 2017, and an Industrial Workshop co-chair in the IEEE Globecom in 2017. His current research interests are in 5G cellular networks, millimeter-wave communications, and wireless energy transmission. He is a member of IEICE and IEEE.

Assistant Professor Gia Khanh Tran

Assist. Prof. 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. 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

Prof. 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 life member of IEEE, and fellow of IEICE.

Postdoctoral Researcher Tao Yu

Dr. Tao Yu received the B.E. degree in Communication Engineering from Taiyuan Institute of Technology, China, in 2008, the M.E. degree in Signal and Information Processing from Communication University of China, in 2010, and Dr.Eng. degree from Electrical and Electronic Engineering Department, Tokyo Institute of Technology in 2017. He has been with Sakaguchi-lab, Tokyo Institute of Technology from 2017 as a postdoctoral researcher. His research interests include wireless sensor networks, localization, distributed control, and building energy management. He is a member of IEICE.

Sakaguchi Laboratory

mmWave Edge Cloud System for 5G (5G-MiEdge)

Introduction - What's 5G-MiEdge ?

In future wireless systems, e.g. 5G & beyond, realization of low latency under restricted backhauling constraints are key problems. As a solution, this research project attempts to establish a new concept based on the combination of ultra-broadband mmWave communications and mobile edge computing (MEC). This project on 5G cellular networks employing mmWave edge clouds is under the collaborative research between Japan and Europe.

System Architecture of 5G-MiEdge

Figure 1 presents the overall view of the 5G-MiEdge system architecture where the selected five use cases and three key technologies are highlighted and inter-connected. All use cases take advantage of three key technologies, namely the mmWave edge cloud, liquid RAN C-plane, and user/application centric orchestration to fulfill their requirements of ultra-high speed jointly with low latency.

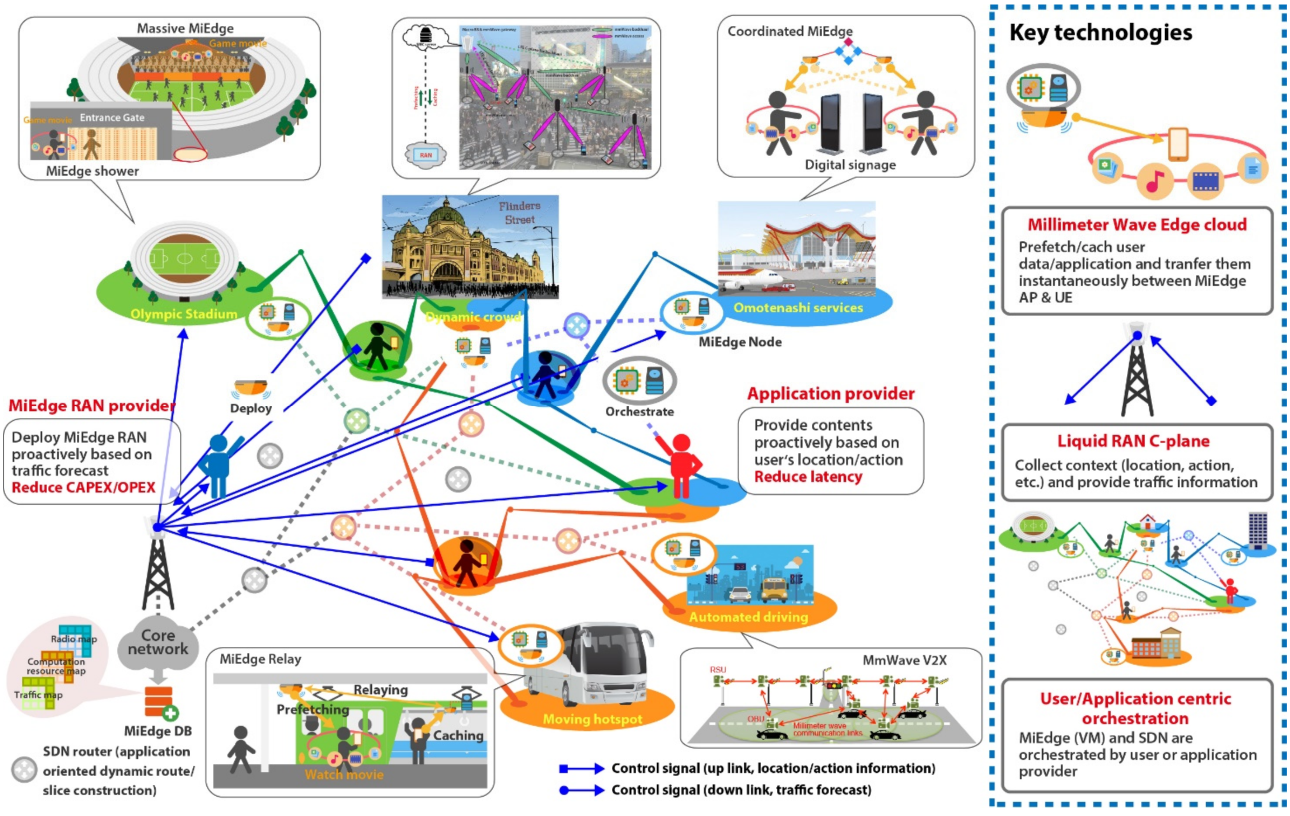


Fig. 1. Overall system architecture (left) describing how to integrate key technologies (right) to fulfil requirements in the five use cases.

In all use cases, the mmWave edge clouds are deployed inside of the scenarios with dense traffic to enhance user experienced data rate and latency by exploiting advantages of both mmWave access and edge cloud at the same time. The MEC relaxes requirements on backhaul capacity by prefetching or caching popular contents and also by running scenario specific applications. To efficiently implement these edge cloud functionalities, our architecture uses a novel liquid RAN C-plane, which collects network and user context, such as user position, network load, and data popularity, and enables the network to orchestrate its radio and cloud resources.

Millimeter-wave Mesh Backhaul Networks

Background

5G communication network is expected to support enhanced mobile broadband services by millimeter-wave overlay heterogeneous network (HetNet). However, connecting backhaul using cable such as optical fibers is extremely costly. To circumvent, we have proposed mmWave mesh backhaul networks (MMBN).

Interference Management

One of the problems toward realizing MMBN is intra-channel interference from other links, so we need interference management to obtain high backhauling rate. As a contribution to solve this problem, we proposed a 3-step approach of deploying mmWave Access Point (AP) in zigzag, selecting Beam Forming (BF) by reflection from walls and finally allocating orthogonal channels to decrease interference signals. Figure 4 shows that coverage using proposed algorithm is improved as compared to conventional approach which deploys APs linearly and alternates channel per hop.

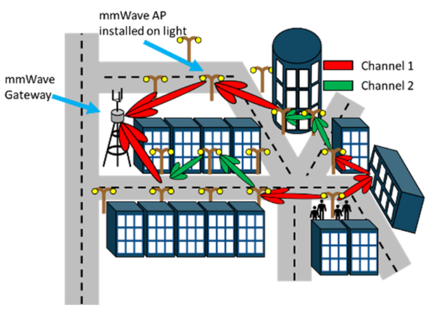


Fig. 2. MMBN architecture

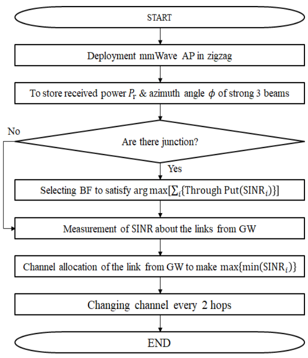


Fig. 3. Algorithm

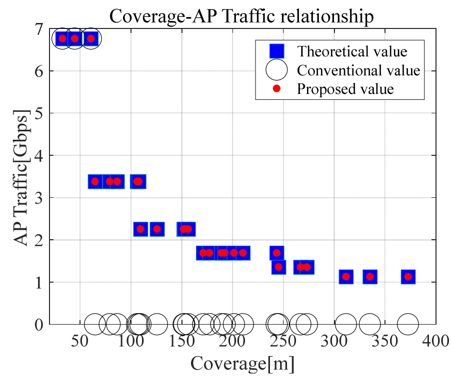


Fig. 4. Coverage characteristic

Testbed Development

As user distribution in practice changes in both time and space, backhaul paths should be optimized dynamically. Therefore, we have been developing SDN-based testbed of mmWave meshed backhaul networks as shown in Fig. 5, which is composed of 1 gateway node, 3 mesh nodes, 1 server node, 1 SDN controller node, and 1 orchestrator node. This testbed supports the scenario of data transmission from server node to virtual users generated in each mesh node. Orchestrator node calculates backhaul paths and the resulting information are delivered to Open vSwitch in each mesh node via SDN controller.

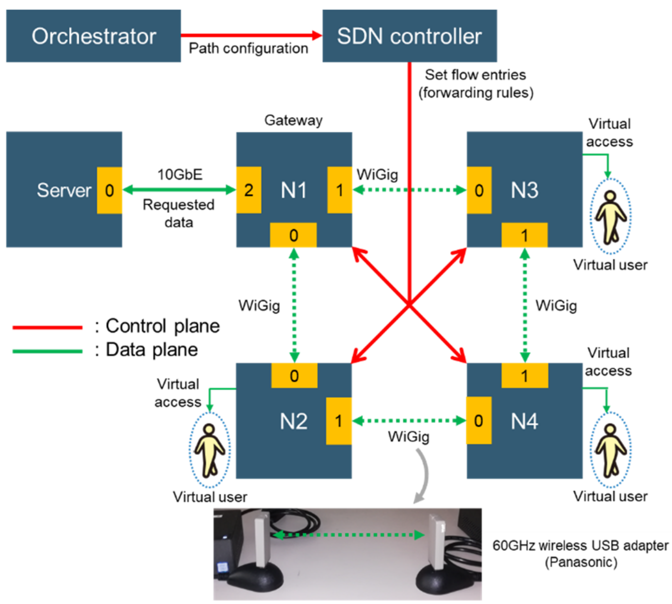


Fig. 5: Testbed system architecture

Sakaguchi Laboratory

mmWave Edge Cloud for 5G Cellular Networks [24], [40]

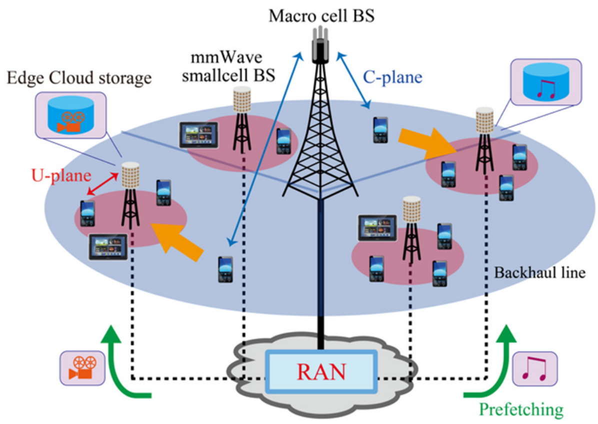


Fig. 6. mmWave Edge Cloud

In recent years, because of various devices including smart phones being connected to mobile networks, mobile traffic has increased exponentially. For offloading the increasing traffic, high-speed access technology utilizing high frequency band like millimeter waves (mmWave) attracts attention. In the last few years, we proposed the concept of mmWave overlaid heterogeneous cellular networks where mmWave small cell base stations (BSs) are introduced into conventional macro cell. We have shown that, system rate is expected to achieve 1000 times that of macro cell only. However, the disadvantage of this approach is that, high capacity / high cost backhaul line such as 10Gbps Ethernet is needed at every BSs to make full use of mmWave high-speed access. To circumvent, we propose mmWave Edge Cloud cellular networks shown in Fig. 6. In this approach, 5G operators prefetch user data into edge cloud storage installed at mmWave smallcell BSs in advance based on user context information such as mobility, traffic. Thanks to this process, the mmWave access can maintain high-speed ability regardless of poor backhaul constraint.

For efficient backhaul resource allocation, it is essential to introduce prefetching algorithm. Fig. 7 shows the flowchart of our proposal. 5G networks always grasp user's future destination and traffic demanded by exploiting proper application e.g. calendar and can decide proper smallcell BS to prefetch by using power map which is measured by 5G operators beforehand. When users are actually approaching the smallcell BS, weighted proportional fairness(WPF) scheduling method considering traffic demand time and traffic size is performed to efficiently select users and the associated traffic to prefetch.

Fig. 8 shows a simulation result about system rate against backhaul capacity. System rate with prefetching (WPF, Round-Robin (RR)) is always higher than that without prefetching and the system rate with WPF under 1 Gbps backhaul achieves about 98% of that under 10 Gbps. This is owing to the efficient use of backhaul resource at spare time. In conclusion, installing edge cloud function with proper prefetching mechanism enables lower backhaul cost while maintaining satisfying system rate.

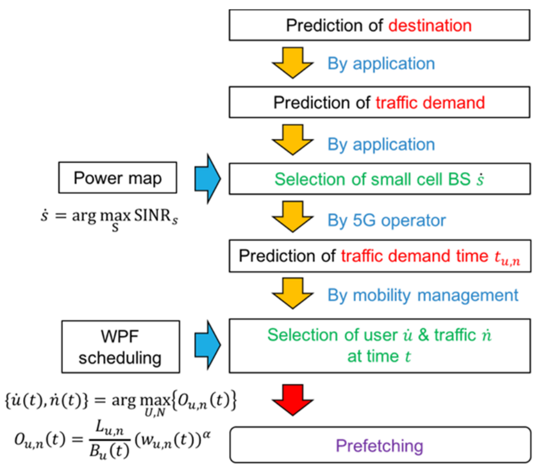


Fig. 7. Flowchart

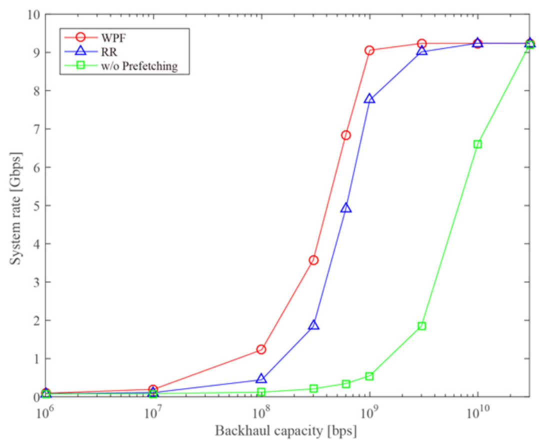


Fig. 8. Simulation result

Optimal Design Method of Beam Patterns for Massive MIMO Systems

Design Concept

For future wireless communication systems, large channel capacity is needed because of the popularization of wireless devices. To increase the channel capacity, massive MIMO (Multi-Input Multi-Output) technology using a large number of antenna elements at least at base station (BS) side is important. For the MIMO system, the propagation environments at BS and a user euipment (UE) sides are not always independent. Thus the beam pattern's optimization of both BS and UE sides are needed.

To address this issue, we have proposed an approach for antenna's design by using spherical mode expansion (SME) as shown in Fig. 9. First, the BS and UE sides iteratively from a joint power angular profile of departure and arrival waves. Next, the current distribution to achieve the optimal beam pattern is calculated by projecting it on the conductor surface to be implemented such as a hemisphere current surface. By using the above scheme, we can maximize channel capacity by matching beam patterns to the propagation environment.

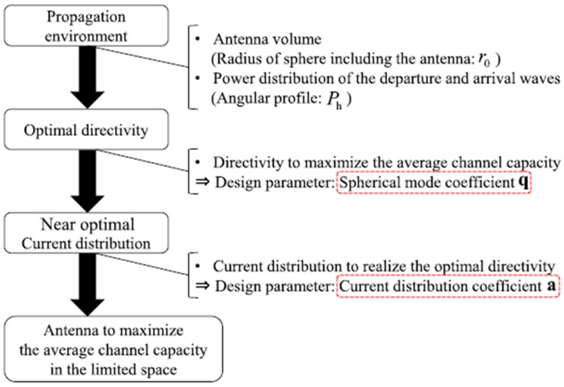


Fig. 9. Antenna design concept.

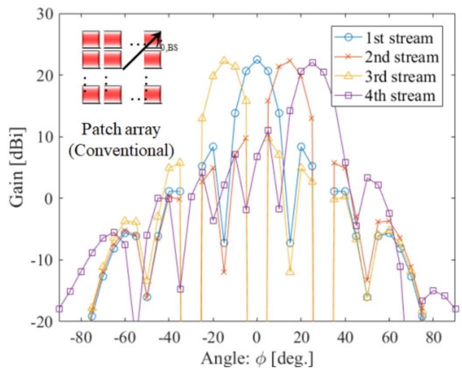


Fig. 10. Conventional beam patterns.

Optimal Beam patterns

For example, when a joint angular profile is given by Gaussian distribution with departure and arrival angles and angular spreads defined in 3GPP UMa NLOS model at 30 GHz, the beam patterns for conventional patch array antennas or the proposed hemisphere current are derived. The beam patterns at the BS side is shown from the first to the fourth streams in the case of a horizontal plane. Different from conventional linear phase shift beam patterns made by patch array antennas (Fig. 10), the beam pattern of the first stream has a peak and those from the second to the fourth stream has a null toward direction from which waves with high intensity come (Fig. 11). The average channel capacity in the conventional and proposed cases are shown in Fig. 12. By using the proposed optimal beam patterns, the average channel capacity is improved because the patterns are orthogonalized with each other and matched to the angular profile.

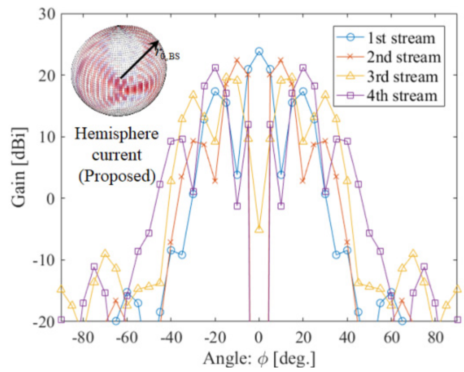


Fig. 11. Optimal beam patterns.

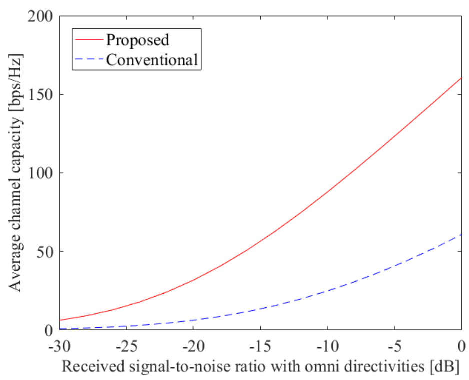


Fig. 12. Average channel capacity.

Sakaguchi Laboratory

Wireless Power Transmission and lighting control

Limited lifetime of the sensor node has long been an issue in WSNs. In order to deal with it, we developed varieties of battery-less sensors such as human detection sensors and wearable acceleration sensors, as shown in Fig.13, and proposed a wireless grid, in which battery-less sensor nodes can be activated by multi-point wireless energy transmission with carrier shift diversity (MPCSD), which can realize seamless supply of energy, compared with simple multi-point scheme (MP). The experiment results in Fig. 14 confirm that MPCSD can seamlessly supply energy. The coverage of MP and MPCSD are 88% and 100% respectively.

(a)Human detection sensor (b) wearable acceleration sensor

Fig. 13. Localized light control system using battery-less WSNs

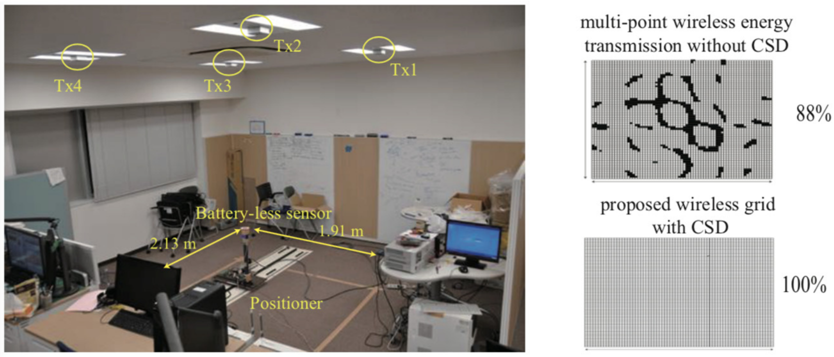


Fig. 14. Localized light control system using battery-less WSNs

As an application of wireless power transmission and indoor localization, a light control system based on user's location and environment luminance level was developed and practically implemented in an office in Tokyo Tech. The system structure is shown in Fig. 15. Owing to the wireless energy transmission system developed by our lab, human detection sensors can be freely deployed in the space. By using sensing data from the multiple battery-less low-cost IR sensors with overlapped coverages, user's locations and motions can be estimated and tracked. The light control scheme mainly focuses on reducing office's lighting energy consumption and satisfying user's The results in Fig. 16 show that this LED light control system reduces the energy consumption significantly by 57%, compared to batch control scheme, and satisfies user's luminance requirement with 100% probability.

