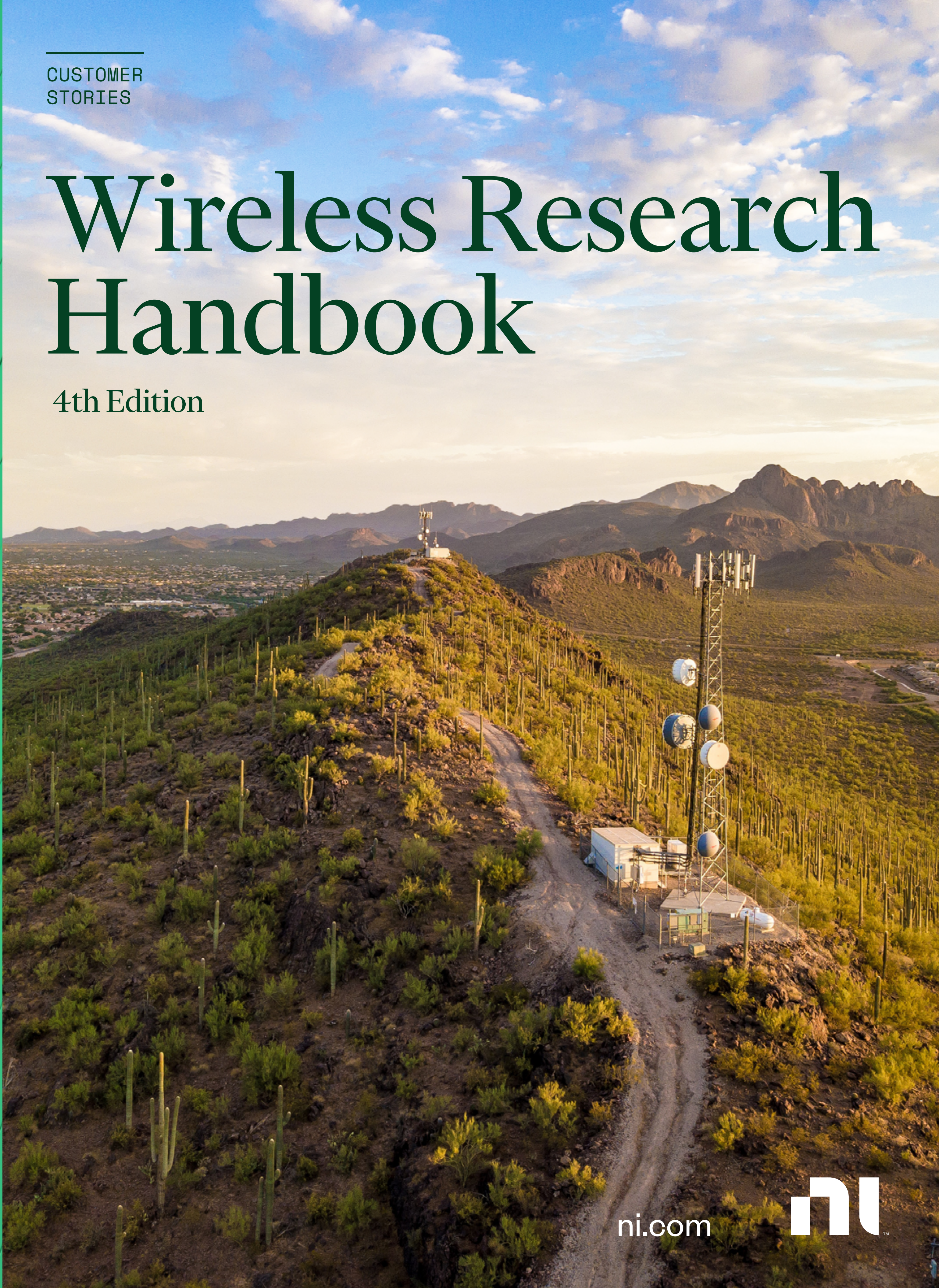
CUSTOMER STORIES

Wireless Research Handbook

4th Edition



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Let's Engineer Ambitiously.

At NI, we believe in the power of making connections between people, ideas, and technology. As an enterprise who consistently accomplishes extraordinary achievements, we know you believe in those connections, too. We're proud to have played a role in your accomplishments, and are inspired by how you've leveraged NI software defined radio (SDR) products to create real world prototypes of cutting-edge wireless communications technology. With all the amazing wireless innovations underway in the world, we are excited to share the 4th edition of our Wireless Handbook, featuring inspiring examples of how researchers are using NI tools to quickly move from mathematical models to over-the-air testbeds.

Even though 5G has begun to roll out, 5G research is by no means complete. Some of the entries for this handbook are for technologies that will be considered for 5G, and some are looking even further into the future. All of them show how researchers have been able to create prototypes of concepts and technology using SDR technology to prove the viability of their ideas and advance our fundamental knowledge of wireless communications.

Thank you to all the researchers who have contributed their work to this book. It inspires us to see how you are creating innovative solutions to the some of the toughest problems in wireless communications today. We hope by sharing these stories, NI can connect knowledge and inspiration and help our community innovate faster.

Let's Engineer Ambitiously.

ERIC STARKLOFF

CEO

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An Evaluation Platform for Beam Tracking in 5G Millimeter Wave Mobile Networks

“The millimeter wave transceiver system offers a high degree of flexibility for various studies on millimeter wave radio communications. We believe, that maturing into a 3GPP-compliant system would open up an even greater application-oriented research potential in the field of millimeter wave mobile radio networks.”

Karsten Heimann,
TU Dortmund University

The Experimental Testbed Enables Reproducible Mobility Emulation and Assessment of Beam Tracking Algorithms by utilizing NI’s SDR-based Millimeter Wave Transceiver System

TU DORTMUND UNIVERSITY | KARSTEN HEIMANN | PROF. DR.-ING. CHRISTIAN WIETFELD | HTTPS://CNI.TU-DORTMUND.DE | VIDEO | PAPER

The Challenge

Emerging frequency ranges in the millimeter wave spectrum provide significant opportunities to cope with rising requirement specifications. However, pencil beam antennas with high gains are required to cope with the challenging radio conditions. The introduced directionality necessitates reconsiderations of conventional signaling procedures and especially a proper alignment of transmitter and receiver beams, even in case of highly mobile devices like vehicles on the ground and in the air.

The Solution

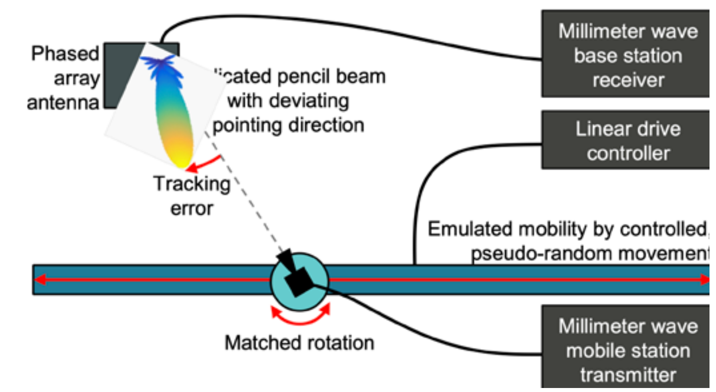
With the help of NI’s millimeter wave transceiver system, the millimeter wave radio propagation channel is studied by focusing on the utilization of phased array antennas, which are capable of forming a pencil beam towards an arbitrary, electronically steerable direction. At this, the software-defined development platform allows for the evaluation of proposed pencil beam alignment algorithms and related protocol procedures.

With our testbed design concept as shown in Figure 1, vehicular communications use cases can be assessed within laboratory measurements in a highly reproducible manner due to the tailored rail system emulating user device mobility. Accordingly, an exemplary drone use case is indicated in Figure 2.

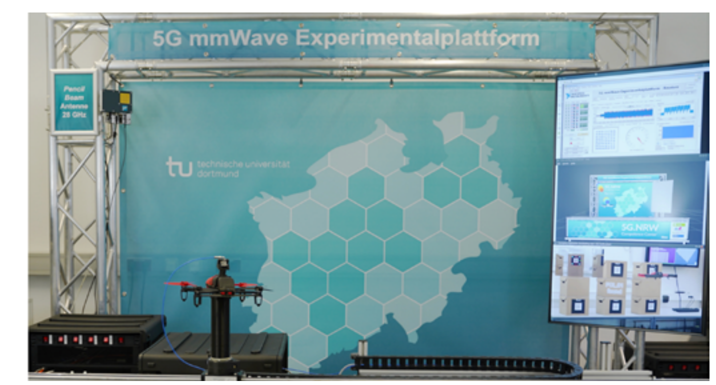
This work was supported by Deutsche Forschungsgemeinschaft (DFG) within the Collaborative Research Center SFB876, project B4 as well as the Ministry of Economic Affairs, Innovation, Digitalisation, and Energy of the state of North Rhine-Westphalia in the course of the Competence Center 5G.NRW under grant number 005-01903-0047.

Next Steps

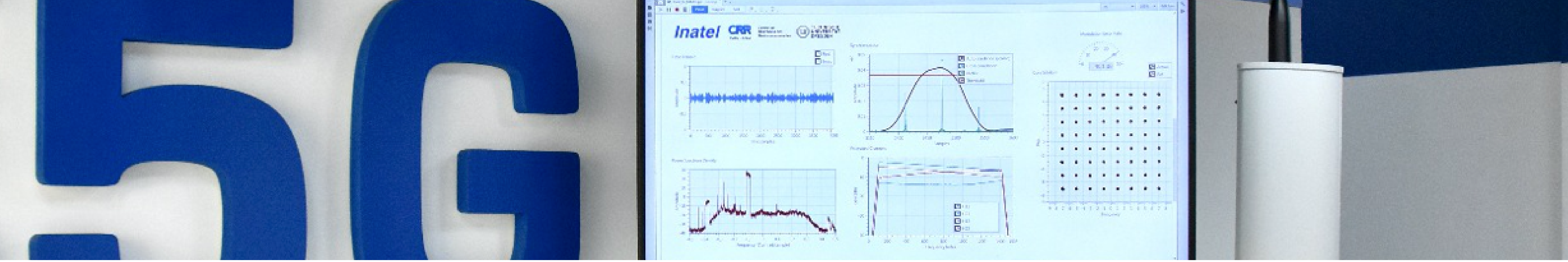
In future research, the system is extended by adding a second base station allowing for investigations into hand-off procedures e.g., in case of link blockage. Additionally, the directionality introduced by the pencil beams will also be exploited to provide enhanced mobile radio network-based user positioning services.



BEAM TRACKING TESTBED DESIGN CONCEPT



MILLIMETER WAVE BEAM TRACKING TESTBED



GFDM-Based Transceiver for Remote Area 5G Applications: Bringing Internet to Everywhere

> "Remote and rural areas are the last boundaries for a universal Internet access. Solutions developed for 5G can be tailored to close this gap, bringing millions of people to the Information Era, creating new services for agrobusiness and new revenues for the operators."

Luciano Mendes,
CRR Inatel

Flexible Transceiver Based on GFDM and Polar Code for Enhancing the Range Coverage in Remote and Rural Areas Applications

RADIOCOMMUNICATION REFERENCE CENTER | LUCIANO MENDES | WHEBERTH DIAS
ALEXANDRE FERREIRA | JULIANO SILVEIRA | TIAGO BARBOSA | TIAGO REIS
WWW.INATEL.BR

The Challenge

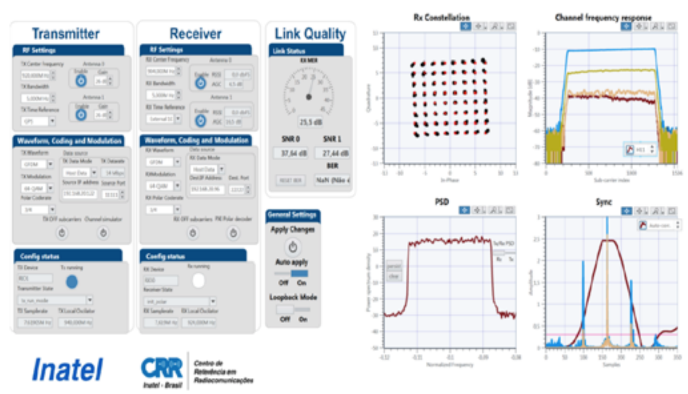
5G networks will provide new services in populated areas, where Massive MIMO and small cells will lead to high throughput. However, these techniques cannot be used remote area operation, where the cell coverage must deliver 100 Mbps at 50 km from the BS, opportunistically using unlicensed TV White Spaces. The physical layer (PHY) must provide robustness to overcome channel impairments and flexibility to reduce the out-of-band emissions, while improving the overall spectrum efficiency of the system.

The Solution

A new PHY, based on robust channel coding and flexible waveform, is mandatory to provide the necessary out-of-band emissions for dynamic and fragmented spectrum allocation in remote areas. High spectrum efficiency over severe selective channels is essential to achieve the high throughput at long distances. Inatel has developed an innovative transceiver based on GFDM and Polar Code, using the NI SDR platform composed by LabView Communications, USRP 2954 and PXI. These fast prototyping tools allowed the development of a real-time 2x2 MIMO transceiver capable of achieving more than 100 Mbps over 24 MHz bandwidth, using a 2x2 MIMO system in UHF. This solution is able to cover more than 31.5 miles, proofing that a 5G operation mode for remote are application is feasible today. This technology can be the key to close the connectivity gap between urban and rural areas.

Next Steps

Dynamic and opportunistic spectrum allocation requires a complete knowledge of the spectrum occupancy in the region where the remote area network is being deployed. Following, we will add the spectrum sensing capability to the UEs and implement a cognitive cycle that allows the BS to decide which channels can be opportunistically exploited by the network.



LABVIEW COMMUNICATION INTERFACE FOR CONTROLLING AND ANALYZE THE TRANSCEIVER PERFORMANCE

INTEGRATION OF THE REMOTE AREA MOBILE NETWORK WITH THE OTHER 5G SCENARIOS

SDR-based Wi-Fi transceiver with Non-Orthogonal Multiple Access

“The prototype designed in our lab shows that the technology is easy-to-implement, provides high gains, and can work on top of standardized Wi-Fi.”