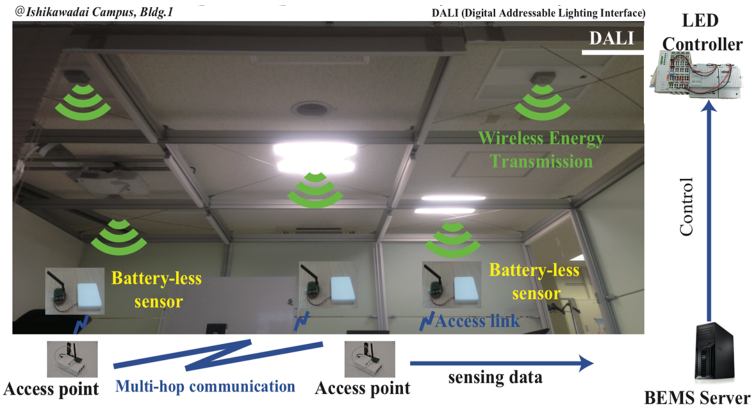


Fig. 15. Localized light control system using battery-less WSNs

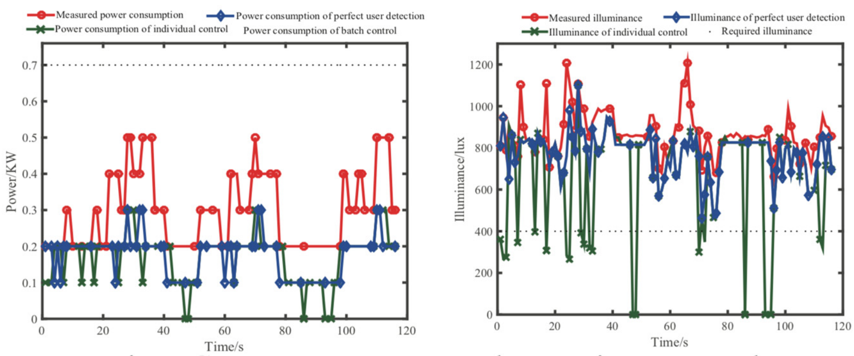


Fig. 16. Experiment result of lighting control

Indoor Localization and Robot Automated Control

We developed a location-based context information prediction system using fingerprint localization by multi-sensors. The system structure is shown in Fig. 17. At learning phase, a training terminal sends radio-wave signals, PDR information, locations, and context information to APs. The AP controller (APC) receives and stores them in database. And the radio maps and context maps are constructed In application server (AS). At estimation and prediction phase, the AS estimates and predict the location and context by fingerprint pattern matching. Experiments and simulations are conducted to evaluate the system performance, which is shown in Figs. 18. The results show that the localization accuracy of RSPD+RSSI+PDR scheme is 1.36 m. And in context prediction, the false positive achieves 24% when miss detection is 5%.

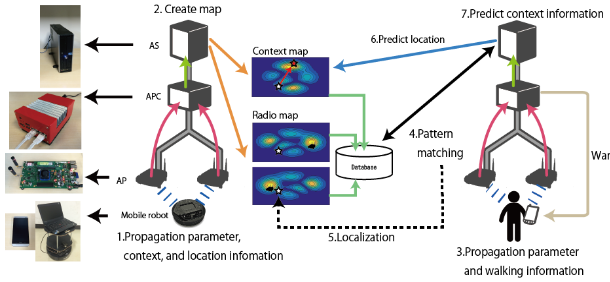


Fig. 17. Structure of location-based context prediction system

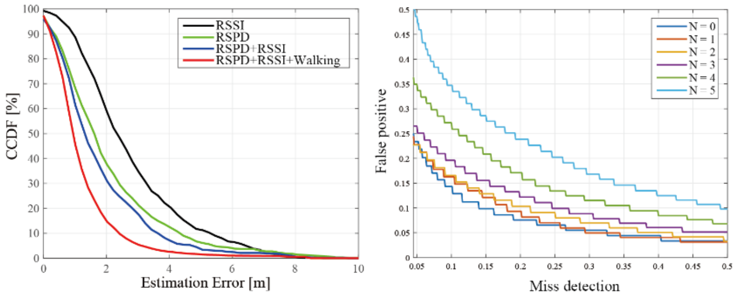


Fig. 18. Experiment result of localization (left) and context prediction (right)

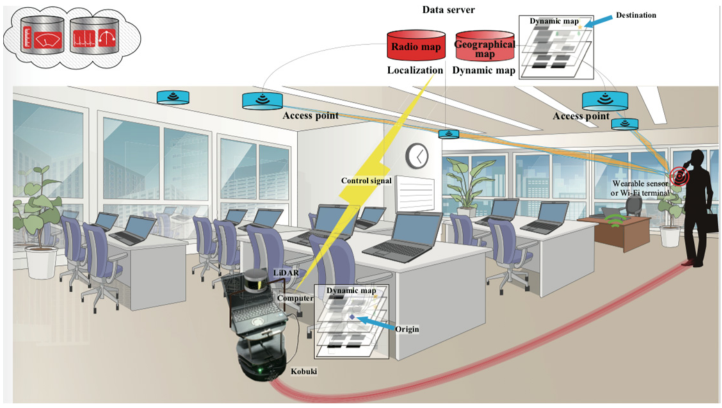


Fig. 19. Structure of location-based context prediction system

We also developed a robot automated control system, which can be employed in many fields, e.g., automated delivery in office and hospital, security surveillance and indoor guide, to enhance the level of automation and reduce human labor. The concept of the system is illustrated in Fig. 19. It combines the fingerprint-based localization, as described previously in this section, and SLMA (Simultaneous Localization and Mapping). In our system, the varieties of employed fingerprints and contexts information are not mapped to the real environments, but directly to the SLAM dynamic map which is made by the robot with LiDAR in the environments. Thus, based on the sensing information from LiDAR on the robot and the Wi-Fi fingerprints from the terminals, the robot can be directly navigated to the target location or context without the time-consuming and complicated target searching process. An experiment is conducted to compare the performance of the conventional searching scheme, in Fig. 20, and our robot automated control system, in Fig. 21. It validates our design exceptions.

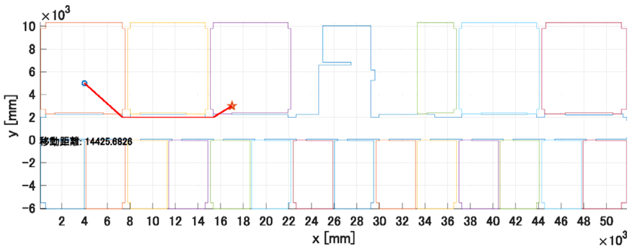


Fig. 20. Routing with proposed method

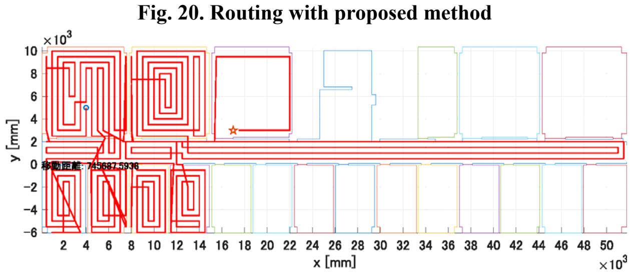


Fig. 21. Routing without proposed method

Fujii and Omote Laboratory

Specially Appointed Professor Teruya Fujii

Dr. Teruya Fujii 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 Hideki Omote

He received his B.S. and M.S. degrees from the University of Nagoya, Japan, in 1997 and 1999, respectively. He joined Japan Telecom Co, LTD. (currently, Softbank Corp.) in 1999. Since then, he has been engaged in the research of radio propagation for mobile communication systems. He also has been engaged in the standardization of radio propagation for mobile communication in ITU-R SG3. He is currently managing Antenna and Propagation Section of Research and Development Division at Softbank Corp. In 2017, he also joined Tokyo Institute of Technology, where he researches radio propagation and modeling. He is a member of IEICE.

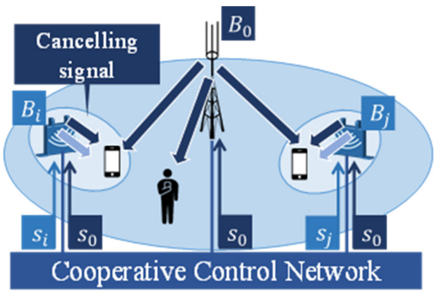
Recent Research Topics

- **3D Layered Cell Construction in Broadband Mobile Communication**
  - Transmit Interference Canceller for 3D Layered Cell Construction in Broadband Mobile Communication
  - Propagation Characteristics for 3D Layered Cell Construction in Broadband Mobile Communication

A Study on Transmit Interference Canceller for 3D Layered Cell Construction in Broadband Mobile Communication [1], [2]

For three-dimensional (3D) layered cell construction, a large number of small cells located in a Macro cell coverage area requires effective utilizations of frequency resources. In the 3D layered cell construction, the same frequency bands are used in both macro and small cells. It is necessary to avoid the mutual co-channel interference. The interference avoidance can be achieved by enhanced Inter-Cell Interference Coordination (eICIC), in which the frequency resources are divided to macro and small cells in time domain. However, in this technique, it has a problem that macro and small cells cannot use all of frequency resources. To resolve this problem, we propose "transmit interference canceller in small cells" that cancels the macro cell signal received at terminal in each small cell through cooperative control network.

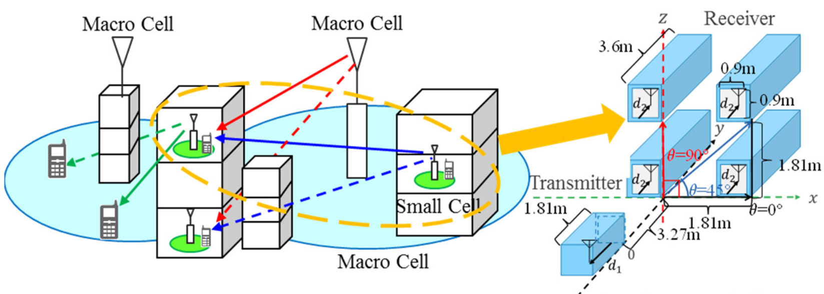
By using the proposed "transmit interference canceller", we showed that the communication quality such as SINR (Signal power to Noise and Interference Power Ratio) and communication capacity in small cells can be improved remarkably.



3D cell construction

A Study on Propagation Characteristics for 3D Layered Cell Construction in Broadband Mobile Communication [3]

In order to overcome the increasing traffic problems of mobile terminal for use in high-rise floors of buildings, the three-dimensional (3D) layered cell construction which has the small cells in various floors is considered. To evaluate the wireless transmission technology for the 3D layered cell construction, it is necessary to clarify the time-spatial characteristics composed of the path loss, the delay profile and the spatial arrival angular profile for travelling waves from indoor high-rise office to another indoor high-rise office. In this research, we measured the path loss characteristic as one of the time-spatial characteristics by using scale model. From the measured results, we found that the path loss characteristics depends on the mutual position between Indoors. We also simulated by ray tracing method and confirmed that the simulation results agree well with measured results.



3D Cell Construction

Scale Model

Hirokawa Laboratory

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

Professor Jiro Hirokawa

Prof. 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. He is a Fellow of IEEE and IEICE.

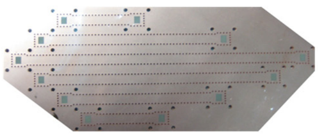
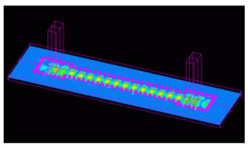
Specially Apointed Assistant Professor Takashi Tomura

Dr. Tomura was born in Sendai, Japan. He 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. He is currently a Specially Appointed Assistant Professor at the Tokyo Institute of Technology, Tokyo. 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. He is a member of the IEICE.

Our Research Interests

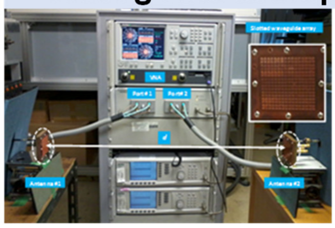
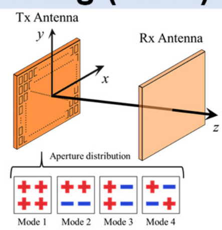
Hirokawa laboratory have researched antennas, feeding circuits, electromagnetic analysis theory and wireless communication systems. Main target frequency band is millimeter wave band and higher band such as 120 GHz and 350 GHz. The features of our antennas are planar, high gain, high efficiency and wide 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

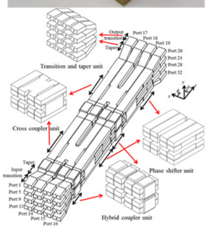
Rectangular coordinate orthogonal multiplexing (ROM)

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

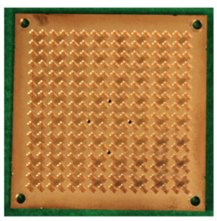
2-D beam-switching one-body Butler matrix

- 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)

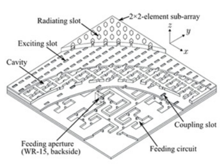


- $4^2 \times 4^2$-way one-body 2-D beam-switching waveguide Butler matrix
- Reduced its length and conduction losses by half.
- Reduced the number of components and volume.

Corporate-feed Slot Array Antenna with Plate-laminated Waveguide

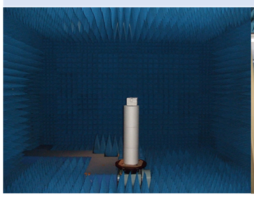


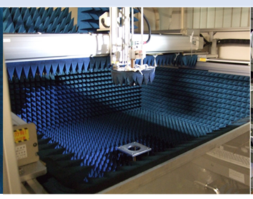
- Published in the IEEE transaction in 2011.
- After that, research is also started in Sweden, Singapore, China, etc.
- Designed in various frequency bands like 38-GHz band, 60-GHz band, and 120-GHz band, etc.



✓ 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 Laboratory

Perpendicular-Corporate Feed in a Three-Layered Parallel-Plate Slot Array Antenna

This study discusses the structural problem on metal contact by the diffusion bonding of laminating metal plates in double-layer corporate-feed slot array antennas. To remove metal contact in the radiating part of the conventional model, we introduce dielectric with proper permittivity in the region between a coupling-aperture layer and radiating-slot layer as shown in Fig. 1. The dielectric excites a standing wave in the region and then provides uniform excitation for the array. We define the novel feeding structure as a perpendicular-corporate feed. This technology contributes to advancing the performance of planar array antennas for the millimeter-wave applications in terms of fabrication.

Fig. 2 shows a 16×16-element three-layered parallel-plate slot array fed by a perpendicular-corporate feed. The antenna consists of three layers: a parasitic-slot layer, a radiating-slot layer including dielectric and a coupling aperture layer with a feeding circuit. In Fig.2, the layers are described with a distance to show an internal structure. However, in an actual antenna, they are stacked. The antenna is fed by a feed aperture, which is the same size as the standard waveguide WR-15, from its backside. The feeding circuit is a planar corporate feed composed of H-planes and T-junctions. The coupling-aperture layer is placed between the feeding circuit and dielectric. The radiating-slot layer is mounted on the dielectric directly. The parasitic-slot layer is placed on the top of the radiating-slot layer with an air gap. The air gap between the radiating-slot layer and parasitic-slot layer is hollow. For both radiating and parasitic slots, each slot spacing is constant: $0.86\lambda_0$ (4.20 mm) in *x* and *y* directions. λ_0 is the wavelength at the design frequency of 61.5 GHz. Polarization is along the *x*-axis.

Fig. 3 describes measured and simulated radiation patterns in the E-plane (*xz*) at 61.5 GHz. the measured pattern is in good agreement with the simulated one. The measured pattern presents a uniform-excitation pattern including an element pattern. Fig. 4 reveals measured and simulated realized-gain, gain, and directivity. Realized-gain, which includes a reflection loss, and conductor and dielectric losses, is measured by the comparison with a standard gain horn antenna in an anechoic chamber. Directivity is derived from measured near-field distribution by Fourier transform. Gain is calculated by adding the measured reflection loss into measured realized-gain. The measured realized-gain degrades comparing to the simulated one because of the reflection loss. Then, the measured gain is also degraded due to the same reason. However, the measured directivity is in good agreement with the simulated one. The aperture efficiency greater than 90 % is achieved over 5-GHz bandwidth. At the design frequency, the measured directivity is 33.5 dBi with the aperture efficiency of 90.6 % and the realized gain is 31.7 dBi with the antenna efficiency of 61.0 %.

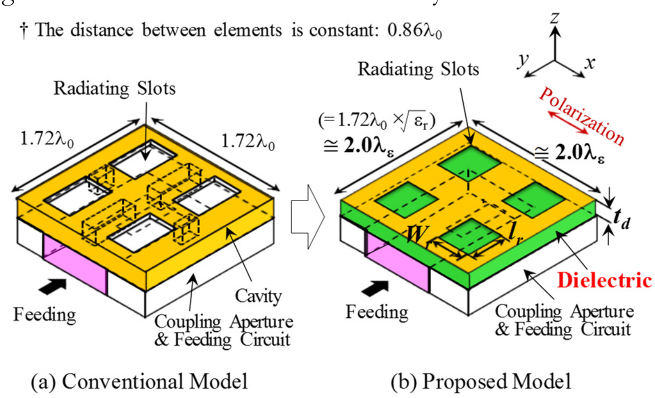


Fig. 1 Difference between the proposed and conventional models.

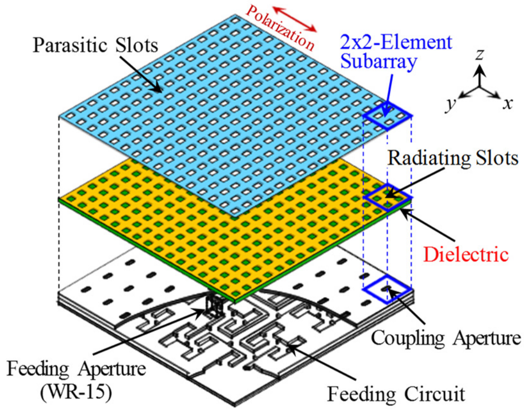


Fig.2 16×16-element three-layered parallel-plate slot array fed by the perpendicular-corporate feed.

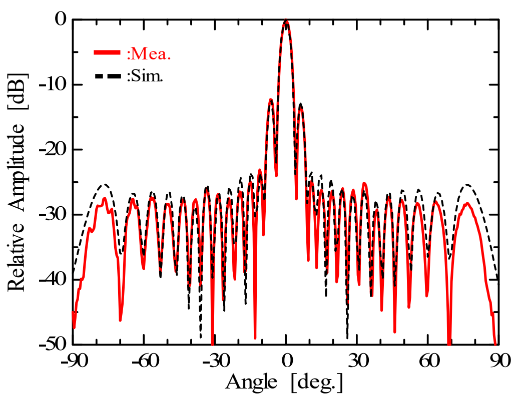


Fig. 3 Radiation patterns in the E-plane (*xz*) at 61.5 GHz.

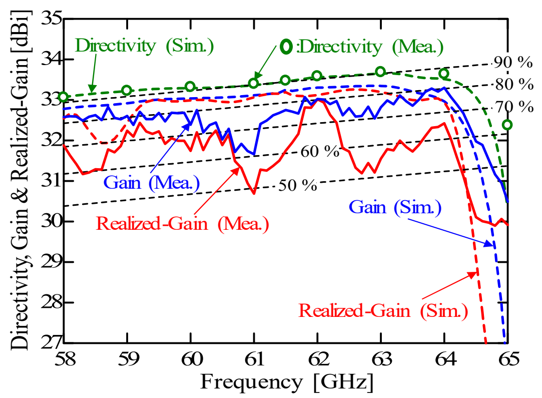


Fig. 4 Frequency characteristics of realized-gain, gain, and directivity.

Low-sidelobe Design of a Waveguide Reflection-canceling Slot Array Antenna in the 60GHz Band

A partial-corporate-feed waveguide reflection-canceling 16x28-slot array antenna is designed for 60 GHz band in order to suppress the sidelobe level by excitation of Taylor distribution for both the feed and the radiating waveguides. Sidelobe level of excitation coefficient of Taylor distribution is set -30dB ($\bar{n} = 8$) in H-plane and -25dB ($\bar{n} = 5$) in E-plane.

Fig.1 shows the top view of the proposed design of the antenna. There are 28 radiating waveguides with 16 longitudinal radiating slots, each of which suppresses the reflection by a wall as shown in Fig.1A. A feed waveguide is placed on the bottom of the radiating waveguides. It has inclined coupling slots, each of which suppress the reflection by a wall as shown in Fig.1B. A partial-corporate-feed structure is proposed to reduce the long-line effect as shown in Fig.1.

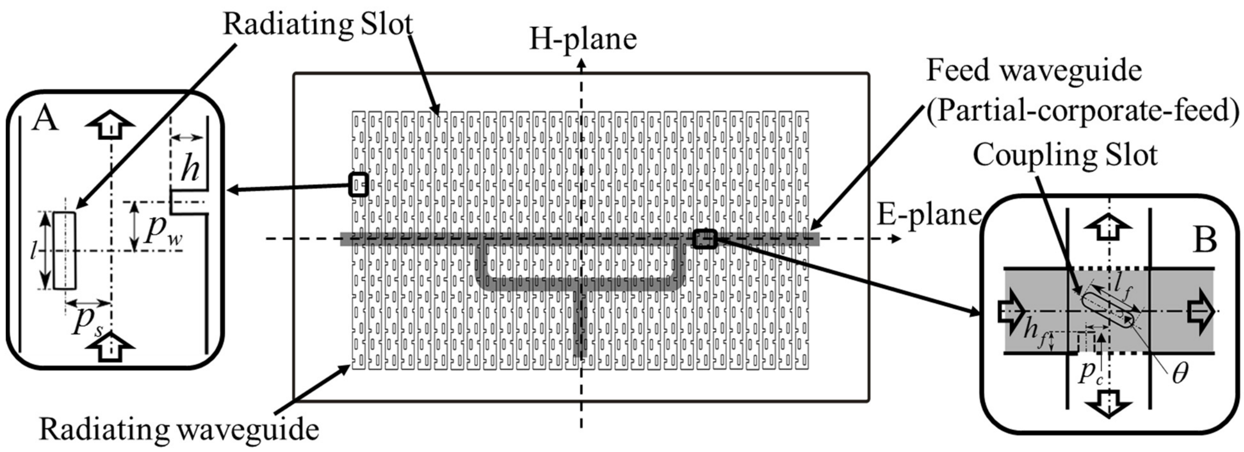


Fig. 1 Antenna structure

The full structure of the antenna is analyzed by HFSS. The conductivity is assumed to be 5.8×10^{7}S/m. The realized gain is 34.0dBi at 60.5GHz and reflection is reduced -12dB in the bandwidth from 60GHz to 61GHz. Figure 2 and Figure 3 shows H-plane pattern and E-plane pattern. These sidelobe level is surpressed lower than -25dB and -18dB respectivery.