Dr. Evgeny Khorov,
Head of Wireless Networks Lab, IITP RAS

Enhancing Wi-Fi Networks Performance with a Backward-Compatible Wi-Fi Device using Power-Domain Non-Orthogonal Multiple Access

WIRELESS NETWORKS LAB | INSTITUTE FOR INFORMATION TRANSMISSION PROBLEMS | RUSSIAN ACADEMY OF SCIENCES | ILYA LEVITSKY
ALEKSEY KUREEV | EVGENY KHOROV | HTTP://WIRELESS.IITP.RU/

The Challenge

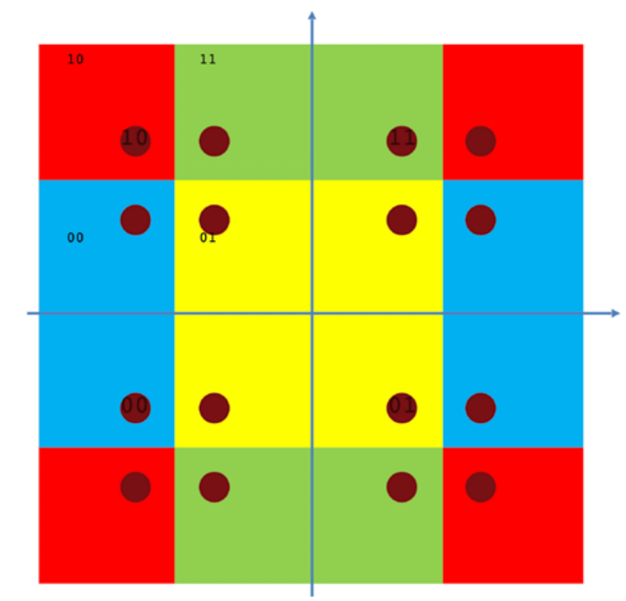
Nowadays, Wi-Fi networks become dramatically overcrowded with various devices of different generations. Non-orthogonal multiple access (NOMA) is a promising way to improve spectral efficiency and user experience in scenarios with a large number of clients associated with the same access point. However, until now, NOMA research has been limited only to theoretical work, done mostly for 5G, but not Wi-Fi.

The Solution

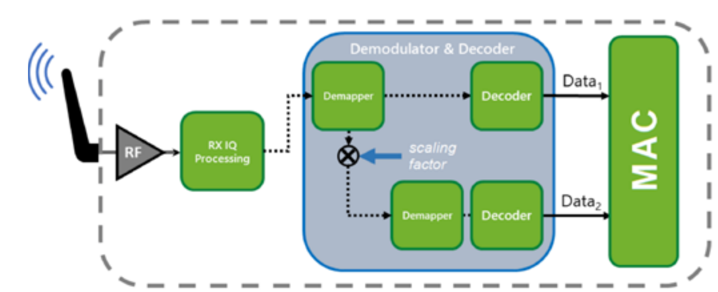
We present the first-ever NOMA over Wi-Fi prototype based on NI USRP RIO. We modified the 802.11 Application Framework so that devices can transmit a NOMA signal using superposition coding and can parse the received NOMA signal. For resilient signal reception, the NOMA transmitter uses symmetric superposition coding. During the tests of our NOMA prototype, we started to face real implementation problems, like hardware complexity and processing latency. Successive Interference Cancellation (SIC), often considered for NOMA signal reception, is not appropriate from these perspectives, so we invented a new algorithm we call Parallel Constellation Demapping (PCD). Additionally, we managed to change Wi-Fi frames so that NOMA system is backward-compatible: legacy devices can receive a part of the signal. Our prototype not only demonstrates the feasibility of the NOMA Wi-Fi concept, but shows 40% performance gain compared to legacy Wi-Fi.

Next Steps

We see NOMA as a real candidate for future Wi-Fi. Yet to be considered useful, NOMA should prove to be efficient in cooperating with existing Wi-Fi features like MIMO. Our plan is to improve the prototype by introducing MIMO capability and then find the achievable performance gains.



SYMMETRIC SUPERPOSITION CODING



PARALLEL CONSTELLATION DEMAPPING

Real-Time MIMO Wireless Channel Emulation System

Building an Expandable Real-Time MIMO Wireless Channel Emulator Using NITM PXI Software Defined Radio (SDR) Hardware

NANJING UNIVERSITY OF AERONAUTICS AND ASTRONAUTICS
ASSOC. PROF. QIUMING ZHU | KAI MAO | WENQING HUANG
DONGYANG ZHANG | WWW.NUAA.EDU.CN/

The Challenge

Increasing demand for wireless communication requires more complex communication systems. However, how to test the system under real-world channel conditions in a laboratory environment poses a challenge for all system designers.

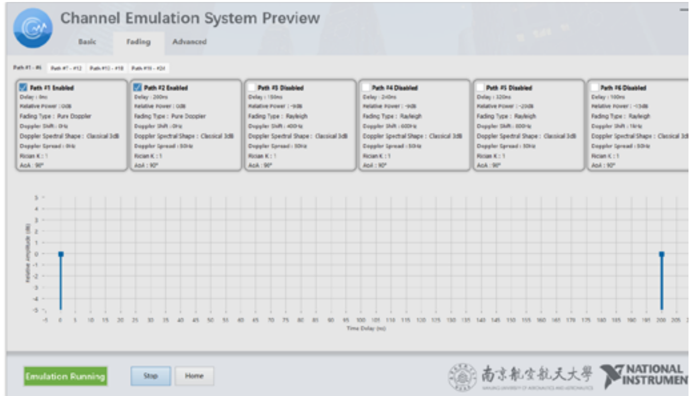
The Solution

In this work, we demonstrate a real-time channel emulation system based on the NI PXI platform. Compared with field tests, the hardware emulation method is visible, controllable, and repeatable. It provides better real-time emulation and is more efficient than the software simulation method. It could be utilized in various development cycles of communication systems, from algorithm verification to performance and reliability test. By leveraging high-performance PXI hardware and innovative FPGA algorithms, we addressed the following challenges:

- Real-time DSP of multichannel wideband signals
- High-throughput data transfer and distribution
- High-precision nonstationary phase-continuous fading generation

Next Steps

We are implementing more channel models in this system, such as geometry-based stochastic model (GBSM), to emulate different real-world scenarios. Besides, higher MIMO channel count could be easily added due to the flexibility of our architecture. We are also investigating channel models for specific applications such as V2X and satellite communications.



SOFTWARE USER INTERFACE

EVM DEGRADATION IN LTE DUE TO CHANNEL EFFECT

SDR-based Monitoring of Resource Allocations on the LTE Air Interface with FALCON

“The availability of professional SDRs and open protocol stacks melts the boundaries between simulation and field experiment and allows for immediate testing on a real-world prototype.”

Robert Falkenberg and Prof. Dr.-Ing. Christian Wietfeld,
TU Dortmund University

Real-Time Cell Load Analysis by Decoding the Physical Downlink Control Channel (PDCCH) of All Active Subscribers using General Purpose Computers and SDRs

TU DORTMUND UNIVERSITY | ROBERT FALKENBERG | PROF. DR.-ING. CHRISTIAN WIETFELD | HTTPS://CNI.TU-DORTMUND.DE | PAPER

The Challenge

The development of methods that increase the quality of mobile network services requires precise data of the instant network load. However, generally only the network operator has direct access to the network-side live data. Alternatively, a client-based control channel analysis is a way to monitor resource allocations, permitting the assessment of the cell activities and network loads. But existing open-source approaches lack reliability, accuracy, or real-time capability, which can lead to an incomplete or deviant overall view.

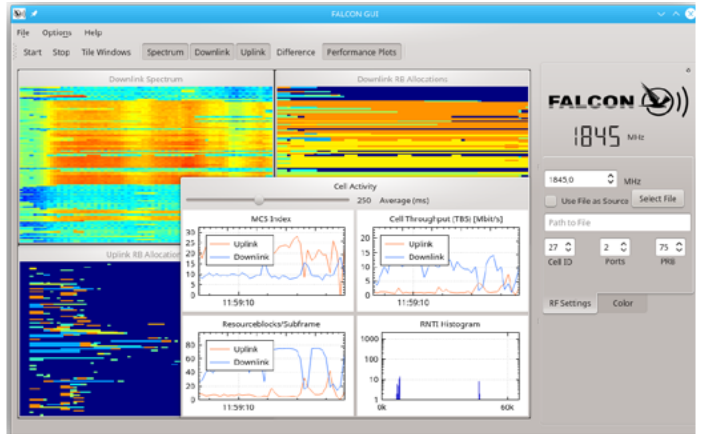
The Solution

On the basis of SDR solutions, like the NI USRP B210, combined with the efficient srsLTE library, we succeeded to develop FALCON: an open-source instrument for reliable decoding of the entire Physical Downlink Control Channel (PDCCH) of an LTE cell in range. FALCON combines previous attempts with a novel shortcut-decoding approach for fast and accurate data extraction from the received signal. It reveals the number of currently active devices including their Radio Network Temporary Identifiers (RNTIs) and their individual resource allocations.

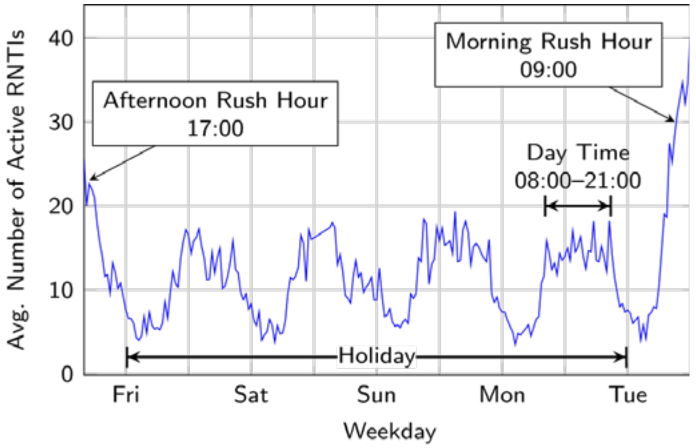
Our field measurements show that FALCON lowers the fraction of false data by three orders of magnitude, compared to the best previous approach. In addition, the intuitive GUI makes it easy to get started and can even be used for educational purposes. This work was supported by Deutsche Forschungsgemeinschaft (DFG) within the Collaborative Research Center SFB876, project A4.

Next Steps

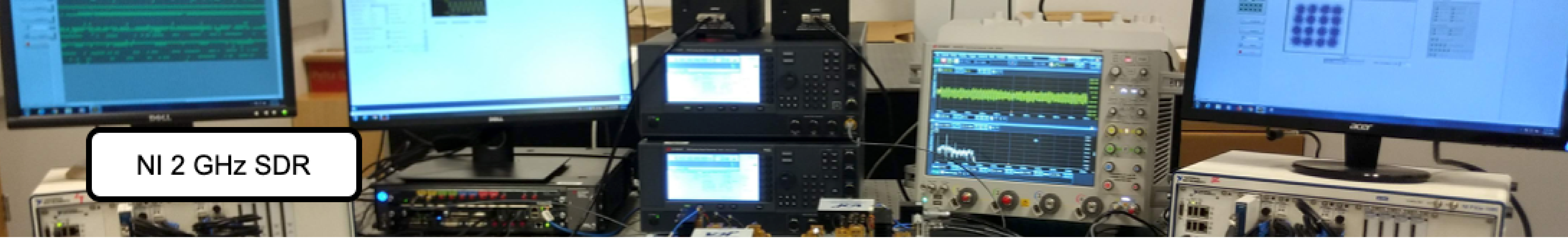
In future research, FALCON in conjunction with machine learning will be used to enable client-side load-dependent network switching to increase data transmission efficiency. In addition, the instrument allows the derivation of realistic user behavior models for the development of Network Data Analytics Functions (NWDAF).



FALCON'S LIVE PLOTS OF THE CELL ACTIVITY



LONG TERM MONITORING OVER SEVERAL DAYS



Real-time Ultrabroadband Networking in the Terahertz Band

"After many years of channel modeling, it is time to take THz communications research to the next level. The National Instruments software-defined-radio platform enables the design and testing of real-time communication and networking solutions at THz frequencies with multi-GHz bandwidths."

Josep M. Jornet,

Associate Professor, Department of Electrical and Computer Engineering, Northeastern University

Designing and testing, for the first time, real-time multi-GHz-wide communication and networks at frequencies from 120 GHz to 1.1 THz

ULTRABROADBAND NANONETWORKING LABORATORY (UN LAB) | INSTITUTE FOR THE WIRELESS INTERNET OF THINGS | DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING | NORTHEASTERN UNIVERSITY | PRIYANGSHU SEN, RESEARCH ASSISTANT, DR. VIDUNETH ARIYARATHNA | POSTDOCTORAL FELLOW DR, JOSEP M. JORNET, PROFESSOR | HTTPS://WWW.UNLAB.TECH

The Challenge

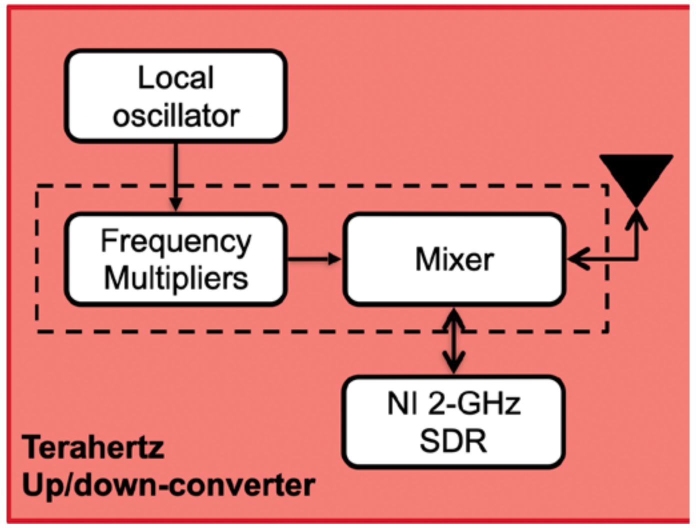
The need to support denser and faster wireless networks has motivated the exploration of uncharted regions of the electromagnetic spectrum. In this context, the Terahertz (THz) band (from 100 GHz to 10 THz) will play a key role in future wireless systems. In the last ten years, much work has been done towards closing the THz technology gap and modeling the THz channel. Moving forward, a real-time platform is needed to test the performance of communication and networking solutions.