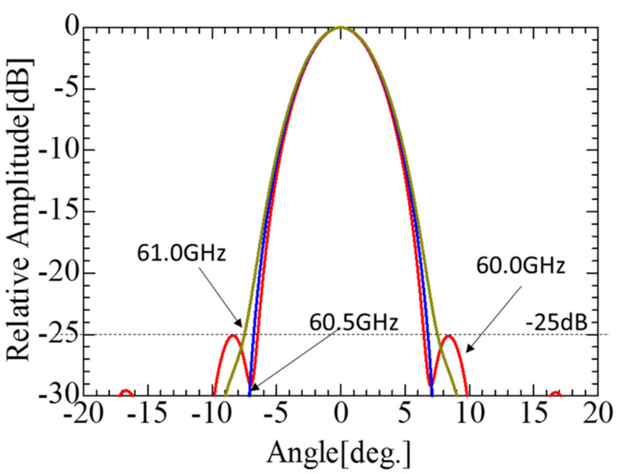


Fig. 2 H-plane pattern

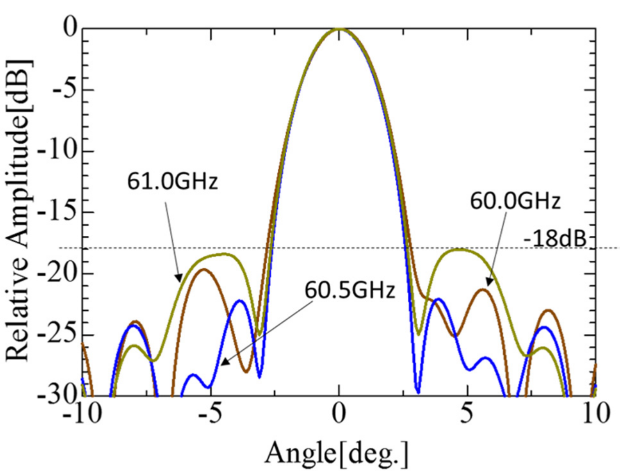


Fig. 3 E-plane pattern

Hirokawa Laboratory

Hybrid Analysis of Mode Matching/FEM for a Waveguide Short-slot 2-plane Coupler considering the Three-dimensional Structural Symmetry

The hybrid analysis of mode matching/FEM for a short slot 2-plane coupler (Fig.1) is presented here. The method combines fast modal analysis of the mode matching technique, which can reduce the computation size, with the flexibility of FEM, which can be used for arbitral cross sections.

The structure of the short-slot 2-plane coupler in Fig.1 is symmetrical in the planes A, B and C, so the structure can be reduced into the one-eighth model. In the coupling region, a PEC or PMC is placed on each of the symmetrical planes B and C in the consideration of the symmetry of the electromagnetic field modes as shown in Fig.2. Firstly, we analyze the generalized scattering matrix (GSM) of the one-eighth model by the hybrid analysis of mode matching/FEM. To apply the method, we derive the eigenmode functions analytically in the input waveguides, but numerically by FEM in the coupling region since analytical solutions cannot be obtained. Then we calculate the GSM of the overall structure by using the GSM of the one-eighth model and the structural symmetry. With respect to the symmetry plane A, the GSM including the output waveguide is obtained by cascade connection of the GSM of the one-eighth model. With respect to the symmetrical planes B and C, taking the polarity of the electric fields of each mode into consideration, the GSM of the overall structure is derived by adding or subtracting the GSM of the four cases shown in Fig.2.

The computed S-parameters when the input signal is excited from the input waveguide 1 are shown in Figs. 3. The analyzed results agree well with those by the HFSS. The computation time is 46s for the calculation of the GSM of the whole structure at 100 frequency points using a PC with Intel Core i7 3.40 GHz, 16 GB memory. For the analysis of the HFSS the computation time is 96s and the computation time was reduced.

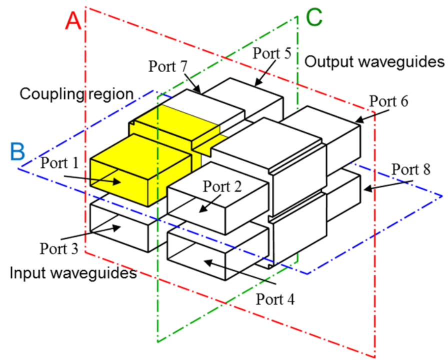


Fig. 1 Short-slot 2-plane coupler

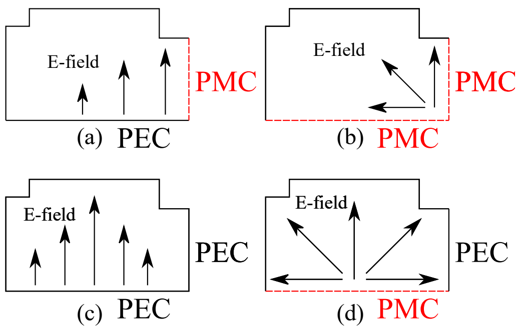


Fig.2 Electric filed distributions in the coupling region

(a)TE10-like mode (b)TM/TE11-like mode

(c)TE20-like mode (d)TM21-like mode

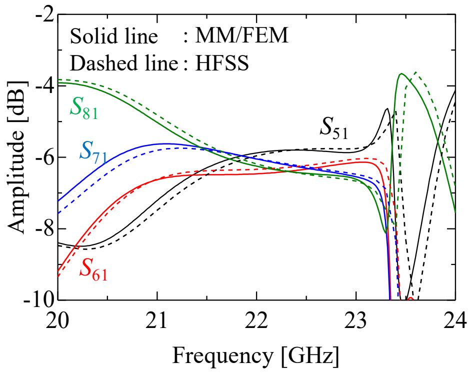


Fig. 3 Analysis results

Design of Short-slot 2-plane Coupler

Short-slot couplers work as fundamental component of several microwave circuits. The number of couplers in the component is depended on the component functionality. The loss, the volume, and the complexity of microwave circuits are proportional to the number of couplers. Single short-slot 2-plane coupler performs as a combination of two short-slot H-plane and two short-slot E-plane couplers. It helps to reduce the loss, the volume, and the complexity of microwave circuits.

The short-slot 2-plane coupler has four input ports and four output ports. Each port is adjacent to neighbor ports horizontally (H-plane) and vertically (E-plane). The operation of the short-slot 2-plane coupler is analogous to that of the short-slot 1-plane coupler. But in the design of the 2-plane coupler, four propagation modes (TE10, TE20, TM/TE11, and TM21) which have different polarity and phase constant two-dimensionally are considered.

For acquiring the characteristic of hybrid or cross couplers, the structure of the coupler should be designed by following procedures.

1. The initial values of a' and b' are chosen so that TE30 mode should be decayed by TM/TE21 modes can propagate in a rectangular waveguide.
2. The dimensions of the notches are roughly designed so that only TE21-like mode should be decayed with keeping the propagation of TM21-like modes.
3. The dimensions of the notches are tuned by optimization to satisfy $\beta 20 = \beta 11 = (\beta 10 + \beta 21)/2$ where βij is the phase constant of TEij-like (ij=10, 20, 11) or TMij-like (ij=11, 21) modes.
4. The size and the position of the ports are determined so that the couplings of the propagating modes should be equalizing.
5. The length of the coupled region l should be chosen to satisfy under the conditions.
   Hybrid coupler – $l(\beta 10-\beta 21)/2=\pi/2$, $l(\beta 10-\beta 20)/2=\pi/4$
   Cross coupler – $l(\beta 10-\beta 21)/2=\pi$, $l(\beta 10-\beta 20)/2=\pi/2$

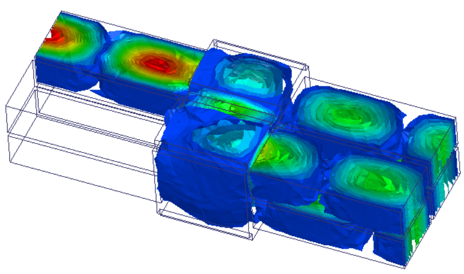


Fig. 1 2-plane hybrid coupler

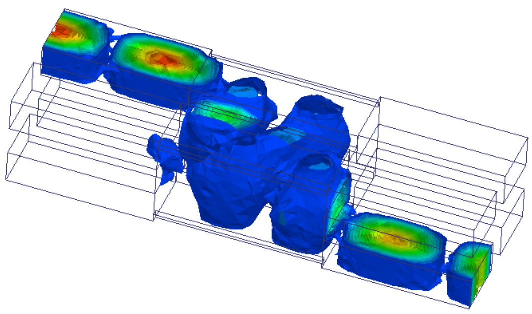


Fig. 1 2-plane cross coupler

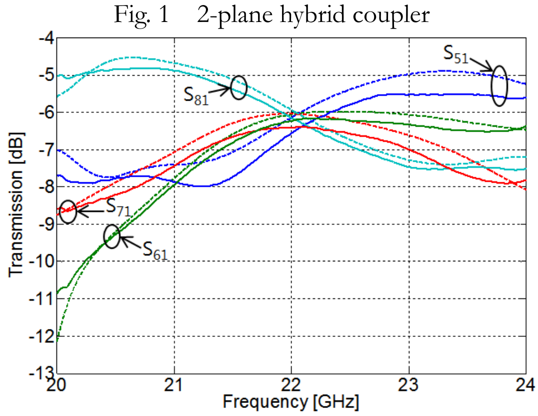


Fig.3 Transmission coefficients of 2-plane hybrid coupler

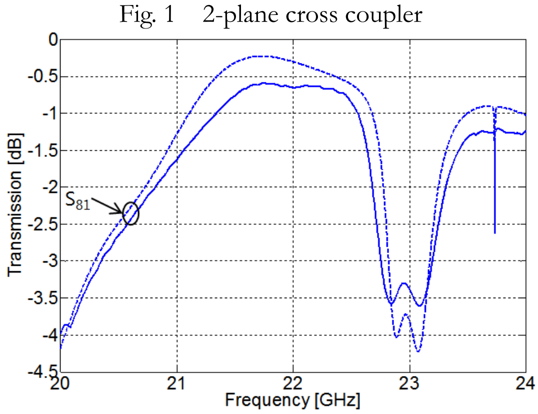


Fig. 4 Transmission coefficient of 2-plane cross coupler

Hirokawa Laboratory

Rectangular-coordinate Orthogonal Multiplexing Transmission System by using Monopulse Corporate-feed Waveguide Slot Array Antenna

In order to improve the data transmission rate, the multiplexing transmission such as MIMO (multiple input multiple output) and OAM (orbital angular momentum) techniques is a key technique. In this research, we have proposed a LOS (line of sight) short-range multiplexing transmission system named as a ROM (rectangular-coordinate orthogonal multiplexing) transmission. Fig. 1 shows the ROM transmission system. The system is based on two identical multimode antennas and uses two-dimensional beam mode orthogonality in the rectangular-coordinate system.

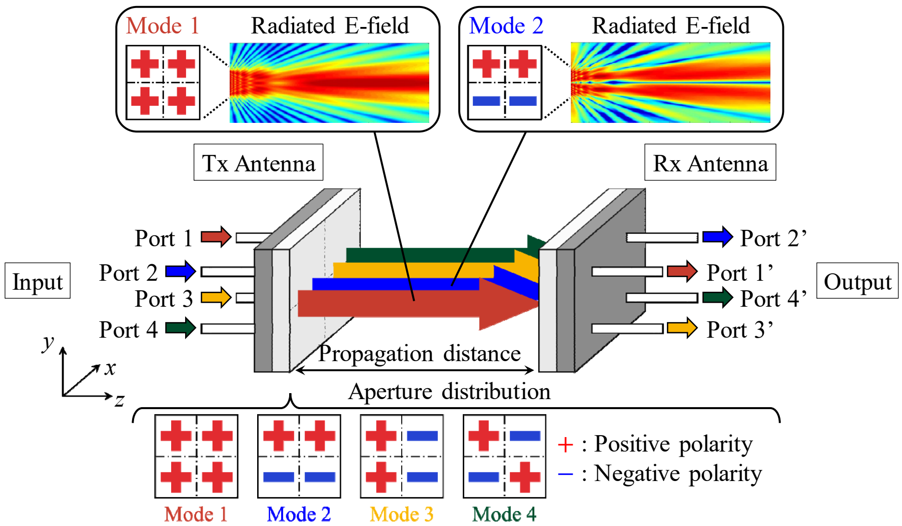


Fig. 1 Rectangular-coordinate orthogonal multiplexing transmission system

The multimode antenna structure is shown in Fig. 2. The antenna is a monopulse array antenna composed of a monopulse circuit and a corporate-feed waveguide slot array antenna. The antenna has four input port. The Radiating part is excited four orthogonal combination of polarity depending on the input port. The transmission between Tx and Rx antenna of the system (Fig. 1) is shown Fig. 3.

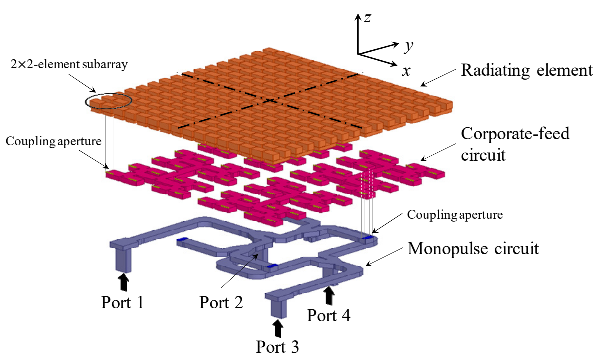


Fig. 2 Antenna structure

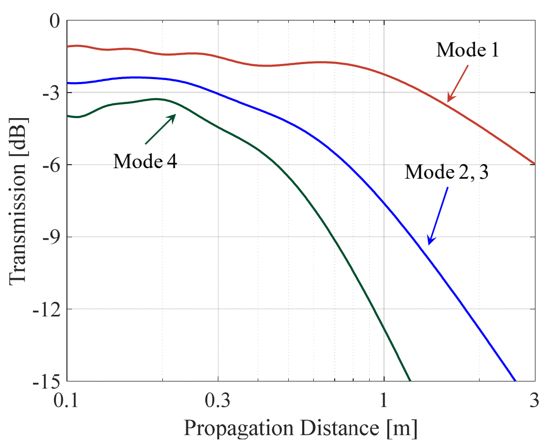


Fig. 3 Transmission between Tx and Rx antenna

Evaluation of Field Strength Distribution by Modified Edge Representation (MER) in Compact Range Communication with Shadowing Objects

A novel compact-range communication was introduced as a promising system to offload mobile traffic and provide gigabit data access. This system adopts large array antenna in 60-GHz band to form a quasi-plane wave illumination zone almost free of multipath in near-field region. One notable degradation of the system is attributable to shadowing effect by objects like walls, human bodies, and etc. In order to evaluate the performance of the system in presence of shadowing objects, numerical techniques are liable to be adopted. However, full wave solutions by numerical techniques (e.g. method of moment (MoM), finite element method (FEM), and etc.) are computationally infeasible due to the large size of an object and the small wave length in millimeter band. Here, we adopt Modified Edge Representation (MER) to deal with the current problem because of the advantages over the other numerical techniques in aspect of computational time and memory requirement.

Modeling and field evaluation of the system

Compact range system is illustrated in Fig. 1. In Fig. 2, the simple model of the system is shown in Cartesian coordinate, the array antenna is represented by the array of magnetic dipoles parallel to XY plane and its center is on z-axis. The shadowing object (human bodies, wall, and etc.) is represented by a rectangular perfectly electrical conductor (PEC) whose center is situated at origin. The observation point P is varied along the blue-dashed separated by incident shadow boundary (ISB: red line) into shadow region and non-shadow region.

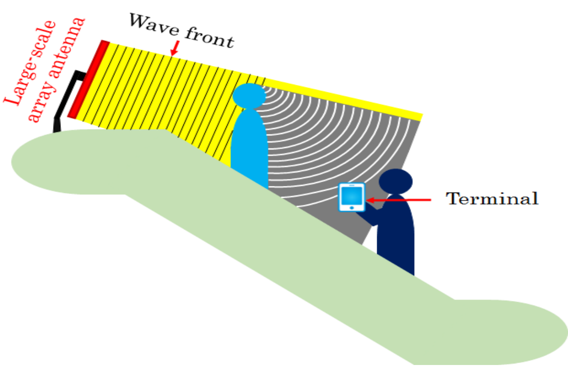


Fig. 1 Compact-range system

MER Fortran-based codes are implemented to calculate the aforementioned model. Normalized field strength of 32x32-slot array antenna in presence of PEC rectangular plate 57x40 cm^2 measured experimentally and calculated by MER are compared in Fig. 3 for both with and without plate cases. The agreement is acceptable. This verifies how accurate MER is. The results indicate the shadowing effect quantitatively: the substantial decrease of field strength in the region behind PEC plate (shadow region). Also, communication might be impossible in this region.

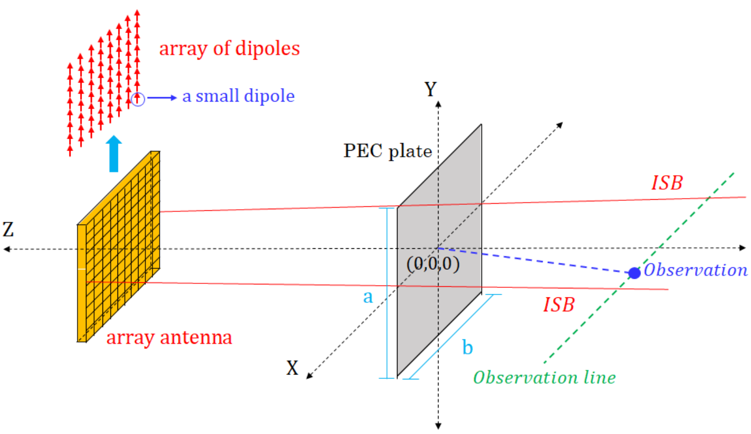


Fig. 2 simple model of the system with shadowing

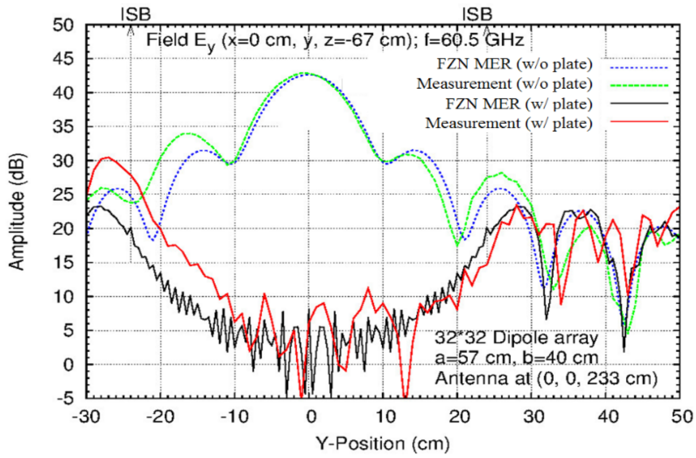


Fig. 3 MER vs. measurement

Hirokawa Laboratory

14 Gbit/s Data Transmission with Beamforming of Arrayed 60 GHz Compact Antenna Modules Using Variable Optical Delay Line

In order to accommodate recent explosive data traffic, the deployment of many small cells is now required. In such a situation, however, the electromagnetic wave interference among those plural base stations which causes the degradation of signal quality will increase. Furthermore, the installation of many base stations causes the increase of cost and power consumption of radio access network. In order to alleviate these problems, we studied remote RF beamforming technique using radio-over-fiber (RoF) transmission technique.

Fig. 1 shows the experimental setup for 14 Gbit/s 16QAM data transmission with beamforming. The module used in this experiment mainly consists of cavity antenna, UTC-PD, and optical fiber. The 60 GHz band RoF signal emitted from optical fiber is focused on the light-receiving area of UTC-PD by a lens and converted to the 60 GHz band RF signal. The converted RF signal is propagated over a coplanar line formed on the top surface of an aperture of the cavity antenna, and then radiated. We arranged eight compact antenna modules to a 1 × 8 array. The radiation pattern was controlled by changing the optical path length using VDL. We measured the received RF power and signal to noise ratio (SNR) of the 16QAM signal by the oscilloscope at each observation angle.

Fig. 1 (a) and (b) show the relative RF amplitude and SNR at each observation angle in the case of the peak angle of RF amplitude is 0 degrees and 30 degrees. In both cases, the measured RF powers and SNRs almost coincided with the simulated results for the main lobes where the received RF power was relatively large. On the other hand, the measured data did not agree well with the simulated results for the side lobes where the received RF power level was relatively small, especially where the signals were smaller than 10dB compared to the peak values of the main lobes and close to the level of noises. It can be emphasized, however, that we could obtain the SNR of more than 16.6 dB in the vicinity of the main lobe that corresponds to the bit error rate (BER) of 1.0×10^{-3} required for error-free data transmission with a low-density parity-check (LDPC) code. Thus, the 14 Gbit/s digital data transmission with antenna beamforming operation of arrayed 60 GHz band compact antenna modules was successfully realized.