The Solution

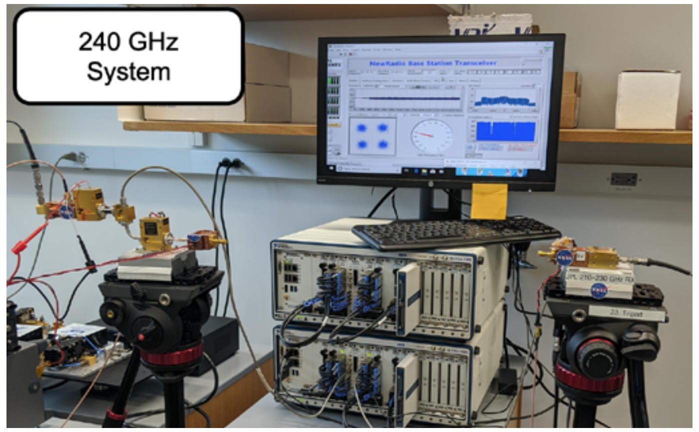
In our group, we are utilizing the National Instruments mmWave software-defined-radio platform with 2 GHz bandwidth as the starting point to design, implement, and test new physical and link layer solutions for THz communication networks. While the bandwidth of this platform is lower than that of arbitrary waveform generators and digital storage oscilloscopes, which are at the basis of most of THz experimental setups (some in our laboratory), the NI platform allows the testing of new techniques in dynamically changing conditions. Among others, we have implemented automatic gain control, automatic frequency offset control, phase noise compensation, and modulation and coding scheme selection for multi-GHz wide channels at 120 GHz, 240 GHz and 1.05 THz, both with single carrier and multi-carrier modulations, and for distances ranging from tens of centimeters to tens of meters.

Next Steps

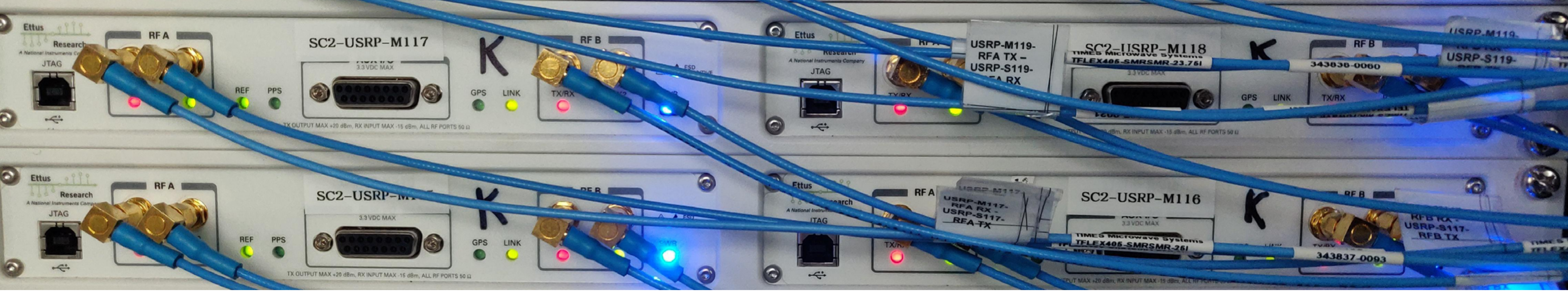
Moving forward, our focus is on going up in the protocol stack and testing the performance of new medium access control protocols, neighbor discovery techniques, relaying strategies, and routing protocols for THz mobile ad hoc networks. In parallel to that, we are also exploring mechanisms to aggregate multiple 2 GHz channels.



BLOCK DIAGRAM A FREQUENCY-MULTIPLIED THZ TRANSCEIVER SYSTEM



REAL-TIME 2-GHZ-WIDE OFDM WIRELESS LINK AT 240 GHZ



Colosseum: The World's Largest Radio Frequency Network Emulator

"For the first time, Colosseum enables researchers to conduct fully controlled and reproducible radio-channel experiments at scale over state-of-the-art hardware with technologies that will be the foundation of 5G and the wireless Internet of Things, spectrum sharing, smart cities, connected vehicles, and industry 4.0, among others."

S. Basagni (co-PI),
Institute for the Wireless Internet of Things, Northeastern University.

Enabling repeatable wireless research at-a-scale through massive emulation of thousands of real-world networks on hundreds of physical wireless radios

INSTITUTE FOR THE WIRELESS INTERNET OF THINGS, DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING | NORTHEASTERN UNIVERSITY
WWW.NORTHEASTERN.EDU/WIOT/

The Challenge

Today, spectrum is managed by dividing it into mostly exclusively licensed bands through a rigid human-driven process that is clearly unable to exploit the full potential capacity of the spectrum. New methodologies for effective spectrum management are sought that enable optimized spectrum usage in collaborative ways and achieve ultimate experiment reproducibility in a repeatable environment. To this day, however, the research and industry communities are missing a flexible tool to test these new solutions and to seamlessly emulate thousands of real-world networks on hundreds of physical wireless radios.

The Solution

Colosseum is the answer that academic researchers and industry practitioners were waiting for to create virtual worlds and emulate wireless signals traveling through space and reflecting off multiple objects between transmitters and receivers. Colosseum is made of 21 specialized server racks that drive a a total of 256 NI USRP X310 software-defined radios that can emulate more than 65k wireless channels. By using Colosseum, any realistic network scenarios can be created and investigated by generating more than 52 terabytes of data per second, far exceeding the amount of information contained in the entire printed collection of the Library of Congress. As such, Colosseum is by far the world's largest radio frequency emulator.

Next Steps

Opening Colosseum to the research community will be game-changing for shaping the future of wireless networked systems that are powered by artificial intelligence and big data. We plan for Colosseum to be operational 24x7x365, and accessible through a simple web interface, interactively or via scheduled batch jobs. It will serve a wide range of stakeholders, including US academic researchers, all federal agencies and their contractors, as well as R&D groups from US industry, thus enabling innovation and shaping impactful next-generation wireless research for years to come.

TWO COLOSSEUM RACKS

Massive MIMO Channel Dataset for Ultra-Dense Indoor Scenarios

“KU Leuven is the first research institute to distribute a real-world Massive MIMO testbed. By doing this, researchers can verify the real benefits and challenges related to distributed Massive MIMO. By doing so, we learned that reality is more fascinating than simplifying assumptions.”