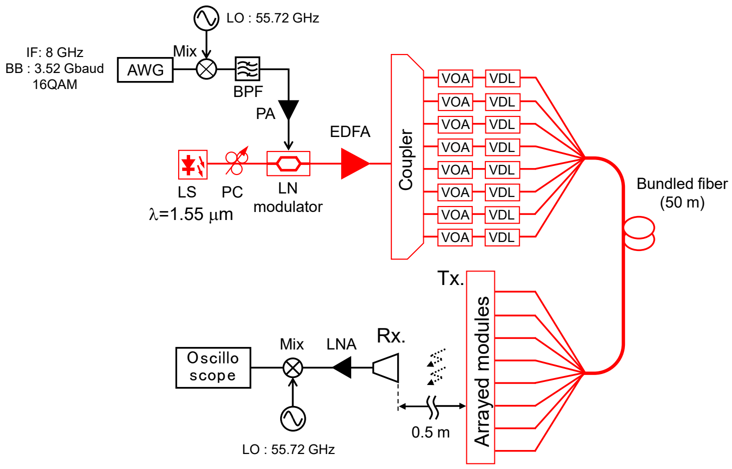


Fig. 1. Experimental setup

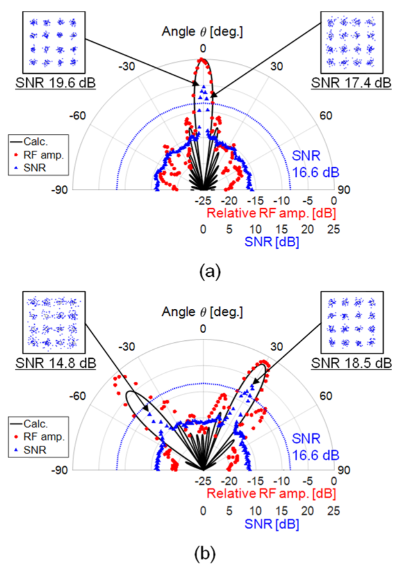


Fig. 2. Measured RF amp. and SNR: (a) 0 degrees. (b) 30 degrees.

Visiting Professor Fumio Watanabe

Dr. Watanabe has 40 years of experience in research and development of satellite and mobile communication systems including IMT-2000, IMT-Advanced, WiMAX and 5G. He has been active for a long time in international standardization of mobile communication systems in ITU-R and fora. He joined KDD in 1980. He was an Executive Director, General Manager of KDDI from 2006 responsible for mobile radio access networks and R&D activities. He is now the Chairman of KDDI Research Inc. He is also CTO of UQ Communications Inc. and the President of KDDI Foundation. He received Piero Fanti International Prize in 1989, the R & D Awards of Radio Systems in 1991, the meritorious Awards on ITU activities in 2001, the Commendation for Science and Technology by the Minister of Education in 2010, and Maejima memorial Awards in 2013, respectively. He is the chairman of Broadband Wireless Access Committee in ARIB. He is a fellow of IEIEC.

Performance Analysis and Hardware Verification of Feature Detection using Cyclostationarity in OFDM Signal

Our study deals with a CP-OFDM signal detection based on its cyclostationary feature. The detection flow is explained in Fig. 1. We utilize the signal structure that the CP is a copy of the end portion of the OFDM symbol as shown in Fig. 2. Previous studies mainly relied on software simulations based on the Monte Carlo method. We experimentally confirm the detection performance by implementing the detector into an FPGA (Fig. 3) and analytically clarify the relationship between the design parameters of the detector and its detection performance (Fig. 4).

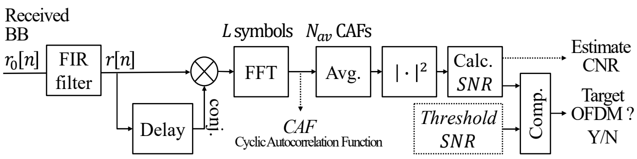


Fig. 1 Detection flow

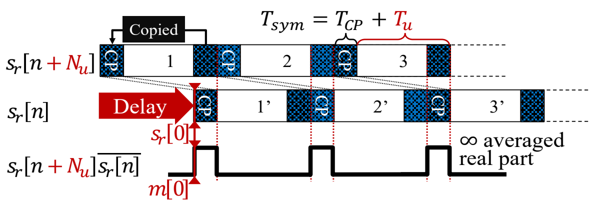


Fig. 2 Principle of CP feature detection

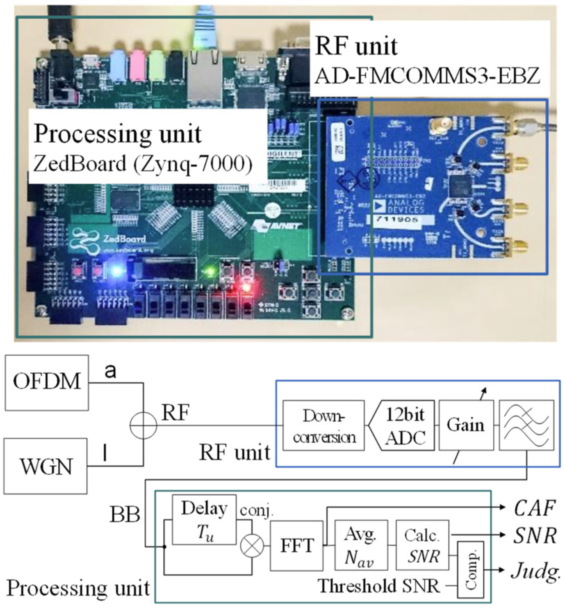


Fig. 3 Hardware implementation

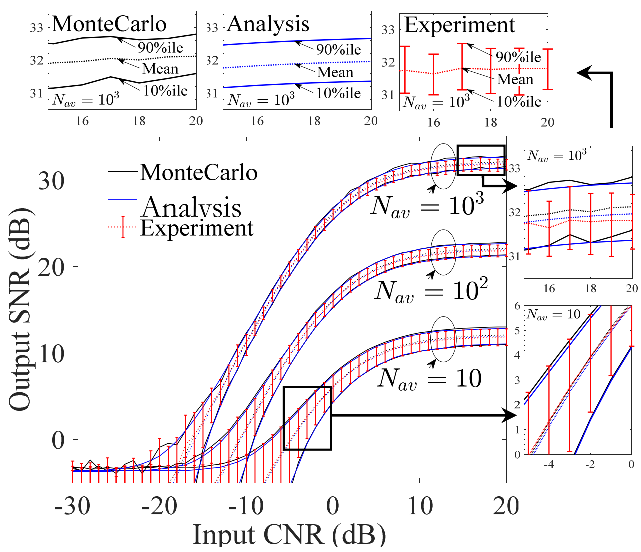


Fig. 4 Theoretical Analysis

Fukawa Laboratory

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

Professor Kazuhiko Fukawa

Prof. 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 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

Assist. Prof. Chang 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 sendor 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, 10 Gbps 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
  - ✓ Eigenmode 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 cochannel interference environment
- Neural network based power control
- 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 10 Gbps

Phase noise compensation

I/Q imbalance compensation

Real zero coherent detection

In-House Simulator Design & Implementation

FPGA on-board system simulators

4x4 MIMO fading simulators

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

A Joint Interference Suppression and Multiuser Detection Scheme Based on Eigendecomposition for Three-Cell Multiple Relay Systems [3], [5], [7]

To suppress inter-cell interference for three-cell half-duplex relay systems, joint interference suppression and multiuser detection (MUD) schemes that estimate weight coefficients by the recursive least-squares (RLS) algorithm have been proposed but show much worse bit error rate (BER) performance than maximum likelihood detection (MLD). To improve the BER performance, this paper proposes a joint interference suppression and MUD scheme that estimates the weight coefficients by eigenvalue decomposition. The proposed scheme carries the same advantages as the conventional RLS based schemes; it does not need channel state information (CSI) feedback while incurring much less amount of computational complexity than MLD. In addition, it needs to know only two out of three preambles used in the system. Computer simulations of orthogonal frequency-division multiplexing (OFDM) transmission under three-cell and frequency selective fading conditions are conducted. It is shown that the eigendecomposition-based scheme overwhelmingly outperforms the conventional RLS-based scheme although requiring higher computational complexity. A downlink half-duplex multi-cell relay system with three cells is shown in **Fig. 1**. The system is assumed to employ single frequency reuse. The base stations (BSs), relay stations (RSs), and mobile stations (MSs) are assumed to have single transmit and receive antennas. It is also assumed that the RSs are fixed and free from interference by using directional receive antennas. As for the channel, there are three kind of channels, i.e., channels between BSs and MSs, channels between BSs and RSs, and channels between RSs and MSs. Regarding all the channels, let us consider OFDM transmission over quasi-static frequency-selective fading channels, and let us assume that the symbol timing synchronization is perfect and that the maximum delay time of the propagation paths does not exceed the guard interval (GI).

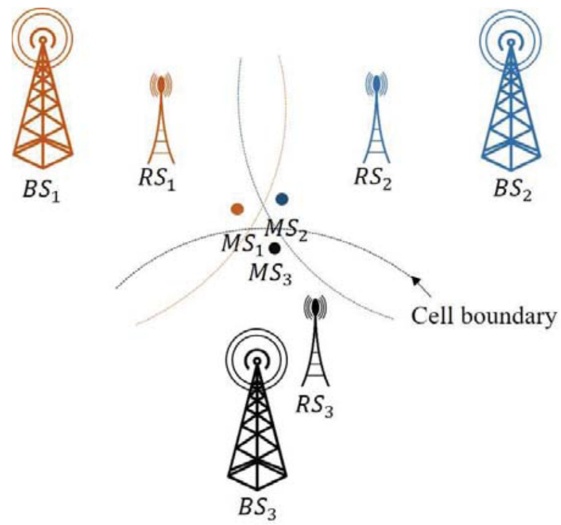


Fig. 1. A half-duplex multiple relay system with three cells.

Transmission occurs in two phases. In the first phase, the BSs are synchronized and transmit signals for the corresponding MSs. The RSs receive the signals only from the corresponding BSs of the cells they belong to. On the other hand, the MSs receive the signals from all the BSs, which means that the MSs suffer from co-channel interference. As shown in **Fig. 2**, let $Y_{ml}^{(p)}(i,n)$ denote the signals received by the l-th MS (l = 1, 2, 3) in the frequency domain of the p-th phase (p = 1, 2). The receiver detects the transmitted signals $S_{b_l}(i,n)$, from the l-th BS, by using the received signals $Y_{ml}^{(p)}(i,n)$ and let $\hat{S}_{b_l}(i,n)$ be a detected signal of $S_{b_l}(i,n)$; where i and n are the indexes of OFDM symbols and subcarriers, respectively.

In the second phase, the RSs are synchronized and transmit signals for the corresponding MSs. Let $S_{r_k}(i,n)$ denote the signal transmitted by the k-th RS. The MSs receive the signals from all the RSs, which means that the MSs suffer from interference again. The RSs are assumed to employ the non-selective decode-and-forward (DF) scheme. The DF relay decodes information bits from the received signals and transmits modulation signals that are generated from the decoded information bits.

To improve the BER performance, an eigendecomposition-based (ED) scheme is proposed in this paper. Similar to RLS-JD that proposed in our previous works, two user signals are detected by MUD and channel estimation is not necessary. Let the desired MS be MS_1 and let us suppose that the signals from BS_1 and BS_2 are detected by MUD. An error signal is defined as a difference between the linear combining output and its replica signal, where the linear combining aims to suppress $S_{b_3}(i,n)$ from BS_3. Decision directed (DD) estimation is employed to improve estimation accuracy. For the RLS algorithm, the DD estimation utilizes the detected data symbols. The RLS algorithm is recursively conducted once each data symbol pair is detected. For the proposed scheme, the DD estimation utilizes each detected data symbol pair to update the estimated covariance matrix of the signals including the received signals.

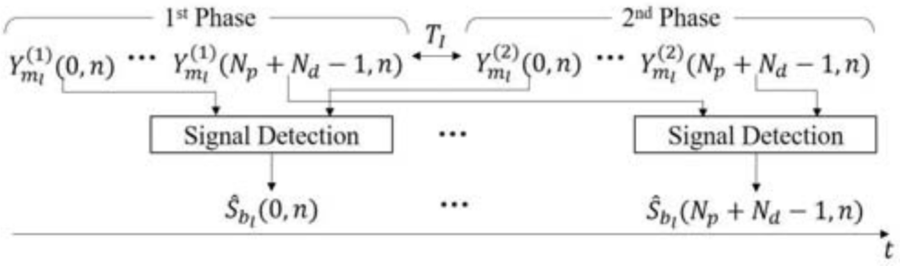


Fig. 2. Received signals in the first and second phases.

Complexity of MLD and RLS-JD and the proposed ED based schemes was compared here. MLD has the lowest complexity during the preamble because it requires only CSI. During the data period, complexity of MLD grows roughly proportional to M^3 while the order of the complexity of the ED-based scheme is M^2, where M is the modulation order. Considering the additional complexity to obtain preamble information and CSI for the third transmitter, it can be concluded that MLD is much harder to implement than the ED-based schemes, especially for high modulation order, M and long data length, N_d. In addition, the ED-based scheme requires a more amount of computational complexity than the RLS-JD based scheme while the former is expected to outperform the latter.

Figure 3 show average bit error rate (BER) performances of MLD, the RLS-JD based schemes, and ED when preamble length (PL) = 4 and average E_b/N_0 of RS was set to 30 dB. In the figures, B = 4 and ξ = 10 dB. Where B is the parameter of the number of the smallest eigenvalue components included in the proposed ED based scheme, and ξ is the power ratio of signals received in phase 2 to those in phase 1. The tendency of the average BER performances remains the same irrespective of E_b/N_0 of the RSs and the overall BER performance degrades only slightly when E_b/N_0 of RS is decreased to 15 dB. When the average E_b/N_0 of RS is equal to 30 dB, ED can outperform RLS-JD based schemes. However, ED is inferior to RLS-JD-DD-ES when average E_b/N_0 of MS is greater than or equal to 29.8 dB. ED with DD (ED-DD) outperforms all RLS-JD based schemes irrespective of average E_b/N_0 of MS. This is because ED-DD can fully exploit the diversity effect using plural error signals, whereas the RLS-JD schemes use only one error signal and cannot fully exploit the diversity effect.

Figure 4 shows BER performances with ξ being a parameter when average E_b/N_0 of RS was 30 dB, B = 4, and PL = 4. It can be seen that the BER performance of ED and ED-DD degrades as ξ increases. The reason is that when the difference in E_b/N_0 between phase1 and phase 2 becomes larger, the diversity effect is deteriorated.

In this paper, a joint interference suppression and MUD based on eigendecomposition in a three-cell scenario with half-duplex relays has been proposed. The proposed scheme detects two user signals while suppressing the other user signal, and estimates weight coefficients for linear suppression by eigenvalue decomposition in contrast with the conventional scheme. Computer simulations for OFDM transmission under three-cell and frequency selective fading conditions have shown that proposed scheme can improve the BER performance compared to the conventional RLS-based scheme.

Complexity of the proposed scheme called the ED-based scheme has also been evaluated. It is shown that complexity of the ED-based scheme grows roughly proportional to M^2 rather than M^3 which is the order for MLD, where M is the modulation order. In addition, the ED-based scheme needs to know only two out of the three preamble sequences while MLD needs to know the three preamble sequences. Therefore, the ED-based scheme can be implemented with much lower complexity than MLD.

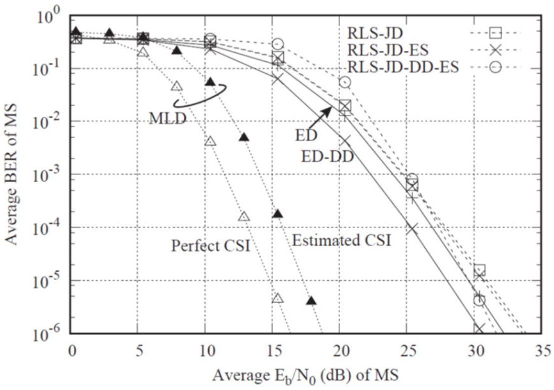


Fig. 3. BER performance with E_b/N_0 of RS being 30 dB, B = 4, ξ = 10 dB and PL = 4.

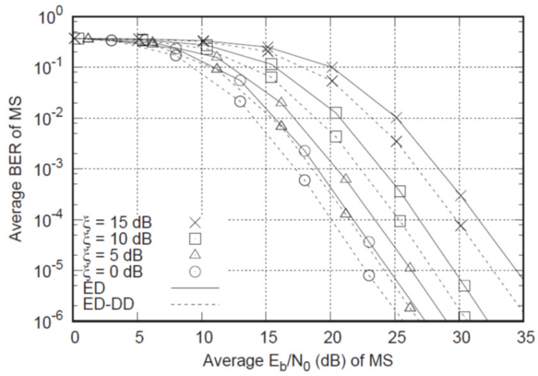


Fig. 4. BER performance for varying ξ with E_b/N_0 of RS being 30 dB, B = 4 and PL = 4.

Semi-Blind Interference Cancellation with Single Receive Antenna for Heterogeneous Networks [4], [6], [11]

In order to cope with severe interference in heterogeneous networks, this paper proposes a semi-blind interference cancellation scheme, which does not require multiple receive antennas or knowledge about training sequences of the interfering signals. The proposed scheme performs joint channel estimation and signal detection (JCESD) during the training period in order to blindly estimate channels of the interfering signals. On the other hand, maximum likelihood detection (MLD), which can be considered the optimum JCESD, must perform channel estimation for all transmitted signal candidates of the interfering signals and must search for the most likely signal

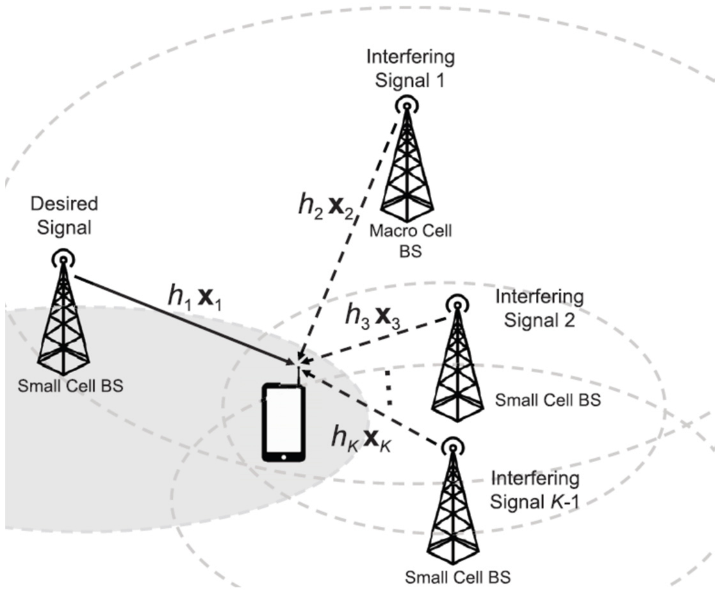


Fig. 5. A heterogeneous network.

candidate. Therefore, MLD incurs a prohibitive amount of computational complexity. To reduce such complexity drastically, the proposed scheme enhances the quantized channel approach, and applies the enhanced version to JCESD. In addition, a recalculation scheme is introduced to avoid inaccurate channel estimates due to local minima. Using the estimated channels, the proposed scheme performs multiuser detection (MUD) of the data sequences in order to cancel the interference. Computer simulations show that the proposed scheme outperforms a conventional scheme based on the Viterbi algorithm, and can achieve almost the same average bit error rate performance as the MUD with channels estimated from sufficiently long training sequences of both the desired signal and the interfering signals, while reducing the computational complexity significantly compared with full search involving all interfering signal candidates during the training period.

Let us consider a heterogeneous network shown in **Fig. 5**, in which one desired BS and $K-1$ interfering BSs of different types are densely allocated. Therefore, one UE simultaneously receives one desired signal and $K-1$ interfering signals where K is a positive integer to denote the number of signals. Suppose a single-input single-output (SISO) system employing OFDM. Let us assume that transmission timing of all the BSs is roughly synchronized and that all channels are quasi-static frequency selective fading. It is also assumed that the transmission timing offset plus the maximum delay time of the propagation paths does not exceed the guard interval (GI) of the OFDM symbol. Therefore, the inter-carrier interference and ISI do not occur. The receiver of UE removes signal components corresponding to GI and transforms the resultant time-domain signals into frequency-domain signals by fast Fourier transform (FFT). For simplicity, let us consider a generic signal model of a certain frequency subcarrier in the OFDM system.

The proposed semi-blind interference cancellation scheme using only single antenna mainly consists of a suboptimal JCESD based on an enhanced version of the quantized channel approach, which is called the quantized channel search (QCS) algorithm, a recalculation scheme, and MUD under the maximum likelihood (ML) criterion. **Fig. 6** shows a flowchart of the proposed scheme. The gray rectangular corresponds to the QCS algorithm that provides channel estimates by using the quantized channels, which is the main part of the proposed scheme. The channel estimate from QCS is verified by the recalculation scheme, in order to avoid selecting a local minimum as the estimate. Finally, MUD of data symbols under the ML criterion is carried out with the verified channel estimate. The proposed scheme iterates both the quantized channel generation and the local search. In contrast with the original method, a new set of quantized channels aims not to narrow the search area but to explore a completely different search area. For this purpose, the local search will check the search area thoroughly as described in the next subsection. The local search operates in the same manner as the expectation-maximization (EM) algorithm, and iteratively finds the pairs of a transmitted symbol matrix and a channel vector that have small replica errors. The quantized channel generation is illustrated in **Fig. 7a** and the local search is illustrated in **Fig. 7b**.

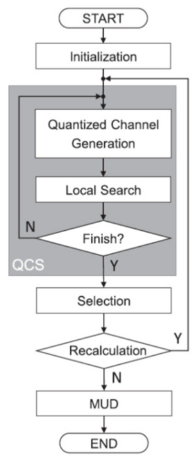


Fig. 6. Flow chart of the proposed scheme.