Dr. Sofie Pollin,
Networked Systems Group, KU Leuven

An Antenna Topology Study

KU LEUVENH | DR. SOFIE POLLIN | PROFESSOR ANDREA P. GUEVARA
SIBREN DE BAST AND CHENG-MING CHEN, PHD RESEARCH
NETWORKED SYSTEMS GROUP | WWW.ESAT.KULEUVEN.BE/

The Challenge

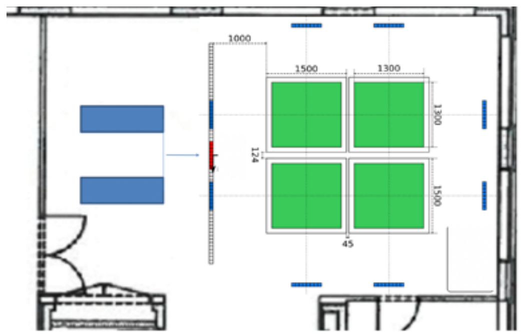
In future indoor scenarios, multiple devices will require simultaneous network access, providing high throughput, high reliability, or even localization services. Throughput density, link reliability, and localization accuracy all critically depend on the channel properties. Ray tracing simulations rely on simplified environments and antenna models. In order to analyze the complete channel, extensive measurement campaigns of complex scenarios that includes multipath propagation and antenna distribution are required.

The Solution

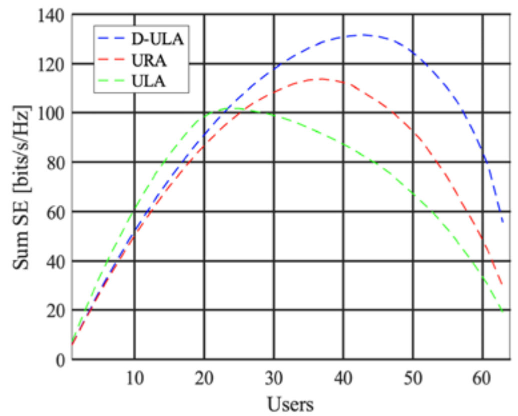
To create an ultra-dense virtual scenario, the 64-antenna KU Leuven massive MIMO tested based on NI hardware is used to collect the channel information of four users deployed in more than 250k positions with the aid of XY positioners that provide us a position error below 1 mm. The channel collection was implemented in the LabView MIMO Application Framework, where data collection was synchronised with the UE positioner. Thanks to the antenna modularity, this experiment was repeated for multiple antenna topologies, i.e., a Uniform Rectangular Array, Uniform Linear Array and Distributed-Uniform Linear Array. Based on this dataset, multiple parameters can be studied offline as user scheduling and localization for different antenna topologies.

Next Steps

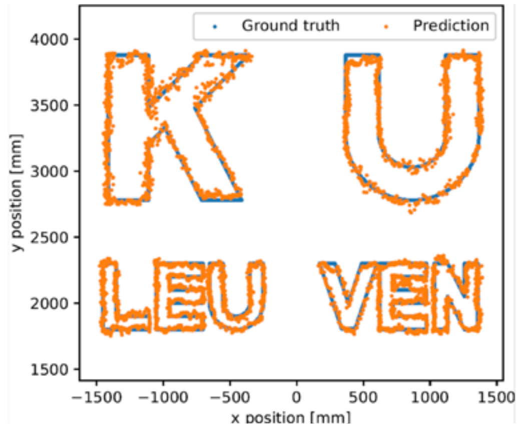
New measurement campaigns are planned for lower frequencies (< 1 GHz) as well as other indoor environments and mobility scenarios. In addition, an extension of the testbed will allow us to deploy the two-cell scenario where pilot contamination and co-channel interference will be studied. A mmWave extension is also planned and a first mmWave link was already established.



MEASUREMENT CAMPAIGN MAPS FOR ULTRA-DENSE INDOOR SCENARIOS



UL SUM SE FOR DIFFERENT ANTENNA DISTRIBUTION AND NUMBER OF USERS WITH ZER-FORCING COMBINING VECTOR



A VISUALIZATION EXAMPLE OF USER LOCALIZATION

In-band Full-duplex Radar-communication System

"KU Leuven is the first research institute to enable real-time monostatic radar and in-band full duplex experiments, motivating the research community to do joint sensing and communication experiments."

Dr. Sofie Pollin,
Networked Systems Group, KU Leuven

System level analysis

KU LEUVENH | NETWORKED SYSTEMS GROUP | DR. SOFIE POLLIN, PROFESSOR
SEYED ALI HASSANI, PHD RESEARCHER | NETWORKED SYSTEMS GROUP
WWW.ESAT.KULEUVEN.BE/

The Challenge

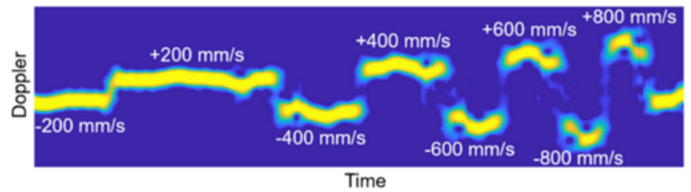
The use of in-band full-duplex (IBFD) is a promising improvement over classical TDD or FDD communication schemes. From a radar point of view, an IBFD transceiver can be seen as a monostatic radar, which is affected by the communication signal. The challenge is to exploit the reflections of the communication signal to extract the Doppler state of the channel, enabling applications like body/hand gesture detection and indoor vehicular applications via a single platform, etc., a Wi-Fi access point.

The Solution

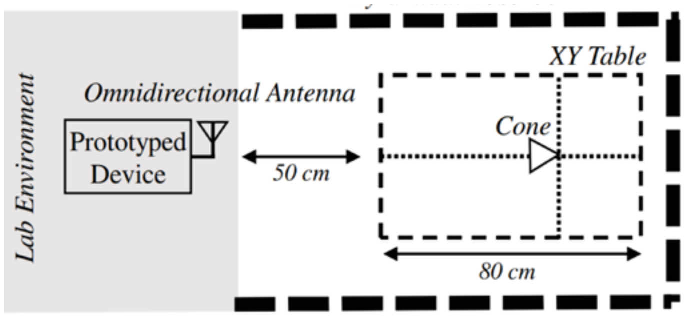
There are two sources of interference inherent in an IBFD communication scenario that interfere with the radar. The first is the strong direct Tx leakage, which degrades the Doppler signal by producing an unwanted DC component. The second is the presence of an active second party transmitter, emitting a communication signal concurrently with the radar. KUL's IBFD platform benefits from an electrically balanced duplexer (EBD) at the RF stage to suppress the direct Tx self-interference (SI). It removes the unwanted DC signal from the Doppler, enhancing the sensitivity of detecting slow movements in the device's surroundings. Besides, our implementation applies multiple stages of decimation, which enable a correlation-based Doppler radar to overcome the impact of a probable simultaneous transmission, which is a typical case in IBFD communication.

Next Steps

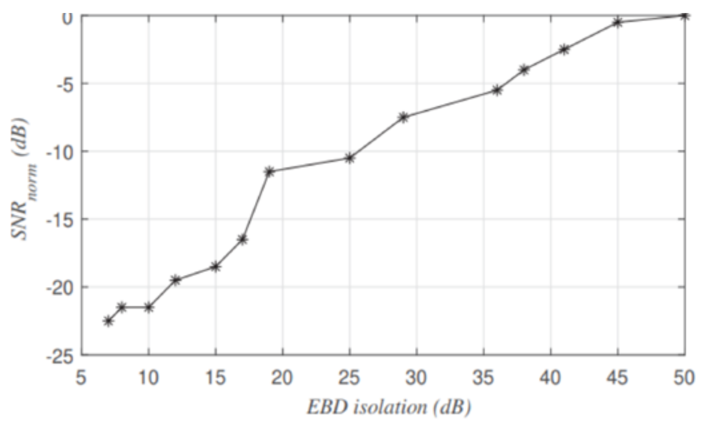
Since the environmental reflections of the Tx signal are highly correlated with the transmit message, a dynamic SI cancellation scheme presumably attenuates them as well, degrading the radar detection. Thus, our system tends to freeze the SI rejection modules during the period it estimates Doppler. Other approaches have to be studied to enable joint radar and communication without the need for compromising one of the functionalities.



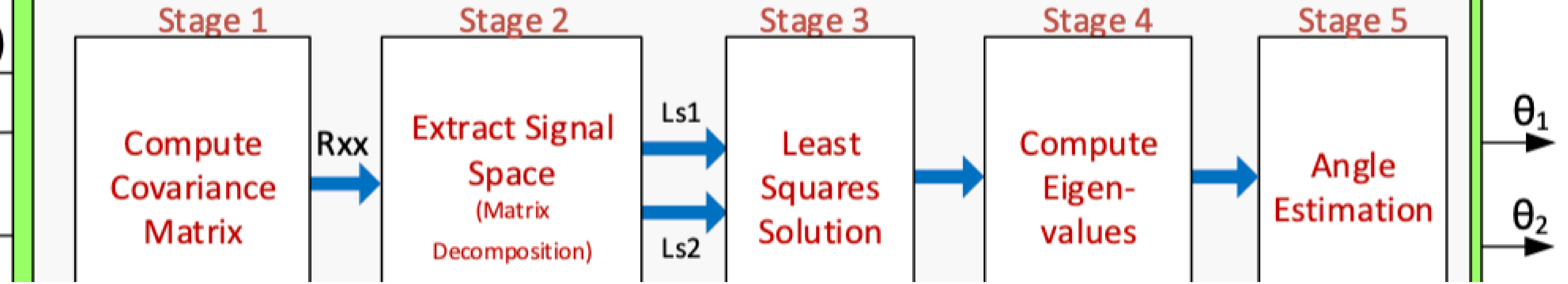
MEASURED DOPPLER IMAGE



MEASUREMENT SETUP SCHEMATIC, INCLUDING THE RADAR CAPABLE IBFD DEVICE AND AN X-Y POSITIONER



MEASURED INFLUENCE OF SELF-INTERFERENCE CANCELLATION ON THE QUALITY OF THE DETECTED DOPPLER



Hardware Implementation of Computationally Efficient DOA Estimation Algorithms on NI USRP

Hardware implementation of Cholesky and LDL-decomposition based DOA Estimation Algorithms on NI USRP SDR Platform

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The Challenge

Implementing computationally intensive DOA estimation algorithms that estimate the DOA angles for multiple sources in the fastest possible time, using the least amount of hardware resources, and experimentally validating their performance and estimation accuracy on a prototype testbed constructed using the NI USRP SDR platform.

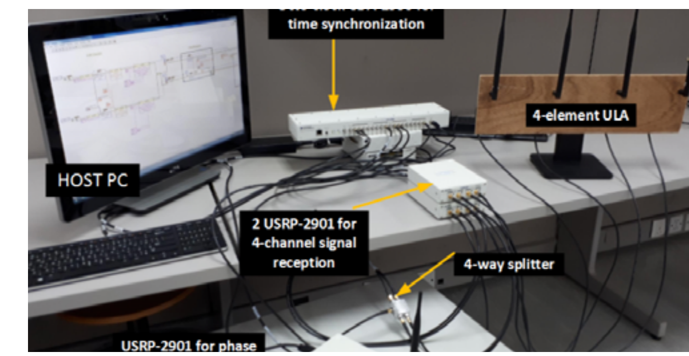
The Solution

Utilizing NI hardware, LabVIEW software, and LabVIEW FPGA high throughput modules to design and build a complete hardware prototype testbed for real-time DOA estimation that can be used to experimentally validate the performance of the proposed DOA estimation algorithms based on LDL and Cholesky decomposition. Uniform linear arrays of 4 and 8 antenna elements are deployed at the receiver which is connected to USRP-2901 units.

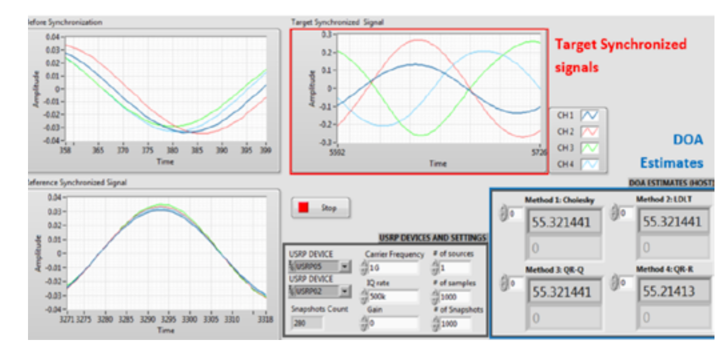
The USRP unit first amplifies the received signal, downconverts it to baseband signals (I and Q), filters out noise and high-frequency signals, and digitizes the signals (I and Q) before being passed on to the data/signal processor. A FlexRIO is used for FPGA implementation of the DOA estimation algorithms using LabVIEW FPGA modules.

Next Steps

We intend to continue our work in the development of more efficient DOA estimation algorithms, and implement and experimentally validate the developed algorithms using NI hardware and software. In the future, we will consider DOA estimation of coherent sources and different array configurations such as L-shaped, circular, etc.



TESTBED FOR REAL-TIME EXPERIMENTAL VALIDATION OF PROPOSED METHODS USING A 4-ELEMENT ULA



SCREENSHOT - REAL-TIME DOA ESTIMATION RESULTS FOR TWO SOURCES LOCATED AT 550 AND 1300, RESPECTIVELY, FROM THE 4-ELEMEN

Live Satellite Precoding Demonstration

A live end-to-end demonstrator of precoding techniques to enable full frequency reuse in the forward link of future multi-beam satellite systems

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The Challenge

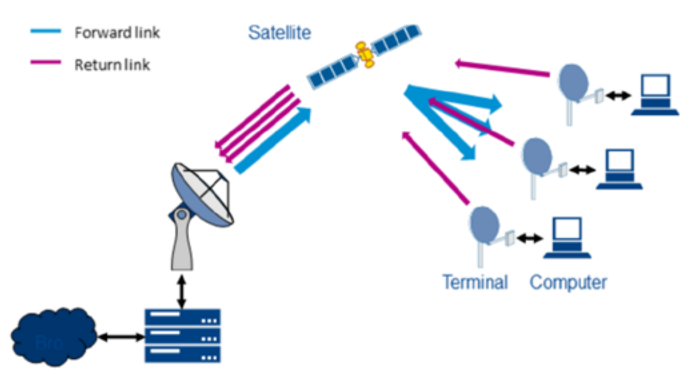
The objective of this study is to implement and demonstrate, using over the air transmission through a real GEO satellite, Multi-User Multiple Input Single Output digital signal processing techniques, namely precoding, in the forward link of a multi-beam satellite system operating in full frequency reuse. The recent paradigm has been proposed and studied in the direction of the management and the exploitation of the interference amongst beams.