Simulations were conducted under the following conditions. Condition 1: The average received power of the one interfering signal was assumed to be 3 dB weaker than that of the desired signal. Condition 2: The average received power of the one interfering signal was assumed to be the same as that of the desired signal. Condition 3: The average received powers of the two interfering signals were

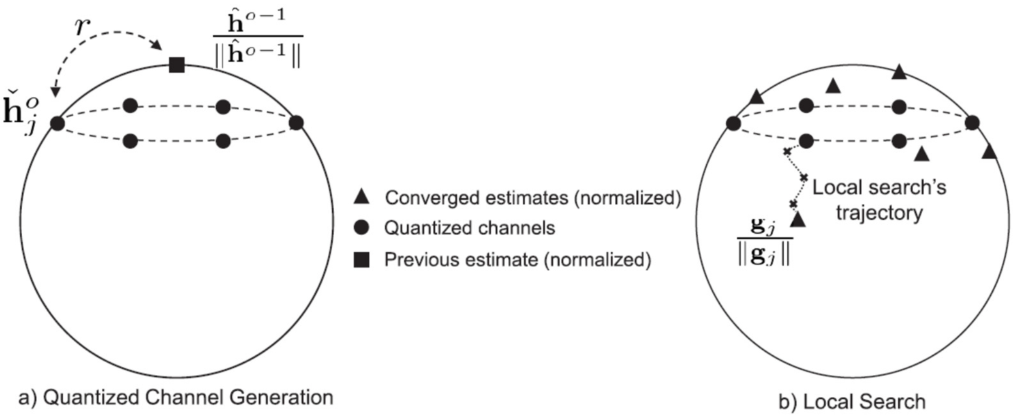


Fig. 7. Flow chart of the proposed scheme.

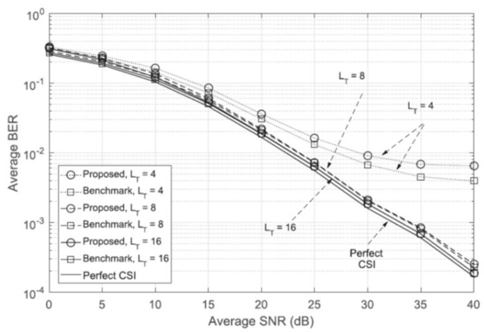


Fig. 8. Average BER performance under condition 1.

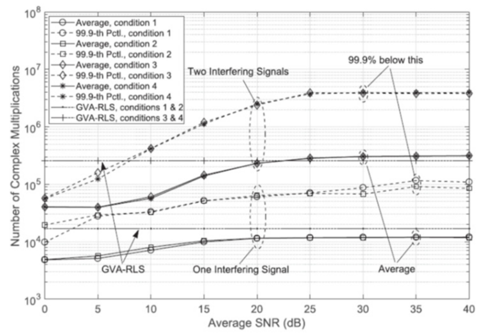


Fig. 9. Number of complex multiplications under conditions 1 to 4 with LT = 8.

assumed to be 3 dB stronger and 3 dB weaker than that of the desired signal. Condition 4: The average received powers of the two interfering signals were assumed to be the same as that of the desired signal.

Figure 8 show the average BER performances corresponding to condition 1, with the length of the training sequences LT being a parameter. The average BER of the proposed scheme is indicated by the circle. For comparison, MUD under the ML criterion with the channel estimated by the RLS algorithm using the known transmitted symbol matrix during the training period was investigated, of which the results were indicated by the square and labeled as "Benchmark". The channel estimate of the benchmark can be considered equal to the channel estimate achieved by MLD during the training period. It can be seen from it that the proposed scheme achieves almost the same performances as the benchmark in a high SNR region with LT = 8 and 16. Especially for LT = 16, the proposed scheme achieves exactly the same performance as the benchmark in the high SNR region, which infers that the proposed scheme has found one of the equivalent transmitted symbol matrices successfully. The degradations in performances of the proposed scheme become larger as LT decreases. This is because the RLS algorithm requires long training sequences in order to converge and short training sequences deteriorate accuracy of the channel estimation by RLS, which is likely to lead to a local minimum. For sufficient convergence of the RLS estimate, the number of inputs should be at least as twice as the number of unknown parameters. Since even the benchmark cannot provide sufficient performances with LT = 4, this paper sets LT = 8 and 16, hereafter. Finally, the computational complexity of the QCS in the proposed scheme was evaluated in terms of the number of complex multiplications. The average numbers and the 99.9-th percentiles of the complex multiplications required under all the conditions are shown in **Fig. 9**.

Evaluation for Wireless Sensor Networks with LT Codes Considering Probabilities of Transmission Failure [9], [10]

For monitoring environments of wide fields, the applications of wireless sensor networks (WSN) have been widely studied. Each sensor node in the WSN must be a low-cost and energy-constrained device that operates simple processing tasks. In the classical scenarios, a small number of reliably powered sink nodes are employed inside the WSN. At the sink nodes, the data is either processed or forwarded to an external network. However, in many cases, WSNs may be deployed at inaccessible locations where it is not feasible to set up the reliable sinks and/or to access the external network reliably. In such cases, a convenient approach is to use the mobile collectors (e.g. ground or aerial vehicles) that are required to connect only a subset of sensor nodes due to topology constraints. The distributed packet-centric method has been proposed, which employs LT codes in creating and distributing rateless packets across the WSN by simple bitwise XOR operations. The availability of this novel scheme was shown in the conventional works; however, it still needs to be evaluated under more realistic channels that may incur packet transmission errors.

In this paper, we investigate the LT code rateless packet approach for the WSN by considering the probabilities of the transmission failure among the sensor nodes. A modified scheme that allows the mobile collector to directly collect the data packet of the communicating sensor node beside the rateless packets is proposed. In addition, this paper theoretically analyzes the numbers of the total transmissions and the survival rateless packets of the modified scheme. Finally, computer simulations show that the modified scheme is very effective on improving the average decoded packet error rate.

The random geometric graph $\mathcal{G}(N,r)$ is considered as the WSN model, where N sensor nodes are uniformly distributed on a unit square area, and any sensor node can communicate with any neighbor within the transmission range r. Note that we consider the probability of the packet transmission failure, P_{e}, of each rateless packet in each hopping. All the N nodes perform sensor measurements periodically; and in each node, the measured data is placed in an sensor data packet. Additionally, every sensor data packet has an equal length. The set of all sensor data packets produced at the beginning of each period represents one data generation, and the distributed rateless encoding of the sensor data packets belonging to a single generation is focused here. In each sensor node, the distributed rateless packets are stored in a memory buffer that has sufficient capacity. In data collection phase, the mobile collector starts at a randomly selected node and collects rateless packets by performing random walk across the WSN.

The processes of data encoding, dispersion and collection mainly follows the conventional method, but have some modifications due to the assumption of probability of transmission failure. In a rateless packet, the Rateless Packet Data is the content of this packet, the Generation ID denotes the period when the data were measured, the Sensor IDs denotes the sensors whose data packets are encoded in the rateless packet content, while the Degree Counter and the Mixing-Time Counter control the process of encoding. In the initialization phase, every sensor node generates b rateless packets, copies its current sensor data packet in the rateless packet data field, and puts its ID in the sensor IDs field; i.e., total bN rateless packets are initialized across the N sensor nodes. The degree, d, is drawn randomly from a selected distribution of degree, $\Omega(d)$, by the node independently for each of its b rateless packets. The degree counter is set with the value $d-1$ that is the remaining degree to be collected, for the rateless packet content is initialized with the local sensor data packet. Finally, the mixing-time counter is set to a chosen mixing-time value τ that is a global parameter of this WSN. In the encoding and dispersion phase, every rateless packet adds the remaining $d-1$ sensor data packets to its content in the packet-centric manner. The rateless packets perform normal random walk across the WSN, and every rateless packet is processed by every sensor node on the path using following rule. 1) The sensor node only decreases mixing-time counter of the rateless packet by one and forwards the rateless packet to the next random hopped node, when the mixing-time counter is larger than zero. 2) The sensor node adds its sensor data packet to the rateless packet content, decrease the degree counter by one, puts its sensor ID into the list of sensor IDs, resets the mixing-time counter to the initial value τ, and then forwards the updated rateless packet to the next node, when the mixing-time counter is zero and the degree counter is larger than zero. 3) Otherwise, when both mixing-time counter and degree counter are zero, the rateless packet is stored in the memory buffer of the final hopped node. In the collection and decoding phase, at a randomly selected sensor node, the mobile collector starts the data gathering, and the two-dimensional random walk across the unit square area from this sensor node. The constraint on the random walk of the collector is that the collector avoids to visit the already visited sensor nodes. At each sensor node, the collector moves all the rateless packets from the sensor node buffer memory into its own buffer memory. Note that the transmission failure probability for the packet/data moving is also considered in this evaluation, and the probability of the successful moving of each packet is defined as Pm. Once the collector collects more than a preset number, $d_{\max}$ of rateless packets, the mobile collector performs the iterative hard decoding over the collected rateless packets. The completely decoded rateless packets will be discard; and the decoding process rests when there is no rateless packet with only-one ID in its sensor IDs field. The collection-and-decoding process for the rateless packets is repeated until a sufficient number N' of rateless packets is collected for successful decoding. The modifications summarized as: 1) The sensor node and the mobile collector can detect the transmission error in the received rateless packets, for the error-detection encoding, e.g. cyclic redundancy check (CRC), is assumed to be employed in the sensor data packets and the rateless packets. However, the error correction or the retransmission will not be conducted to reduce the complexity and power consumption of the sensor nodes. The rateless packets including transmission error will be discarded by the sensor nodes or mobile collector. 2) Mobile collector can directly collect the data packet of the current communicating sensor node. The directly collected data packets are equivalent to the rateless packets with $d = 1$ and is expected to increase the probability of successful decoding. 3) The maximum degree of the probability distribution function is set to $d_{\max}$ ($< N$) that can reduce the complexity of the decoder and the length of the sensor IDs field in a rateless packet. It also can increase the probability of the $d = 1$ rateless packets lightly. Following the setting of the WSN, we analyze the numbers of transmissions and the survival rateless packets in this section. The power consumption of the WSN may increase with the numbers of transmissions, while the successful probability of decoding may increase with the number of survival rateless packets.

Figs. 10 and **11** show the number of survival rateless packets and the total number of transmissions, respectively. We can see the theoretical results are well matched with the simulation results. When M = 3, it has large number of trans-missions, but also has large number of survival packets; however, it also needs more number of collected packets for decoding.

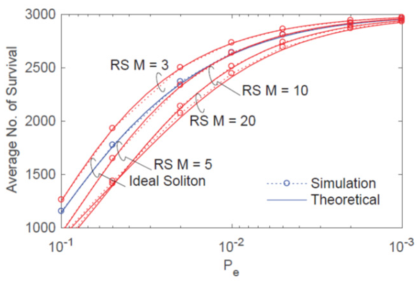


Fig. 10. Average number of survival rateless packets (τ = 3).

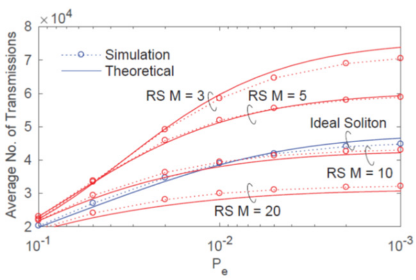


Fig. 11. Average total number of transmissions (τ = 3).

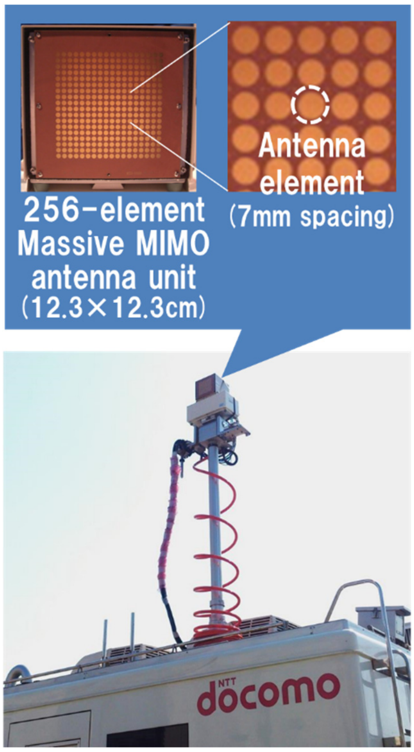
Okumura Laboratory

Homepage: http://www.radio.ce.titech.ac.jp/

Visiting Professor Yukihiko Okumura

Dr. Okumura received his B.S and M.S degrees in electrical engineering from the Tokyo University of Science, Tokyo, Japan, in 1989 and 1991, respectively, and his Ph.D. degree in engineering from the Tohoku University, Sendai, Japan, in 2006. In 1991, he joined the Radio Communication Systems Laboratories of Nippon Telegraph and Telephone Corporation (NTT), and since 1992, he has been engaged in the research, standardization and development of wideband/broadband mobile radio communication technologies, terminals and system, at the NTT Mobile Communication Network, Inc. (now NTT DOCOMO, INC.) He is a senior member of IEEE.

Research Interests



In the fifth-generation mobile communication system (5G) where research and development are proceeded for commercial service starting from 2020, to accommodate both rapid growing of mobile data traffic due to the spread of smartphone/tablets and qualitative change of data traffic caused by the spread of IoT (Internet of Things), dramatic improvement of the system capability, higher bit rates of data communication, drastic increase of the number of connected devices, and larger reduction of power consumption and cost of radio access network and mobile terminals are required compared for 4G. Moreover, in order to flexibly allow new mobile services and applications that needs from various industries create, further enhancement of 5G and consecutive research of next-generation mobile communication system where novel radio access technologies can be introduced in phased approach are needed.

Okumura laboratory focuses on the flowing research topics:

- ✓ ***Proposal and performance evaluation of radio access system for next-generation mobile communication system***
- ✓ ***Radio access technologies for further enhancement of next-generation mobile communication system***
- ✓ ***Radio control technologies and mobile services and applications for further enhancement of next-generation mobile communication system***

In addition to computer simulations etc. on above research topics, experimental trials using experimental equipment are promoted, and students can tackle a variety of researches in the state-of-the-art corporate research and development environment.

Contributions

Takada Laboratory

Books

[1] Sukhumarn Archasantisuk, Takahiro Aoyagi, Tero Uusitupa, Minseok Kim, and Jun-ichi Takada, "Human Movement Identification Using the Radio Signal Strength in WBAN," accepted for publication in Fardin Derogarian and Fernando Velez (eds.), Wearable Technologies and WBSNs for Healthcare, IET (peer reviewed).
[2] Yew Siang Poong, Shinobu Yume Yamaguchi and Jun-ichi Takada, "Analysing Mobile Learning Acceptance in the World Heritage Town of Luang Prabang, Lao PDR," in Helen Sara Farley, Angela Murphy, Laurel Evelyn Dyson (eds.), Mobile Learning in Higher Education in the Asia Pacific - Harnessing Trends and Challenging Orthodoxies, pp. 191-212, Springer Nature Singapore, 2017.
[3] Jun-ichi Takada, "Spectrum Use in Future," 100-year History of IEICE, pp. 425-427, IEICE, Sept 2017 (in Japanese).

Transactions and Letters

[4] Yee-Loo Foo and Jun-ichi Takada, "Aggregate Interference of Equidistant Cognitive Radios," Wireless Personal Communications, vol. 92, pp. 1053-1069, Feb. 2017.
[5] Jun-ichi Naganawa, Jun-ichi Takada, Takahiro Aoyagi, and Minseok Kim, "Antenna De-embedding in WBAN Channel Modeling using Spherical Wave Functions," IEEE Transactions on Antennas and Propagation, vol. 65, no. 3, pp. 1289-1300, Mar. 2017.
[6] Mohammad Tariqul Islam, Md. Zulfiker Mahmud, Norbahiah Misran, Jun-ichi Takada, and Mengu Cho, "Microwave Breast Phantom Measurement System With Compact Side Slotted Directional Antenna," IEEE Access, vol. 5, pp. 5321-5330, Apr. 2017.
[7] Takuichi Hirano, Ning Li, and Kenichi Okada, "Analysis of Effective Material Properties of Metal Dummy Fills in a CMOS Chip," IEICE Transactions on Communications, vol. E100-B, no. 5, pp. 793-798, May. 2017.
[8] Karma Wangchuk, Kento Umeki, Tatsuki Iwata, Pnawit Hanpinitsak, Minseok Kim, Kentaro Saito, and Jun-ichi Takada, "Double Directional Millimeter Wave Propagation Channel Measurement and Polarimetric Cluster Properties in Outdoor Urban Pico-cell Environment," IEICE Transactions on Communications, vol. E100-B, no. 7, pp. 1133-1144, Jul. 2017.
[9] Kentaro Saito, Jun-ichi Takada, Minseok Kim, "Dense Multipath Component Characteristics in 11-GHz-Band Indoor Environments", IEEE Transactions on Antennas and Propagation, vol. 65, no. 9, pp. 4780-4789, Sep. 2017.
[10] Azril Haniz bin Abdul Aziz, Gia Khanh Tran; Kentaro Saito, Kei Sakaguchi, Jun-ichi Takada; Daisuke Hayashi, Toshihiro Yamaguchi, and Shintaro Arata, "A Novel Phase-difference Finger-printing Technique for Localization of Unknown Emitters," IEEE Transactions on Vehicular Technology, vol. 66, no. 9, pp. 8445-8457, Sept. 2017.
[11] Panawit Hanpinitsak, Kentaro Saito, Jun-ichi Takada, Minseok Kim, and Lawrence Materum, "Multipath Clustering and Cluster Tracking for Geometry-Based Stochastic Channel Modeling," IEEE Transactions on Antennas and Propagation, vol. 65, no. 11, pp. 6015-6028, Nov. 2017.
[12] Ceelia Leong, Jun-ichi Takada, Shinya Hanaoka, and Shinobu Yamaguchi, "Impact of Tourism Growth on the Changing Landscape of a World Heritage Site: Case of Luang Prabang, Lao PDR," Sustainability, vol. 9, no. 11, Nov. 2017.
[13] Tianyang Min, Kentaro Saito, and Jun-ichi Takada, "Development of Directional Channel Sounder Using USRP and GNU Radio," ASEAN Engineering Journal Part A, vol. 7, no, 1, pp. 74-83, 2017.
[14] Minseok Kim, Jun-ichi Takada, Kentaro Saito, "Multi-dimensional Radio Channel Measurement, Analysis and Modeling for High Frequency Bands," IEICE Transactions on Communications, Vol.E101-B, No.2, pp.293-308, Feb. 2018.

International Conference

[15] Minseok Kim, Tatsuki Iwata, Kento Umeki, Jun-ichi Takada, and Shigenobu Sasaki, "mm-wave Indoor Channel Cluseter Analysis by Multi-path Component Extraction from Directional Antenna Scanning," COST CA15104 3rd Management Committee Meeting and 3rd Technical Meeting, TD(17)03055, Feb. 2017 (Lisbon, Portugal).
[16] Brecht Hassens, Kentaro Saito, Emmeric Tanghe, Wout Joseph, and Jun-ichi Takada, "Modeling the Power Angular Profile of Dense Multipath Components using Multiple Clusters," COST CA15104 3rd Management Committee Meeting and 3rd Technical Meeting, TD(17)03056, Feb. 2017 (Lisbon, Portugal).
[17] Kentaro Saito, Jun-ichi Takada, and Minseok Kim, "11 GHz Band MIMO Channel Characteristics in a Street Micro-Cell Environment," 11th European Conference on Antennas and Propagation (EuCAP 2017), Mar. 2017 (Paris, France).
[18] Minseok Kim, Tatsuki Iwata, Kento Umeki, Jun-ichi Takada, and Shigenobu Sasaki, "Indoor Channel Characteristics in Atrium Entrance Hall Environment at Millimeter-wave Band," 11th European Conference on Antennas and Propagation (EuCAP 2017), Mar. 2017 (Paris, France).
[19] Jun-ichi Takada, Koichi Ogawa, and Kei Sakaguchi, "Spatial Fading Emulator - Early OTA Device in Japan," 11th European Conference on Antennas and Propagation (EuCAP 2017), Mar. 2017 (Paris, France).
[20] Minseok Kim, Kento Umeki, Shigenobu Sasaki, and Jun-ichi Takada, "Modified Channel Model For Outdoor Open Area Hotspot Access Scenario," IEEE P802.11 Task Group ay Meeting, IEEE 802.11-16/0342r0, March 2017 (Vancouver, Canada).
[21] Takuichi Hirano, and Jiro Hirokawa, "Computer Graphics Based Education Materials for Electromagnetic Waves," Vietnam Japan Microwave 2017 (VJMW 2017), 1A-3, June 2017 (Hanoi, Vietnam).
[22] Takuichi Hirano, "Software GSM Solver to Solve Scattering Characteristic for Arbitrarily Connected Scattering Matrices," 2017 Thailand-Japan Microwave (TJMW 2017), TH3-03, June 2017 (Bangkok, Thailand).
[23] Jun-ichi Takada, "De-embedding of Antennas from Propagation Channel in Wireless Communications (II) --- Comparison between Plane Wave Modeling and Spherical Wave Modeling," 2017 Asian Workshop on Antennas and Propagation, June 2017 (Sapporo, Japan).
[24] Takuichi Hirano, and Jiro Hirokawa, "Education Materials of Electricity and Magnetism using MATLAB," 2017 IEEE International Symposium on Radio-Frequency Integration Technology (RFIT 2017), pp. 16-18, Aug. 2017 (Seoul, Korea).
[25] Azril Haniz, Gia Khanh Tran, Kei Sakaguchi, Jun-ichi Takada, Toshihiro Yamaguchi, Tsutomu Mitsui, Shintaro Arata, "Deterministic and Probabilistic Fingerprint-based Localization utilizing RSS and Phase-difference," 4th International Workshop on Smart Wireless Communications (SmartCom 2017), published as IEICE Technical Report, vol. 117, no. 257, SR2017-69, pp. 11-18, Oct. 2017 (Rome, Italy).
[26] Tossaporn Srisooksai, Jun-ichi. Takada, and Kentaro Saito, "Portable wide-band channel sounder based software defined radio for studying the radio propagation in an outdoor environment," 2017 International Symposium on Antennas and Propagation (ISAP 2017), Nov. 2017 (Phuket, Thailand).
[27] Azril Haniz, Gia Khanh Tran, Kei Sakaguchi, Jun-ichi Takada, Daisuke Hayashi, Toshihiro Yamaguchi, and Shintaro Arata, "Hybrid fingerprint-based localization of unknown radios: Measurements in an open field," 2017 IEEE Asia Pacific Microwave Conference (APMC 2017), pp. 865-868, Nov. 2017, (Kuala Lumpar, Malaysia).

Domestic Conference

[28] Takuichi Hirano, "Influence of Higher-Order

Modes at Waveguide Ports in Electromagnetic Simulation," IEICE Technical Report, vol. 117, no. 140, MW2017-67, pp. 207-210, July 2017 (in Japanese).
[29] Kentaro Saito, Panawit Hanpinitsak, Jun-ichi Takada, Wei Fan, and Gert F. Pedersen, "The Delay and Directional Characteristics of Propagation Channels from 3GHz Band to 28GHz Band in Indoor Environment," IEICE Technical Report, vol. 117, no. 150, AP2017-65, pp. 111-116, July 2017.
[30] Kosuke Murakami, Kentaro Saito, and Jun-ichi Takada, "Development of SIMO Channel Sounder in 12GHz band by Utilizing Radio-on-Fiber Technology," IEICE Technical Report, vol. 117, no. 178, SRW2017-12, pp. 19-24, Aug. 2017 (in Japanese).
[31] Kentaro Saito, Qiwei Fan, Nopphon Keerativoranan, and Jun-ichi Takada, "Outdoor-to-Indoor Radio Propagation Loss Measurement by using an Unmanned Aerial Vehicle in 4.9 GHz band," IEICE Technical Report, vol. 117, no. 178, SRW2017-13, pp. 25-30, Aug. 2017 (in Japanese).
[32] Azril Haniz, Gia Khanh Tran, Kei Sakaguchi, Jun-ichi Takada, Toshihiro Yamaguchi, Shintarou Arata, "A Study on Spatial Averaging of RSS Fingerprints for Localization of Unknown Radios," IEICE Society Conference, B-17-25, Sept. 2017.
[33] Junming Jiang, Azril Haniz, and Jun-ichi Takada, "Development of Device-free Indoor Localization System by using Raspberry Pi," 2017 IEICE Society Conference, B-17-26, Sept. 2017.
[34] Satoshi Nishida, Jun-ichi Takada, Gilbert Siy Ching, and Yukiko Kishiki, "Radio Propagation Experiment in a Subway and the Attenuation Constant Classified based on Tunnel Structure," 2017 IEICE Society Conference, B-1-10, Sept. 2017 (in Japanese).
[35] Kentaro Saito, Qiwei Fan, Nopphon Keerativoranan, and Jun-ichi Takada "4.9 GHz band Outdoor-to-Indoor Radio Propagation Measurement by an Unmanned Aerial Vehicle," IEICE Society Conference, B-1-15, Sept. 2017 (in Japanese).
[36] Kosuke Murakami, Kentaro Saito, and Jun-ichi Takada, "Development of MIMO Channel Sounding System in 12GHz Band by Utilizing Radio-on-Fiber Technology," 2017 IEICE Society Conference, B-1-157, Sept. 2017 (in Japanese).
[37] Jun-ichi Takada, "IoT and Smart Spectrum Technology," 2017 IEICE Society Conference, BP-3-1, Sept. 2017 (in Japanese).
[38] Takuichi Hirano, "Different Definitions of Resonance and Calculation of Q factor by Complex Resonant Frequency," 2017 IEICE Society Conference, C-2-49, Sept. 2017 (in Japanese).
[39] Takuichi Hirano, "Similarity of MIMO Eigenmode Transmission in Two Uniform Circular Arrays and OAM Transmission," IEICE Technical Report, vol. 117, no. 291, MW2017-111, pp. 1-4, Nov. 2017 (in Japanese).
[40] Hiroki Ohara, Hirokazu Sawada, Masayuki Oodo, and Fumihide Kojima, "A Study on Arrival Path Extraction for Channel Modeling," IEICE Technical Report, vol. 117, no. 297, SRW2017-48, pp. 23-24, Nov. 2017.
[41] Kosorl Thourn, Takahiro Aoyagi, and Jun-ichi Takada, "Evaluation of the Influence of Reflection from Wave Absorber to Body Area Measurement in Anechoic Chamber Using RMS Time Delay," IEICE Technical Report, vol. 117, no. 319, EMCJ2017-66, pp. 13-16, Nov. 2017.
[42] Yunyi Yao, Kentaro Saito, Azril Haniz, Jun-ichi Takada, "Propagation Loss Prediction By Machine Learning for Wireless LAN Cell Planning," IEICE Technical Report, vol. 117, no. 363, SRW2017-62, pp. 13-18, Dec. 2017.
[43] Kentaro Saito, Jun-ichi Takada, and Minseok Kim, "Radio Propagation Research for the Next Generation Wireless Communication System," IEICE Technical Report, vol. 117, no. 363, SRW2017-64, pp. 25-30, Dec. 2017 (in Japanese).
[44] Nopphon Keerativoranan, and Jun-ichi Takada, "Tracking 1D Hand Motion Directivity by Estimating Doppler Frequency of CSI Information from Commodity Wi-Fi Devices," IEICE Technical Report, vol. 117, no. 366, MW2017-145, pp. 19-24, Dec. 2017.

[45] Xin Du, Kentaro Saito, Jun-ichi Takada, Mitsuki Nakamura, Motoharu Sasaki, and Yasushi Takatori, "Shadowing Effect of Obstacles on Millimeter-wave Band Propagation Channel in Indoor Environment," IEICE Technical Report, vol. 117, no. 382, AP2017-155, pp. 25-29, Jan. 2018 (in Japanese).
[46] Satoshi Nishida, Jun-ichi Takada, Gilbert Siy Ching, and Yukiko Kishiki, "Effect of the Object Inside a Tunnel in the Radio Wave Propagation of a Subway Tunnel," IEICE Technical Report, vol. 117, no. 382, AP2017-157, pp. 37-42, Jan. 2018.
[47] Satoshi Nishida, and Jun-ichi Takada, "Requirement of Train Control Communication Using Un-licensed Wireless Band," IEICE Technical Report, vol. 117, no. xxx, SR2017-xxx, pp. xx-xx, Mar. 2018 (in Japanese).
[48] Kentaro Saito, Jiayue Cheng, and Jun-ichi Takada, "Representation Method of Wireless Network Area Quality by Augmented Reality Technology," IEICE Technical Report, vol. 117, no. xxx, SRW2017-xxx, pp. xx-xx, Mar. 2018 (in Japanese).
[49] Dwi Joko Suroso, Kentaro Saito, and Jun-ichi Takada, "On Investigation of Directional Model for Large Spacing MIMO at 11 GHz Band: Eigenvalues Comparison of Measurement and Channel Synthesis," IEICE Technical Report, vol. 117, no. xxx, SRW2017-xxx, pp. xx-xx, Mar. 2018.
[50] Minseok Kim, Tatsuki Iwata, Shigenobu Sasaki, and Jun-ichi Takada, "Millimeter Wave Indoor Channel Characterization using High Resolution Multipath Parameter Estimation," IEICE Technical Report, vol. 117, no. xxx, SRW2017-xxx, pp. xx-xx, Mar. 2018.
[51] Azril Haniz, Gia Khanh Tran, Kei Sakaguchi, Jun-ichi Takada, Toshihiro Yamaguchi, Tsutomu Mitsui, and Shintaro Arata, "Machine Learning Based Regression of Fingerprint Database for Unknown Emitter Localization," IEICE Technical Report, vol. 117, no. xxx, SR2017-xxx, pp. xx-xx, Mar. 2018 (Yokosuka, Kanagawa).
[52] Tokio Miyake, and Jun-ichi Takada, "Numerical simulation of scattering from random rough surface by using physical optics," IEICE Technical Report, vol. 117, no. xxx, AP2017-xxx, pp. xx-xx, Mar. 2018 (in Japanese).
[53] Kentaro Saito, and Jun-ichi Takada, "Representation Method of Wireless Network Area Quality by Augmented Reality Technology," 2018 IEICE General Conference, Mar. 2018 (in Japanese).
[54] Satoshi Nishida, and Jun-ich Takada, "Study of Train Control Communicatin with Wireless LAN," 2018 IEICE General Conference, Mar. 2018 (in Japanese).
[55] Minseok Kim, Tatsuki Iwata, Shigenubu Sasaki, and Jun-ichi Takada, "Propagation Path Parameter Estimation using Subgrid CLEAN Algorithm," 2018 IEICE General Conference, Mar. 2018 (in Japanese).

Sakaguchi Laboratory

Transactions and Letters

[1] Tao YU, Yusuke KUKI, Gento MATSUSHITA, Daiki MAEHARA, Seiichi SAMPEI, Kei SAKAGUCHI, "Design and Implementation of Lighting Control System Using Battery-Less Wireless Human Detection Sensor Networks," IEICE Trans. Commun. vol. E100-B no.6 pp.974-985, Jun. 2017.
[2] Kei SAKAGUCHI, "How Do We Use Spectrum More Efficiently," Journal of IEICE, vol. 100, no. 8, pp. 825-830, Aug. 2017.
[3] Azril Haniz, Gia Khanh Tran, Kentaro Saito, Kei Sakaguchi, Jun-ichi Takada, Daisuke Hayashi, Toshihiro Yamaguchi, Shintaro Arata, "A novel phase-difference fingerprinting technique for localization of unknown emitters," IEEE Trans. Veh. Tech., vol. 66, no. 9, pp. 8445-8457, Sep. 2017.
[4] Maki ARAI, Masashi IWABUCHI, Kei SAKAGUCHI, Kiyomichi ARAKI, "Optimal Design Method of MIMO Antenna Directivities and Corresponding Current Distributions by Using Spherical Mode Expansion," IEICE Trans.

Commun. vol. E100-B no. 10, pp. 1891-1903, Oct. 2017.
[5] Kei Sakaguchi, Thomas Haustein, Sergio Barbarossa, Emilio Calvanese Strinati, Antonio Clemente, Giuseppe Destino, Aarno Pärssinen, Ilgyu Kim, Heesang Chung, Junhyeong Kim, Wilhelm Keusgen, Richard J. Weiler, Koji Takinami, Elena Ceci, Ali Sadri, Liang Xain, Alexander Maltsev, Gia Khanh Tran, Hiroaki Ogawa, Kim Mahler, Robert W. Heath Jr., "Where, When, and How mmWave is Used in 5G and Beyond," IEICE Trans. Electron., vol. E100–C, no. 10, pp. 790-808 Oct. 2017. (Invited)
[6] Ehab Mahmoud Mohamed, Kei Sakaguchi, Seiichi Sampei, "Wi-Fi coordinated WiGig concurrent transmissions in random access scenarios," IEEE Trans. Veh. Tech, vol. 66, no. 11, Nov. 2017.
[7] Ryosuke SUGA, Hiroki SAITO, Kiyomichi ARAKI, and Osamu HASHIMOTO, "Analytical Study on Environment Improvement of Indoor WLAN by Using Dry Double Wall with Frequency Selective Surface," IEICE Trans. Electron., vol. J100-C, no. 12, pp.585-588, Dec. 2017.
[8] Daisuke Kitahara, Ryosuke Suga, Kiyomichi Araki, and Osamu Hashimoto, "Circular Patch Array Absorber Design for Oblique Incidence by Using Winding Ratio Model of Transformer," IEEE Transactions on Electromagnetic Compatibility (to be published).

International Conference

[9] Hiroaki Ogawa, Gia Khanh Tran, Kei Sakaguchi, Thomas Haustein, "Traffic Adaptive Formation of mmWave Meshed Backhaul Networks," ICC2017, WS-03, IEEE, IEEE, May. 2017.
[10] Gia Khanh Tran, Emmanuel Dotaro, Pascal Thubert, Thomas Haustein, Kei Sakaguchi, "[Panel discussion] Evolutional Technologies & Ecosystems for 5G and Beyond," ICC2017 WDN-5G workshop, May. 2017.
[11] Xi Li, Raihana Ferdous, Carla Fabiana Chiasserini, Claudio Ettore Casetti, Francesca Moscatelli, Giada Landi, Ramon Casellas, Kei Sakaguchi, Shahzoob Bilal Chundrigar, Ricard Vilalta, Josep Mangues, Andres Garcia-Saavedra, Xavier Costa-Pérez, Leonardo Goratti, Domenico Siracusa, "Novel resource and energy management for 5G integrated backhaul/fronthaul (5G-Crosshaul)," in Proc. IEEE ICC Workshops, June 2017.
[12] Jafar Mohammadi, Jian Luo, Valerio Frascolla, Katsuo Yunoki, Koji Takinami, Kei Sakaguchi, Gia Khanh Tran, Sergio Barbarossa, "[Invited] Hardware-In-the-Loop Trials and Demonstrations for 5G mm-Wave Communications: a Waveform Study," EuCNC2017, IEEE, Jun. 2017.
[13] Osamah Ibrahiem Abdullaziz, Marco Capitani, Claudio Ettore Casetti, Carla Fabiana Chiasserini, Shahzoob Bilal Chundrigar, Giada Landi, Xi Li, Francesca Moscatelli, Kei Sakaguchi, Samer T. Talat, "Energy monitoring and management in 5G integrated fronthaul and backhaul," in Proc. EuCNC, June 2017.
[14] Gia Khanh Tran, Kei Sakaguchi, Makoto Ando, "[Keynote] Paving the Way to the Realization of 5G Cellular Networks based on mmWave Small Cell Networking," WoWMoM 2017, SCN workshop, Jun. 2017.
[15] Kei Sakaguchi, Gia Khanh Tran, Hiroaki Ogawa, "mmWave meshed network with traffic and energy management mechanism," in Proc. IEEE SPAWC2017, July 2017.
[16] Gia Khanh Tran, Kei Sakaguchi, Makoto Ando, "Integration of mmWave Access and Backhaul Networks for 5G & Beyond," Japan-China Workshop on the Next Generation Mobile Communication Technology and Application, Jul. 2017.
[17] X. Xu, D. Mori, A. Mazzinghi, A. Freni, J. Hirokawa, M. Ando and K. Araki, "A 60-GHz RLSA fed by Butler matrix carrying three OAM modes," in IEEE International Symposium on Antennas and Propagation (APSURSI), San Diego, California, USA, pp. 1445–1446, July 2017.
[18] Valerio Frascolla, Katsuo Yunoki, Sergio Barbarossa, Valerio Frascolla, Federico Miatton, Gia Khanh Tran, Koji Takinami, Antonio De

Domenico, Emilio Calvanese Strinati, Thomas Haustein, Kei Sakaguchi, Sergio Barbarossa, Sergio Barberis, "[Invited] 5G-MiEdge: Design, Standardization and Deployment of 5G Phase II Technologies," CSCN2017, IEEE, Sep. 2017.

[19] Gia Khanh Tran, Kei Sakaguchi, Makoto Ando, "[Invited] mmWave Heterogeneous Networks in 5G & Beyond," ATC2017, ATC2017, Oct. 2017.

[20] Valerio Frascolla, Kei Sakaguchi, Sergio Barbarossa, Antonio De Domenico, Sergio Barberis, Gia Khanh Tran, Koji Takinami, Thomas Haustein, "[Invited] Use cases and scenario resulting from merging mmWave access with Multi-access Edge Technologies," SmartCom 2017, IEICE technical report, Oct. 2017.

[21] Koji Takinami, Antonio De Domenico, Konstantin Koslowski, Gia Khanh Tran, Yuyuan Chang, Hiroaki Ogawa, Mattia Merluzzi, Sergio Barbarossa, "[Invited] 5G-MiEdge: Introduction of Millimeter-Wave Edge Cloud, a Key Technology for 5G Phase II Deployment," SmartCom 2017, IEICE technical report, Oct. 2017.

[22] Azril HANIZ, Gia Khanh TRAN, Kei SAKAGUCHI, Jun-ichi TAKADA, Toshihiro YAMAGUCHI, Tsutomu MITSUI, Shintaro ARATA, "[Poster Presentation] Simulation-based Analysis of RSS Location Fingerprint under Multipath Fading Effects," SmartCom 2017, Technical Report, IEICE, Oct. 2017.

[23] Hiroyuki KAMATA, Gia Khanh TRAN, Kei SAKAGUCHI, Kiyomichi ARAKI, "[Poster Presentation] Robust and Low Complexity Signal Detection Method based on Power Spectrum under Noise Uncertainty," SmartCom 2017, Technical Report, IEICE, Oct. 2017.

[24] Hiroaki NISHIUCHI, Gia Khanh TRAN, Kei SAKAGUCHI, "[Poster Presentation] Performance Evaluation of Prefetching Algorithm for 5G mmWave Edge Cloud," SmartCom 2017, Technical Report, IEICE, Oct. 2017.

[25] Azril HANIZ, Gia Khanh TRAN, Kei SAKAGUCHI, Jun-ichi TAKADA, Daisuke HAYASHI, Toshihiro YAMAGUCHI, Shintaro ARATA, "[Invited] Hybrid Fingerprint-based Localization of Unknown Radios: Measurements in an Open Field," APMC 2017, pp.865-868, Nov. 2017.

[26] Takahiro Omatsuzawa, Ryosuke Suga, Kiyomichi Araki, and Osamu Hashimoto, "A Study on Active Absorption Transmission Reflection FSS using Diodes," The 39th Progress In Electromagnetics Research Symposium (PIERS) in Singapore, p.879, Nov. 2017.

[27] Daisuke Kitahara, Rryosuke Suga, Kiyomichi Araki, and Osamu Hashimoto, "A Study on Bandwidth Improvement of Circular Patch Array Absorber by Using Perturbation Elements," The 39th Progress In Electromagnetics Research Symposium (PIERS) in Singapore, p.1107, Nov. 2017.

[28] Ricardo Santos, Hiroaki, Ogawa, Gia Khanh Tran, Kei Sakaguchi, Anreas Kassler, "Turning the knobs on OpenFlow-based resiliency in mmWave small cell meshed networks," in Proc. IEEE Globecom Workshops, Dec. 2017.

Domestic Conference

[29] Konstantin Koslowski, Jens Pils, Richard Weiler, Wilhelm Keusgen, Thomas Haustein, Gia Khanh Tran, Hiroaki Ogawa, Hiroaki Nishiuchi, Takashi Tomura, Kei Sakaguchi, "5G-MiEdge - Millimeter-wave Edge Cloud as an enabler for 5G ecosystem-," IEICE Technical Report, SR2017-9, May 2017.

[30] Yu TAO, Gia Khanh TRAN, Kei SAKAGUCHI, "[Invited] A Lighting Control System Using Battery-less Wireless Human Detection Sensor Networks," IEICE Society Conference, IEICE, Sep. 2017.

[31] Azril HANIZ, Gia Khanh TRAN, Kei SAKAGUCHI, Jun-ichi TAKADA, Toshihiro YAMAGUCHI, Shintaro ARATA, "A Study on Spatial Averaging of RSS Fingerprints for Localization of Unknown Radios," IEICE Society Conference, IEICE, Sep. 2017.

[32] Tomohiko Nakamura, Ryosuke Suga, Daisuke

Kitahara, Kiyomichi Araki, Osamu Hashimoto, "Winding Ratio Estimation of Transformer in Equivalent Circuit of Patch Array Wave Absorber," IEICE Society Conference, C-2-43, p.51, Sep. 2017.
[33] Ryosuke Suga, Takahiro Omatsuzawa, Kiyomichi Araki, Osamu Hashimoto, "A Study on Design of Absorption/Transmission/Refection Surface using Two FSSs," IEICE Society Conference, C-15-4, p.163, Sep. 2017.
[34] Kei Sakaguchi, "Millimeter-wave Applications in 5G and Beyond," IEICE Society Conference, BP-4-1, Sep. 2017.
[35] Daisuke Kitahara, Ryosuke Suga, Kiyomichi Araki, Osamu Hashimoto, "A Study on Bandwidth Improvement of Circular Patch Array Absorber by Using Perturbation Elements and Suppression of Polarization Conversion," IEICE Technical Report, MW2017-64, pp.189-193, Sep. 2017.
[36] Daisuke Kitahara, Tomohiko Nakamura, Ryosuke Suga, Kiyomichi Araki, Osamu Hashimoto, "Relation between Structure Parameter of Circular Patch Array Wave Absorber and Its Winding Ratio of Transformer in Equivalent Circuit," IEICE Technical report, MW2017-65, pp.195-199, Sep. 2017.
[37] Kei Sakaguchi, "Applications of mmWave Heterogeneous Network in 5G," IEICE Technical report, RCS2017-185, Oct. 2017.
[38] Takahiro Omatsuzawa, Ryosuke Suga, Kiyomichi Araki, Osamu Hashimoto, "Study on Switching Method of Radio Wave Absorption/Transmission/Reflection Surface and Its Design," IEICE Technical report, EMCJ2017-83, pp.41-45, Dec. 2017.
[39] Azril HANIZ, Gia Khanh TRAN, Kei SAKAGUCHI, Jun-ichi TAKADA,Toshihiro YAMAGUCHI, Tsutomu Mitsui, Shintaro ARATA, "[Invited] Machine Learning Based Regression of Fingerprint Database for Unknown Emitter Localization," IEICE Mobile Communication Workshop, IEICE Technical report, Feb. 2018.
[40] Hiroaki Nishiuchi, Gia Khanh Tran, Kei Sakaguchi, "Proposal of Prefetching Algorithm for 5G mmWave HetNet under Backhaul Constraint," 2018 IEICE General Conf., Mar. 2018.
[41] Makoto NAKAMURA, Gia Khanh TRAN, Kei SAKAGUCHI, "Study on Interference Management for Millimeter-Wave Mesh Backhaul Networks," IEICE General Conf., Mar. 2018.
[42] Tuchjuta RUCKKWAEN, Kiyomichi ARAKI, Takashi TOMURA, Jiro HIROKAWA, Makoto ANDO, "Experimental Evaluation of Intersymbol Interference in Non-Far Region Transmission using 60GHz-Band Large Array Antennas," IEICE General Conference, Mar. 2018. (to be presented)
[43] Tomohiko Nakamura, Daisuke Kitahara, Ryosuke Suga, Kiyomichi Araki, Osamu Hashimoto, "A Study on Coupling between Adjacent Patches of Circular Patch Array Absorber," IEICE General Conference, Mar. 2018. (to be presented)
[44] Daisuke Kitahara, Mika Hirayama, Ryosuke Suga, Kiyomichi Araki, Osamu Hashimoto, "A study on winding ratio design of half-wavelength resonator array absorber," IEICE General Conference, Mar. 2018. (to be presented)
[45] Kiyomichi Araki, "A Role of Digital RF Technologies in SDR," IEICE General Conference, Mar. 2018. (to be presented)
[46] Kei Sakaguchi, "(Inivited) mmWave V2V2X for Automated Driving," IEICE Technical report, 2018-02-RCS-SR-SRW, Mar. 2018. (to be presented)

Oral Presentation

[47] Kei Sakaguchi, "MiEdge: Fusion of mmWave access and mobile edge computing for 5G," IEEE IMS2017, June 2017.
[48] Kei Sakaguchi, "The Challenge and proposition of mmWave in 5G," 5G Taipei Summit, Sep. 2017.

Other Publications

[49] Kei Sakaguchi, Thomas Haustein, Richard Weiler, Antonio De Domenico, Valerio Frascolla, Sergio Barberis, Valerio Palestini, Flavio Muratore, Sergio Barbarossa, Andrea Baiocchi, Antonio Cianfrani,Gia Khanh Tran, Koji Takinami, "D1.1 ~ Use Cases and Scenario Definition ~," 5G-MiEdge Deliverables, 5G-MiEdge, Apr. 2017.

[50] Valerio Frascolla, Federico Miatton, Antonio De Domenico, Kei Sakaguchi, Konstantin Koslowski, Valerio Palestini, Sergio Barberis, Sergio Barbarossa, Gia Khanh Tran, Koji Takinami, Katsuo Yunoki, "D1.2 ~ Mid-term report on joint EU/JP vision, business models and eco-system impact ~," 5G-MiEdge Deliverables, 5G-MiEdge, Jun. 2017.

[51] Kei Sakaguchi, Thomas Haustein, Richard Weiler, Konstantin Koslowski, Antonio De Domenico, Gourab Ghatak, Sergio Barberis, Valerio Palestini, Flavio Muratore, Sergio Barbarossa, Andrea Baiocchi, Antonio Cianfrani, Elena Ceci, Mattia Merluzzi, Gia Khanh Tran, Yuyuan Chang, Koji Takinami, Tomoya Urushihara, Masashi Kobayashi, "D2.1 ~ Requirement and scenario definition for mmWave access, antenna and area planning for mmWave edge cloud ~," 5G-MiEdge Deliverables, 5G-MiEdge, Jun. 2017.

[52] Valerio Frascolla, Federico Miatton, Antonio De Domenico, Kei Sakaguchi, Valerio Palestini, Sergio Barbarossa, Gia Khanh Tran, Koji Takinami, Katsuo Yunoki, "D5.1 ~ First report on dissemination, standards, regulation and exploitation plan ~," 5G-MiEdge Deliverables, 5G-MiEdge, Jun. 2017.

[53] Gia Khanh Tran, "Report on the 10th international workshop on evolutional technologies & ecosystems for 5G and beyond (WDN-5G ICC2017)," The 10th international workshop on evolutional technologies & eco-systems for 5G and beyond, IEICE Communications Society – GLOBAL NEWSLETTER, IEICE, Vol. 41, No. 3, Sep. 2017

[54] Emilio Calvanese Strinati, Nicola di Pietro, Sergio Barbarossa, Elena Ceci, Francesca Costanzo, Mattia Merluzzi, Antonio Cianfrani, Valerio Frascolla, Jürgen Englisch, Robert Zaus, Kei Sakaguchi, Gia Khanh Tran, Yunoki Katsuo, "D3.1 ~ Architecture of mmWave edge cloud and requirement for control signaling ~," 5G-MiEdge Deliverables, 5G-MiEdge, Dec. 2017.

Fujii and Omote Laboratory

Domestic Conference

[1] Reina TANIGUCHI, Teruya FUJII, Hideki OMOTE, Kei SAKAGUCHI, "A Control Optimization on Transmit Interference Canceller in HetNet Construction", 2018 IEICE General Conf., Mar. 2018.

[2] Teruya Fujii, Reina TANIDUGHI, Hideki OMOTE, "A Study on Transmit Interference Canceller in HetNet Construction", 2018 IEICE General Conf., Mar. 2018.

[3] Ken IKEDA, Hideki OMOTE, Teruya FUJII, Kei SAKAGUCHI, "Measurements of Path Loss Characteristics using Scale Model for 3D Layard Cell Construction", 2018 IEICE General Conf., Mar. 2018.

Hirokawa Laboratory

Transactions and Letters

[1] Xin Xu, Jiro Hirokawa, and Makoto Ando, "Plate-laminated waveguide monopulse slot array

antenna with full-corporate-feed in the E-band," IEICE Transactions on Communication, vol. E100-B, no.4, pp. 575-585, Apr. 2017.
[2] X. Xu, J. Hirokawa, A. Mazzinghi and A. Freni, "Design of simultaneous generation of three OAM modes by using a RLSA fed by a waveguide circuit in the 60-GHz band," IEICE Tech. Rep., vol. 117, no. 181, AP2017-77, pp. 49–52, Aug. 2017.
[3] P. Lyu, and M. Ando, "Uniform surface-to-line integral reduction of physical optics for curved surfaces by modified edge representation with higher-order correction," Radio Sci., vol. 52, no. 9, pp. 1106–1116, Sep. 2017.
[4] D.-H. Kim, J. Hirokawa, and M. Ando, "One-body 2-D Beam-switching Butler Matrix with Waveguide Short-slot 2-plane Couplers," IEICE Trans. Electron., vol. E100-C, no.10, pp.884-892, Oct. 2017.
[5] K. Furuya, T. Hirasawa, M. Oishi, S. Akiba, J. Hirokawa, and M. Ando, "60 GHz-band photonic-integrated array-antenna and module for radio-over-fiber-based beam forming," IEICE Trans. Commun., vol. E100-B, no. 10, pp.1717-1725, Oct. 2017.
[6] Hisanori IRIE, and Jiro HIROKAWA, "Perpendicular-Corporate Feed in Three-Layered Parallel-Plate Radiating-Slot Array," IEEE Transactions on Antennas and Propagation, vol.65, no. 11, pp. 5829-5836, Nov. 2017.

International Conference

[7] Ryotaro OHASHI, Takashi TOMURA, and Jiro HIROKAWA, "Feasibility of Antenna System for Rectangular-coordinate Orthogonality Multiplexing by using Corporate-feed Waveguide Slot Array Antenna and Monopulse Circuit," Proc. of 2017 Asian Workshop on Antennas and Propagation (AWAP), P1-13, pp. 31-32, Hokkaido, Japan, June 28-30, 2017.
[8] Tatsuya NAGAYAMA, Shigeyuki AKIBA, and Jiro HIROKAWA, "60 GHz-Band Antenna Beam Forming by Radio-over-Fiber with Variable Delay Line," Proc. of 2017 Asian Workshop on Antennas and Propagation (AWAP), P1-16, pp.37-38, Hokkaido, Japan, June 28-30, 2017.
[9] Mikihiro ARUGA, Takashi TOMURA, and Jiro HIROKAWA, "Design of the Feeding Layer in a Waveguide Reflection-canceling Slot Array Antenna to improve the Bandwidth in the 60GHz Band," Proc. of 2017 Asian Workshop on Antennas and Propagation (AWAP), P1-18, pp.41-42, Hokkaido, Japan, June 28-30, 2017.
[10] Masahiro WAKASA, Takashi TOMURA, and Jiro HIROKAWA, "Hybrid Analysis of Mode Matching/FEM for a Waveguide Short-slot 2-plane Coupler considering the Three-dimensional Structural Symmetry," Proc. of 2017 Asian Workshop on Antennas and Propagation (AWAP), P2-12, pp.79-80, Hokkaido, Japan, June 28-30, 2017.
[11] Jiro HIROKAWA, "Proposal of Rectangular Coordinate Orthogonal Multiplexing Antenna System," Proc. of 2017 Asian Workshop on Antennas and Propagation (AWAP), I-5, pp.117, Hokkaido, Japan, June 28-30, 2017.
[12] Tatsuya Nagayama, Kotoko Furuya, Shigeyuki Akiba, Jiro Hirokawa, and Makoto Ando, "Millimeter-Wave Antenna Beam Forming by Radio-over-Fiber with 1.3 μm Light Source and Variable Delay Line," 22nd OptoElectronics and Communications Conference, Oral 3-4S-3, July 31 - Aug. 4. 2017.
[13] D.-H. Kim, J. Hirokawa, and K. Nishimori, "Design of one-body 64×64-way 2-D beam-switching Butler matrix," IEEE Intl. Symp. Antennas Propag., San Diego, USA, Jul. 9-14, 2017.
[14] X. Xu, D. Mori, A. Mazzinghi, A. Freni, J. Hirokawa, M. Ando and K. Araki, "A 60-GHz RLSA fed by Butler matrix carrying three OAM modes," in IEEE International Symposium on Antennas and Propagation (APSURSI), San Diego, California, USA, pp. 1445–1446, July 2017.
[15] Ryotaro Ohashi, Takashi Tomura, and Jiro Hirokawa, "Feasibility on Multiplexing Antenna System Based on Rectangular-coordinate Orthogonality by Using Two-Dimensional 180-Degree Hybrid," Proc. of International Symposium on

Antennas and Propagation (ISAP), 1048, Phuket, Thailand, 30 Oct.-2 Nov. 2017.
[16] Masahiro Wakasa, Dong-Hum Kim, Takashi Tomura, and Jiro Hirokawa, "Mode Matching/FEM Hybrid Analysis for a Short-Slot 2-Plane Coupler Considering the Structural Symmetry," Proc. of International Symposium on Antennas and Propagation (ISAP), 1049, Phuket, Thailand, 30 Oct.-2 Nov. 2017.
[17] Mikihiro Aruga, Takashi Tomura, and Jiro Hirokawa, "Design of a Partial-Corporate-Feed Circuit of a Waveguide Reflection-Canceling Slot Low-Sidelobe Array Antenna in the 60 GHz Band," Proc. of International Symposium on Antennas and Propagation (ISAP), 1078, Phuket, Thailand, 30 Oct.-2 Nov. 2017.
[18] T. Ruckkwaen, M. Ando, T. Tomura, J. Hirokawa, and M. Ali, "Evaluation of Field Strength Distribution by Modified Edge Representation (MER) in Compact Range Communication with Shadowing Objects," Proc. of International Symposium on Antennas and Propagation (ISAP), 1176, Phuket, Thailand, 30 Oct.-2 Nov. 2017.
[19] Akihide Nagamine, Kanshiro Kashiki, Fumio Watanabe, and Jiro Hirokawa, "Performance Analysis and Hardware Verification of Signal Detection Scheme Using Cyclic Prefix in OFDM," Proc. of The 20th International Symposium on Wireless Personal Multimedia Communications (WPMC2017), pp.94-99, Yogyakarta, Indonesia, December 18, 2017.

Domestic Conference

[20] Takashi Tomura, Haruhisa Hirayama, Jiro Hirokawa, "Measurement evaluation of a two-slot array antenna fed by a post-wall waveguide in the 60-GHz band for mobile terminals," IEICE Technical Report, vol.117, no. 77, AP2017-40, pp. 1-6, June, 2017 (in Japanese).
[21] Haruka ARAKAWA, Hisanori IRIE, Takashi TOMURA, Jiro HIROKAWA, "Suppression of E-plane Sidelobes using a Slit Layer in a Corporate-feed Waveguide Slot Array Antenna consisting of 2x2-element Radiating Units," IEICE Technical Report, vol. 117, no. 150, AP2017-50, pp. 29-34, July, 2017 (in Japanese).
[22] Yuta Saito, Takashi TOMURA, Jiro HIROKAWA, Kenichi Okada, "Feasibility of a 60GHz-band Semi-rigid Cable Monopole Antenna for Inserting into an Oscillator Chip," IEICE Technical Report, vol. 117, no. 150, AP2017-48, pp. 19-22, July, 2017 (in Japanese).
[23] Takashi Tomura, Jiro Hirokawa, "Study on Design of Waveguide Slot Array Antennas by Filter Design Theory," Proc. of IEICE Soc. Conf., B-1-77, Sept., 2017 (in Japanese).
[24] Shuki Wai, Takashi Tomura, Jiro Hirokawa, "Feeding Circuit Design for Arbitrary Number of Division of Corporate-feed Waveguide Slot Array Antennas," Proc. of IEICE Soc. Conf., B-1-84, Sept., 2017 (in Japanese).
[25] Hisanori Irie, Takashi Tomura, Jiro Hirokawa, "Design of a Circularly-Polarized 2×2-Element for Perpendicular-Corporate Feed Four-Layered Parallel-Plate Slot Array Antenna," Proc. of IEICE Soc. Conf., B-1-82, Sept., 2017 (in Japanese).
[26] Akihide Nagamine, Kanshiro Kashiki, Fumio Watanabe, Jiro Hirokawa, "Performance Analysis of a Signal Detection Scheme Using Cyclic Prefix in OFDM," Proc. of IEICE Soc. Conf., B-17-17, Sept., 2017 (in Japanese).
[27] Tatsuya Nagayama, Shigeyuki Akiba, Takashi Tomura, Jiro Hirokawa, "40 GHz Band Antenna Beam Forming by Radio-over-Fiber with 1.3 μm Band Light Source and Variable Delay Line," Proc. of IEICE Soc. Conf., C-14-17, Sept., 2017 (in Japanese).
[28] Ryotaro OHASHI, Takashi TOMURA, Jiro HIROKAWA, "Design of the Excitation Coefficients of Monopulse Waveguide Slot Array Antenna with Corporate-feed in Rectangular-coordinate Orthogonal Multiplexing Transmission," IEICE Technical Report, vol. 117, no. 215, AP2017-90, pp. 13-17, Sept., 2017 (in Japanese).

Contributions

[29] Masahiro WAKASA, Takashi TOMURA, Jiro HIROKAWA, "Mode Matching/FEM Hybrid Analysis for a Short-slot 2-plane Coupler considering the Three-dimensional Structural Symmetry," IEICE Technical Report, vol. 117, no. 215, AP2017-91, pp. 19-23, Sept., 2017 (in Japanese).

[30] Hisanori IRIE, Takashi TOMURA, Jiro HIROKAWA, "Design of a Perpendicular-Corporate Feed in a Four-Layered Parallel-Plate Circularly-Polarized Slot Array Antenna," IEICE Technical Report, vol. 117, no. 242, AP2017-97, pp.15-18, Oct., 2017 (in Japanese).

[31] Ryotaro OHASHI, Takashi TOMURA, Jiro HIROKAWA, "Design of 16x16-element Mono-pulse Waveguide Slot Array Antenna with Corporate-feed in Rectangular-coordinate Orthogonal Multiplexing Transmission," IEICE Technical Report, vol. 117, no. 382, AP2017-170, pp. 111-114, Jan., 2018 (in Japanese).

[32] Shuki Wai, Takashi TOMURA, Jiro HIROKAWA, "A Configuration Method of the Feeding Circuit with Arbitrary Number of Division in a Cooperate-feed Waveguide Slot Array Antenna," IEICE Technical Report, vol. 117, no. 382, AP2017-171, pp. 115-171, Jan., 2018 (in Japanese).

[33] Tatsuya Nagayama, Shigeyuki Akiba, Takashi Tomura, Jiro Hirokawa, "Millimeter-Wave Band Beamforming of Array-Antenna Integrated with Photodiode by Radio-over-Fiber Technique Using Variable Optical Delay Line," IEICE Technical Report, vol. 117, no. 409, MWP2017-84, pp. 197-202, Jan., 2018 (in Japanese).

[34] Hisanori Irie, Takashi Tomura, Jiro Hirokawa, "Design of a 2×2-Element for Perpendicular-Corporate Feed Four-Layered Parallel-Plate Slot Array Antenna," Proc. of IEICE Gen. Conf., March, 2018 (to be published in Japanese).

[35] Takashi Tomura, Jiro Hirokawa, "Design of Feed Structure for 2×2-Element Waveguide Slot Array by Filter Design Theory," Proc. of IEICE Gen. Conf., March, 2018 (to be published in Japanese).

[36] Yuta Saito, Jiro Hirokawa, Takashi Tomura, Kenichi Okada, "Radiation of a Semi-rigid Cable Monopole Antenna Inserting into a 60GHz-band Oscillator Chip," Proc. of IEICE Gen. Conf., March, 2018 (to be published in Japanese).

[37] Yuki SUNAGUCHI, Masahiro WAKASA, Takashi TOMURA, Jiro HIROKAWA, "Reflection suppresssion of Short Slot E-plane Coupler by a Step Structure," Proc. of IEICE Gen. Conf., March, 2018 (to be published in Japanese).

[38] Akihide Nagamine, Kashiki Kenshiro, Fumio Watanabe, Jiro Hirokawa, "Aggregate detection of multiple DSRC channels based on cyclo-stationarity in 5.9GHz," Proc. of IEICE Gen. Conf., March, 2018 (to be published in Japanese).

[39] Soichi Sakurai, Takashi Tomura, Jiro Hirokawa, Akihiko Hirata, "Wideband Design of Corporate-feed Plate-laminated Waveguide 16×16-Slot Array Antenna in 120GHz Band," Proc. of IEICE Gen. Conf., March, 2018 (to be published in Japanese).

[40] Tuchjuta RUCKKWAEN, Kiyomichi ARAKI, Takashi TOMURA, Jiro HIROKAWA, Makoto ANDO, "Experimental Evaluation of Intersymbol Interference in Non-Far Region Transmission using 60GHz-Band Large Array Antennas," Proc. of IEICE Gen. Conf., March, 2018 (to be published).

[41] Haruka ARAKAWA, Hisanori IRIE, Takashi TOMURA, Jiro HIROKAWA, "Improvement of a Slit Layer Suppressing E-plane Sidelobes in a Corporate-feed Waveguide Slot Array Antenna consisting of 2x2-element Radiating Units," IEICE Technical Report, March, 2018 (to be published in Japanese).

[42] Kentaro WADA, Ryotaro Ohashi, Takashi TOMURA, Jiro HIROKAWA, "Design of Dual-polarized Slot Array Antenna with Monopulse Corporate-feed Waveguides for Two-dimensional Orthogonal Multiplexing," IEICE Technical Report, March, 2018 (to be published in Japanese).

Fukawa Laboratory

Transactions and Letters

[1] Yousuke Sano, Kazuaki Takeda, Satoshi Nagata, Takehiro Nakamura, Xiaohang Chen, Anxin Li, Xu Zhang, Huling Jiang, and Kazuhiko Fukawa, "Investigation on Non-Orthogonal Multiple Access with Reduced Complexity Maximum Likelihood Receiver and Dynamic Resource Allocation," IEICE Trans. Commun., vol. E100-B, no. 8, pp. 1301-1311, Aug. 2017.
[2] Hiroshi Suzuki, Kazuhiko Fukawa, and Satoshi Suyama, "Application and Development of Interference Cancelers in Mobile Communications," IEICE Trans. Commun., vol. J100-B, no. 9, pp. 673-692, Sept. 2017 (in Japanese).
[3] Ahmet Ihsan Canbolat, and Kazuhiko Fukawa, "A Joint Interference Suppression and Multiuser Detection Scheme Based on Eigendecomposition for Three-Cell Multiple Relay Systems," IEICE Trans. Commun., vol. E100-B, no. 10, pp. 1939-1945, Oct. 2017.
[4] Huiyu Ye, and Kazuhiko Fukawa, "Semi-Blind Interference Cancellation with Single Receive Antenna for Heterogeneous Networks," IEICE Trans. Commun., vol. E101-B, no. 1, pp. 232-241, Jan. 2018.

International Conference

[5] Ahmet Ihsan Canbolat, and Kazuhiko Fukawa, "A Joint MMSE Interference Suppression and Multiuser Detection Scheme for Multi-Cell Wireless Relay Communications," VTC 2017-Spring, June 2017.
[6] Huiyu Ye, Kazuhiko Fukawa, and Yuyuan Chang, "A Quantized Channel Approach based Single Antenna Interference Cancellation Scheme," IWCMC 2017, June 2017.
[7] Ahmet Ihsan Canbolat, and Kazuhiko Fukawa, "Joint Interference Suppression and Multiuser Detection for Three-Cell Multiple Relay Communications," IWCMC 2017, June 2017.
[8] Yuyuan Chang, and Kazuhiko Fukawa, "Phase Noise Compensation for mm-Wave MU-MIMO OFDM Systems," SmartCom 2017, Oct. 2017.
[9] Yuyuan Chang, and Kazuhiko Fukawa, "Evaluation for Wireless Sensor Networks with LT Codes Considering Probabilities of Transmission Failure," RWW 2018, Jan. 2018.

Domestic Conference

[10] Yuyuan Chang, and Kazuhiko Fukawa, "A Theoretical Analysis of Total Number of Transmissions for Wireless Sensor Networks using LT Codes," IEICE Society Conference, B-19-5, Sept. 2017 (in Japanese).
[11] Huiyu Ye, Kazuhiko Fukawa, and Yuyuan Chang, "Semi-blind Interference Cancellation for MIMO HetNet Systems," IEICE Society Conference, B-5-34, Sept. 2017.
[12] Tsuyoshi Yoneda, Yuyuan Chang, and Kazuhiko Fukawa, "Wireless Physical Layer Security Schemes Using Random Phases for MIMO-OFDM Communications and Its Security Rate Analysis," IEICE Technical Report, RCS2018-XX, March 2018 (to be published in Japanese).
[13] Ryutaro Kitajima, Yuyuan Chang, and Kazuhiko Fukawa, "Parameter Control Method for Massive MIMO using Hybrid Beamforming," IEICE Technical Report, RCS2018-XX, March 2018 (to be published in Japanese).
[14] Koi Tou, Yuyuan Chang, and Kazuhiko Fukawa, "Transmit Power and Beamforming Control Using Neural Networks for MIMO Small Cell Networks with Interference Cancellation," IEICE Technical Report, RCS2018-XX, March 2018 (to be published in Japanese).
[15] Tsuyoshi Yoneda, Yuyuan Chang, and Kazuhiko Fukawa, "Security Rate Analysis of Wireless Physical Layer Security Schemes Using Random Phases for MIMO-OFDM Communications," IEICE General Conference, B-5-11, March 2018 (to be published in Japanese).

[16] Koi Tou, Yuyuan Chang, and Kazuhiko Fukawa, "Transmission Beamforming and Power Control Using Neural Network for MIMO Small Cell Networks," IEICE General Conference, B-5-8, March 2018 (to be published in Japanese).

Okumura Laboratory

Transactions and Letters

[1] Nobutaka Omaki, Tetsuro Imai, Koshiro Kitao, Yukihiko Okumura, "Improving Accuracy of Ray-Tracing Prediction in Non Line-of-Sight (NLOS) Urban Street Cell Environment beyond 6GHz," IEICE Trans. Commun., vol. E100-B, no. 4, pp. 566-574, April 2017.
[2] Norihiro Naganuma, Sho Nakazawa, Satoshi Suyama, Yukihiko Okumura, Hiroyuki Otsuka, "Performance evaluation of adaptive control CRE in HetNet with eICIC scheme," IEICE Communications Express, vol. 6, no. 4, pp. 166-171, April 2017.
[3] Akiyoshi Inoki, Hirantha Abeysekera, Munehiro Matsui, Kenichi Kawamura, Takeo Ichikawa, Yasushi Takatori, Masato Mizoguchi, Akira Kishida Yoshifumi Morihiro, Takahiro Asai, Yukihiko Okumura, "Throughput Improvement of Mobile Cooperative WLAN Systems with Identifying and Management of Starved APs/UEs for 5G," IEICE Trans. Commun., vol. E100-B, no. 8, pp. 1366-1376, Aug. 2017.
[4] Tatsunori Obara, Tatsuki Okuyama, Yuki Inoue, Yuuichi Aoki, Satoshi Suyama, Jaekon Lee, Yukihiko Okumura, "Experimental Trial of 5G Super Wideband Wireless Systems Using Massive MIMO Beamforming and Beam Tracking Control in 28GHz Band," IEICE Trans. Commun., vol. E100-B, no. 8, pp. 1256-1268, Aug. 2017.
[5] Yuki Inoue, Shohei Yoshioka, Yoshihisa Kishiyama, Satoshi Suyama, Yukihiko Okumura, James Kepler, and Mark Cudak, "Field Experimental Evaluation for 5G Millimeter Wave Radio Access for Mobile Communications," IEICE Trans. Commun., vol. E100-B, no. 8, pp. 1269-1276, Aug. 2017.
[6] Tasuki Okuyama, Satoshi Suyama, Jun Mashino, and Yukihiko Okumura, "5G Distributed Massive MIMO with Ultra-High Density Antenna Deployment in Low SHF Bands," IEICE Trans. Commun., vol. E100-B, no. 10, pp. 1921-1927, Oct. 2017.

International Conference

[7] Jun Mashino, Kei Satoh, Satoshi Suyama, Yuki Inoue, and Yukihiko Okumura, "5G Experimental Trial of 28 GHz Band Super Wideband Transmission Using Beam Tracking in Super High Mobility Environment," IEEE VTC 2017 Spring, June 2017.
[8] Yuki Inoue, Shohei Yoshioka, Yoshihisa Kishiyama, Satoshi Suyama, Yukihiko Okumura, Tsuneomi Haruna, and Takeshi Tanaka, "Field Experimental Evaluation of Low SHF 5G Radio Access System Employing Higher Rank MIMO," IEEE VTC 2017 Spring, June 2017.
[9] Hiroyuki Seki, Masafumi Tsutsui, Morihiko Minowa, Kotaro Shiizaki, Chiyoshi Akiyama, Tatsuki Okuyama, Jun Mashino, Satoshi Suyama, and Yukihiko Okumura, "Field Experiment of High-Capacity Technologies for 5G Ultra High-Density Distributed Antenna Systems," IEEE VTC 2017 Spring, June 2017.
[10] Kenichiro Yamazaki, Toshifumi Sato, Yasushi Maruta, Tatsuki Okuyama, Jun Mashino, Satoshi Suyama, and Yukihiko Okumura, "DL MU-MIMO Field Trial with 5G Low SHF Band Massive MIMO Antenna," IEEE VTC 2017 Spring, June 2017.
[11] Hiroshi Okazaki, Takahiro Asai, Yukihiko Okumura, "Phased Array Antenna System (PAS) for 5G Cellular Communications," IEEE IMS 2017, June 2017.
[12] Yukihiko Okumura, "New Mobile Communication "5G" Actualized by Evolution on Wireless Signal Processing," IEEE International Workshop on SPAWC 2017, July 2017.

[13] Yukihiko Okumura, "The Mobile Radio Propagation Model "OKUMURA-curve" and the World's First Full-Scale Cellular Telephone System," IEEE HISTELCOM2017, Aug. 2017.
[14] Hiroyuki Miyazaki, Satoshi Suyama, Tatsuki Okuyama, Jun Mashino, and Yukihiko Okumura, "User Selection and Rank Adaptation for Multi-User Massive MIMO with Hybrid Beamforming," IEEE VTC 2017 Fall, Sep. 2017.
[15] Tatsuki Okuyama, Jun Mashino, Satoshi Suyama, Yukihiko Okumura, Kotaro Shiizaki, Chiyoshi Akiyama, Hiroyuki Seki, Masafumi Tsutsui, Morihiko Minowa, "Antenna Deployment of 5G Ultra High-Density Distributed Massive MIMO by Low-SHF-Band Indoor and Outdoor Experiments," IEEE VTC 2017 Fall, Sep. 2017.
[16] Hiroshi Okazaki, Takahiro Asai, Yukihiko Okumura, "Power Devices and PAs for 5G Systems," European Microwave Week 2017 Workshop 2017, Oct. 2017.
[17] Satoshi Suyama, Jun Mashino, Yoshihisa Kishiyama, Yukihiko Okumura, "[Invited Talk] 5G Experimental Trials on Massive MIMO Technologies," SmartCom2017, Oct. 2017.
[18] Yasunori Suzuki, Kunihiro Kawai, Hiroshi Okazaki, Shoichi Narahashi, Takahiro Asai, Yukihiko Okumura, "Experimental Investigations of 28-GHz-Band Power Amplifier for Massive MIMO Transmitter," IEEE APMC 2017, Nov. 2017.
[19] Tetsuro Imai, Minoru Inomata, Yukihiko Okumura, "Radio Propagation Simulation Technique for 5G Mobile Communication," The 2017 Indonesia-Japan Workshop on Antennas and Wireless Technology, Dec. 2017.
[20] Yasunori Suzuki, Kunihiro Kawai, Hiroshi Okazaki, Shoichi Narahashi, Takahiro Asai, Yukihiko Okumura, "Requirements of Millimeter-Wave-Band Transmitter for Massive MIMO Base Station," IEEE IMaRC 2017, Dec. 2017.
[21] Tatsuki Okuyama, Satoshi Suyama, Jun Mashino, Shohei Yoshioka, Yukihiko Okumura, Kenichiro Yamazaki, Daisuke Nose, Yasushi Maruta, "Experimental Evaluation of Digital Beamforming for 5G Multi-Site Massive MIMO," IEEE WPMC 2017, Dec. 2017.
[22] Shohei Yoshioka, Satoshi Suyama, Tatsuki Okuyama, Jun Mashino, Yukihiko Okumura, "Digital Beamforming Algorithm for 5G Low-SHFBand Massive MIMO with Intersite Coordination," IEEE International Symposium on WPMC 2017, Dec. 2017.
[23] Yuta Takahashi, Yuki Inoue, Shohei Yoshioka, Yoshihisa Kishiyama, Satoshi Suyama, Jun Mashino, Yukihiko Okumura, Tsuneomi Haruna, Takeshi Tanaka, Armin Splett, and Henrik Liljeström, "Field Experimental Evaluation of Higher Rank MIMO in Quad-directional UE Antenna Configuration for 5G Radio Access System," IEEE International Symposium on WPMC 2017, Dec. 2017.
[24] Akira Kishida, Yoshifumi Morihiro, Takahiro Asai, Yukihiko Okumura, "Cell Selection Scheme for Handover Reduction Based on Moving Direction and Velocity of UEs for 5G Multi-layered Radio Access Networks," IEEE The 32nd International Conference on ICOIN 2018, Jan. 2018.

Domestic Conference

[25] Tetsuro Imai, Koshiro Kitao, Ngochao Tran, Yukihiko Okumura, "A Study on Radio Propagation Prediction of High Frequency Bands in Urban Environment Using Hybrid Method of Ray-Tracing and ER Model," IEICE Technical Report, AP2017-5, April 2017.
[26] Ngochao Tran, Tetsuro Imai, Koshiro Kitao, Yukihiko Okumura, "Evaluation of Effective Gain of Array Antenna at 20-GHz Band in Urban Street Canyon," IEICE Technical Report, AP2017-7, April 2017.
[27] Kei Satoh, Hiroyuki Miyazaki, Jun Mashino, Satoshi Suyama, Yuki Inoue, Yukihiko Okumura, "Outdoor Experiment of 28 GHz-band Super Wide Bandwidth Massive MIMO Transmission

for 5G in Urban Area," IEICE Technical Report, RCS2017-21, April 2017.

[28] Akira Kishida, Yoshifumi Morihiro, Takahiro Asai, Yukihiko Okumura, "A Study of Handover Reduction considering Moving Direction of UE for 5G Multi-layered Networks with Overlay Structure," IEICE Technical Report, RCS2017-22, April 2017.

[29] Jun Mashino, Tatsuki Okuyama, Satoshi Suyama, Yukihiko Okumura, "Uplink Transmission Power Reduction by Using Low SHF Band Massive MIMO for 5G," IEICE Technical Report, RCS2017-23, April 2017.

[30] Masafumi Tsutsui, Takashi Dateki, Hiroyuki Seki, Morihiko Minowa, Chiyoshi Akiyama, Shiizaki Kotaro, Tatsuki Okuyama, Jun Mashino, Satoshi Suyama, Yukihiko Okumura, "Experimental Study of High-Capacity Technologies for 5G Ultra High-Density Distributed Antenna Systems -- Performance at High SHF Band in Field Experiment of Wideband Coordinated MU-MIMO --," IEICE Technical Report, RCS2017-24, April 2017.

[31] Tatsuki Okuyama, Kenichiro Yamazaki, Daisuke Nose, Satoshi Suyama, Jun Mashino, Shohei Yoshioka, Yasushi Maruta, Yukihiko Okumura, "Performance Evaluation of Digital Beamforming by Indoor and Outdoor Propagation Experimental Results for 5G Massive MIMO in Low SHF Band," IEICE Technical Report, RCS2017-25, April 2017.

[32] Shohei Yoshioka, Satoshi Suyama, Tatsuki Okuyama, Jun Mashino, Yukihiko Okumura, "Study on Enhanced Intersite Coordination using Beam Search for 5G Low-SHF-Band Massive MIMO," IEICE Technical Report, RCS2017-30, May 2017.

[33] Hiroyuki Miyazaki, Kei Satoh, Satoshi Suyama, Jun Mashino, Kenji Nakagawa, Hideo Umehara, Akihiro Okazaki, Yukihiko Okumura, "Per-formance Evaluation of High-SHF-Band Massive MIMO with Hybrid Beamforming by Using Real Propagation Channel Data," IEICE Technical Report, RCS2017-31, May 2017.

[34] Akira Kishida, Yoshifumi Morihiro, Takahiro Asai, Yukihiko Okumura, "A Study of Handover Reduction based on Moving Direction and Velocity of Users for 5G Multi-layered Networks," IEICE Technical Report, MoNA2017-3, June 2017.

[35] Ngochao Tran, Koshiro Kitao, Tetsuro Imai, Yukihiko Okumura, Tekehiro Nakamura, Hiroshi Tokuda, Takao Miyake, Robin Wang, Zhu Wen, Hajime Kitano, Roger Nichols, "An Empirical Study on Scattering Characteristics of Radio Wave by a Human Body in Millimeter Waves," IEICE Technical Report, AP2017-41, June 2017.

[36] Tatsuki Okuyama, Shohei Yoshioka, Kenichiro Yamazaki, Daisuke Nose, Satoshi Suyama, Jun Mashino, Yasushi Maruta, Yukihiko Okumura, "Performance Evaluation of Intersite-Coordination Beamforming for 5G Low-SHF-Band Massive MIMO by Outdoor Experimental Results," IEICE Technical Report, RCS2017-56, June 2017.

[37] Masafumi Tsutsui, Takashi Dateki, Hiroyuki Seki, Morihiko Minowa, Chiyoshi Akiyama, Kotaro Shiizaki, Tatsuki Okuyama, Jun Mashino, Satoshi Suyama, Yukihiko Okumura, "Experimental Study of High-Capacity Technologies for 5G Ultra High-Density Distributed Antenna Systems -- Performance Comparison between Low SHF and High SHF Band in Field Experiment of Wideband Coordinated MU-MIMO --," IEICE Technical Report, RCS2017-57, June 2017.

[38] Satoshi Suyama, Tatsuki Okuyama, Shohei Yoshioka, Jun Mashino, Yukihiko Okumura, "Technical Issues and Recent Results for 5G Massive MIMO Using Low SHF Bands," IEICE Technical Report, RCS2017-59, June 2017.

[39] Ngochao Tran, Tetsuro Imai, Koshiro Kitao, Yukihiko Okumura, Takehiro Nakamura, Hiroshi Tokuda, Takao Miyake, Robin Wang, Zhu Wen, Hajime Kitano, Roger Nichols, "[Poster Presentation] An Empirical Study on Scattering Characteristics of Radio Wave by a Human Body in Millimeter Waves," IEICE Technical Report,

AP, June 2017.
[40] Kenji Nakagawa, Shigeru Uchida, Kazuaki Ishioka, Kiyoshige Nakamura, Akihiro Okazaki, Kei Satoh, Satoshi Suyama, Jun Mashino, Yukihiko Okumura, Atsushi Okamura, "Propagation Experiment in LOS environment at 28GHz band for High SHF Wide-band Massive MIMO in 5G," IEICE Technical Report, RCS2017-137, July 2017.
[41] Hiroyuki Miyazaki, Satoshi Suyama, Tatsuki Okuyama, Jun Mashino, Yukihiko Okumura, Kenji Nakagawa, Kiyoshige Nakamura, Akihiro Okazaki, "Performance Evaluation of User Selection Algorithm for High-SHF-Band Massive MIMO by Using Real Propagation Channel Data," IEICE Technical Report, RCS2017-166, Aug. 2017.
[42] Shohei Yoshioka, Tatsuki Okuyama, Satoshi Suyama, Jun Mashino, Yukihiko Okumura, "Coverage Evaluation of Low-SHF-Band and High-SHF-Band Beamforming in 5G Massive MIMO Transmission," IEICE Technical Report, RCS2017-167, Aug. 2017.
[43] Satoshi Suyama, Jun Mashino, Yoshihisa Kishiyama, Yukihiko Okumura, "[Invited Lecture] Throughput improvement of high density WLAN systems by mobile cooperative control toward 5G," IEICE Technical Report, RCS2017-176, Oct. 2017.
[44] Kenichi Kawamura, Akiyoshi Inoki, Hirantha Abeysekera, Munehiro Matsui, Yasushi Takatori, Akira Kishida, Yoshifumi Morihiro, Takahiro Asai, Yukihiko Okumura, "[Invited Lecture] Overview of DOCOMO's 5G Trials for 5G Realization," IEICE Technical Report, RCS2017-179, Oct. 2017.
[45] Hiroaki Asano, Noriyuki Shimizu, Masaaki Yoshino, Takeshi Miyagoshi, Hideki Shingu, Yoshifumi Morihiro, Yukihiko Okumura, "[Invited Lecture] A study of optimal small cell selection technology and high quality mobile video transmission in5Gwireless network systems," IEICE Technical Report, RCS2017-180, Oct. 2017.
[46] Kenichiro Yamazaki, Kazuo Tanada, Daisuke Nose, Kohei Izui, Yasushi Maruta, Toshifumi Sato, Tatsuki Okuyama, Satoshi Suyama, Jun Mashino, Yukihiko Okumura, "[Invited Lecture] Performance of Indoor DL Transmission with Low-SHF-Band Massive MIMO Antenna for 5G," IEICE Technical Report, RCS2017-195, Oct. 2017.
[47] Koshiro Kitao, Tetsuro Imai, Minoru Inomata, Yukihiko Okumura, Kiyoshi Yanagisawa, Jun-ich Tanaka, Taro Eichler, Wilhelm Keusgen, "Study on Delay Characteristics at 40 GHz Band in NLOS Urban Street Cell Environments," IEICE Technical Report, AP2017-94, Oct. 2017.
[48] Tatsuki Okuyama, Satoshi Suyama, Jun Mashino, Yukihiko Okumura, "Impact of Transmission Performance by Massive MIMO Transmitter Configuration in Low SHF Band," IEICE Technical Report, RCS2017-253, Dec. 2017.
[49] Yuta Takahashi, Hiroyuki Miyazaki, Tatsuki Okuyama, Satoshi Suyama, Jun Mashino, Yukihiko Okumura, "Performance Evaluation of Massive MIMO Transmission Using Analog Beamforming in a High SHF Band," IEICE Technical Report, RCS2017-254, Dec. 2017.
[50] Tetsuro Imai, Yukihiko Okumura, "A Study on Radio Propagation Prediction by Using Deep Learning," IEICE Technical Report, AP2017-165, Jan. 2018.
[51] Minoru Inomata, Tetsuro Imai, Koshiro Kitao, Yukihiko Okumura, Motoharu Sasaki, Yasushi Takatori, "Radio Propagation Prediction Method Using Point Cloud Data in NLOS Urban Environments for high frequency bands," IEICE Technical Report, AP2017-173, Jan. 2018.
[52] Tatsuki Okuyama, Satoshi Suyama, Jun Mashino, Yukihiko Okumura, "[Encouragement Talk] Technical Issues of Massive MIMO in Low SHF Bands and Performance Evaluation by Indoor and Outdoor Experiments," IEICE Technical Report, RCS2017-272, Jan. 2018.
[53] Satoshi Suyama, Tatsuki Okuyama, Jun Mashino, Yukihiko Okumura, "Performance

Evaluation of Massive MIMO Transmission with Higher Frequency Band in High Mobility Environments," IEICE Technical Report, RCS2017-289, Jan. 2018.

[54] Minoru Inomata, Tetsuro Imai, Koshiro Kitao, Yukihiko Okumura, "[Invited Lecture] Effects of Vehicles on Dynamic Channel Property for High Frequency Bands in Urban NLOS Environments," IEICE Technical Report, AP2017-185, Feb. 2018.

[55] Masafumi Tsutsui, Takashi Dateki, Hiroyuki Seki, Morihiko Minowa, Chiyoshi Akiyama, Kotaro Shiizaki, Tatsuki Okuyama, Jun Mashino, Satoshi Suyama, Yukihiko Okumura, "Experimental Study of High-Capacity Technologies for 5G Ultra High-Density Distributed Antenna Systems -- Performance Evaluation at Urban Area for Wideband Coordinated MU-MIMO in Field Experiment --," IEICE Technical Report, RCS2017-xxx, Feb. 2018.

[56] Daisuke Nose, Kohei Izui, Kenichiro Yamazaki, Kanada Nakayasu, Tomohiro Kikuma, Yasushi Maruta, Toshifumi Sato, Tatsuki Okuyama, Jun Mashino, Satoshi Suyama, Yukihiko Okumura, "Outdoor DL MU-MIMO and Inter Access Point Coordination Performance of Low-SHF-Band C-RAN Massive MIMO System for 5G," IEICE Technical Report, RCS2017-xxx, March 2018.

[57] Tatsuki Okuyama, Kohei Izui, Kenichiro Yamazaki, Satoshi Suyama, Jun Mashino, Yukihiko Okumura, "Performance Evaluation of Digital Beamforming by Outdoor Trials for 5G Massive MIMO in Low SHF Bands," IEICE Technical Report, RCS2017-xxx, March 2018.

[58] Yuta Takahashi, Yuki Inoue, Shohei Yoshioka, Yoshihisa Kishiyama, Satoshi Suyama, Jun Mashino, Yukihiko Okumura, "Field Experimental Evaluation of MIMO Transmission Performance in Quad-directional UE Antenna Configuration for 5G Radio Access System," IEICE Technical Report, RCS2017-xxx, March 2018.

[59] Hiroyuki Miyazaki, Satoshi Suyama, Jun Mashino, Yukihiko Okumura, "Performance Evaluation of Channel Estimation Algorithm for High-SHF-Band Massive MIMO by Using Real Propagation Channel Data," IEICE Technical Report, RCS2017-xxx, March 2018.

[60] Hiroyuki Miyazaki, Satoshi Suyama, Jun Mashino, Yukihiko Okumura, "[Technology Exhibit] NTT DOCOMO's 5G Trials for 5G Realization," IEICE Technical Report, RCS2017-xxx, March 2018.

[61] Anass Benjebbour, Yoshihisa Kishiyama, Yukihiko Okumura, Chienhwa Hwang, I-Kang Fu, "Outdoor Field Experiments of Spectral Efficiency Enhancements Using Advanced NOMA," IEICE Technical Report, RCS2017-xxx, March 2018.

[62] Minoru Inomata, Tetsuro Imai, Koshiro Kitao, Yukihiko Okumura, "Radio Propagation Prediction Based on Scattering from vehicles for High Frequency Bands in Urban NLOS Environments," IEICE Technical Report, AP2017-xxx, March 2018.

Date of Publication: 28th Feb. 2018.