The Solution

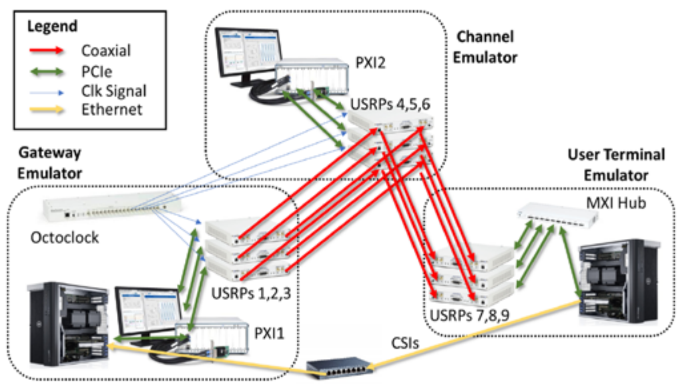
The demonstrator based on software-defined radios provides all the required functionalities of a precoding-based system to correctly exploit its gains. These are synchronization and proper collection of the estimated Channel State Information (CSI) by User Terminals (UTs) to be fed back to the Gateway (GW), precoding-specific sart user-scheduling techniques and Modulation and Coding (Modcod) allocation, computationally efficient calculation of the precoder subject to satellite environment constraints, and application of the resulting precoder to the vectors of symbol streams, one per each beam, to be transmitted by the GW. The transmission is compliant with the DVBS2X standard.

Next Steps

The study will increase the maturity of the technology to a Technology Readiness Level of 5. The precoding demonstrator after the in-lab validations will be expanded to over-the-air experiments. During these experiments, the precoding technology will be demonstrated using a real-time satellite transmission.



PRECODING DEMONSTRATOR: SYSTEM MODEL



PRECODING DEMONSTRATOR: PRINCIPAL DIAGRAM

Arena: A 64-antenna SDR-based Ceiling Grid Platform for 5G-and-Beyond Spectrum Research

"We hope that its open-access system, its three-tiered architecture, its full symbol level synchronization, and its unique line of sight indoor ceiling-grid layout ensuring reconfigurable, scalable, and repeatable real-time real wireless channel experiments will foster the development of new 5G-and-beyond technologies, Internet of Things (IoT), Artificial Intelligence powered wireless networks, cognitive radio, dynamic spectrum access, and massive MIMO applications."

Tommaso Melodia (PI),
Institute for the Wireless Internet of Things, Northeastern University

An open-access indoor wireless testing platform featuring 12 servers, 24 NI USRP synchronized via 4 NI Clock Distributors, and a total of 64 antennas

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The Challenge

As the evolution of wireless networked systems continues to be a crucial commercial, strategic, and geopolitical matter, the community is still lacking a platform to test at scale medium- and short-range radio technologies in an indoor realistic environment able to guarantee high-fidelity, scale, and repeatability of experiments. This is crucial for sub-6 GHz testing indoor deployments such as offices, malls, and airports characterized by fast-varying environment, spatial and time-varying interference, significant multi-path effect, and continuous mobility of surrounding object.

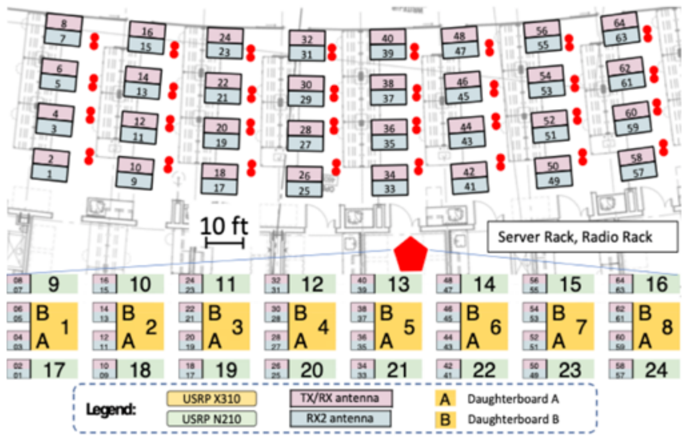
The Solution

Arena is an open-access wireless testing platform based on a grid of antennas mounted on the ceiling of a large office space environment. With 12 computational servers, 24 software-defined radios synchronized at the symbol level, and a total of 64 antennas, Arena provides the computational power and the scale to foster sub-6 GHz 5G-and-beyond spectrum research. Arena is based on a three-tier design, where the servers and the software-defined radios are housed in a double rack in a dedicated room, while the antennas are hung off the ceiling of a 2240 square feet office space and cabled to the radios through identical 100 ft-long cables. This configuration ensures a unique full-testbed synchronization enabling reconfigurable, scalable, and repeatable real-time experimental evaluation in a real wireless indoor environment.

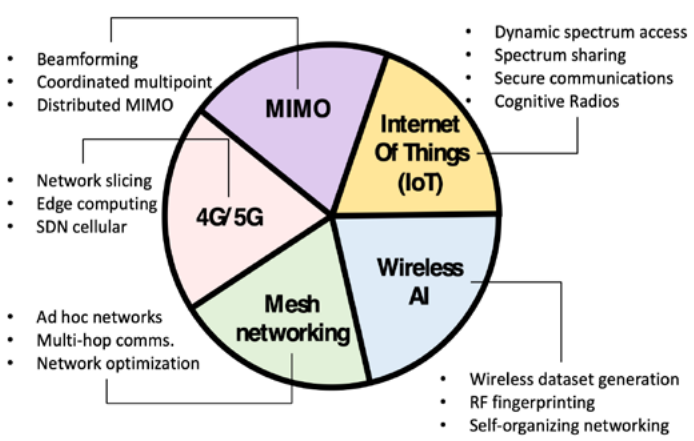
Next Steps

Featuring unprecedented scale and fidelity for an indoor wireless deployment, Arena represents the platform of choice for future WLAN developments.

Being an open-access, accessing from the Internet platform, Arena is already shaping the way we conduct wireless spectrum research at Northeastern University and at other partners around the world. Together with Colosseum and the Platform for Advanced Wireless Research (PAWR) testbeds, we foresee Arena being the driver for open-access rigorous spectrum research.



PRECODING DEMONSTRATOR: SYSTEM MODEL



PRECODING DEMONSTRATOR: PRINCIPAL DIAGRAM

Real-time Multi-Gigahertz sub-Nyquist Spectrum Sensing System for mmWave

"Traditional prototyping and iteration of novel communication system hardware and algorithm design can be laborious and costly. The flexibility of NI MTS SDR system prominently accelerates the development speed and bringing the future closer as never before."

Prof. Yue Gao,
University of Surrey

Validation in recovering real-time wideband millimetre-wave spectrum from compressed samples

INSTITUTE FOR COMMUNICATION SYSTEMS (ICS) | DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING | UNIVERSITY OF SURREY | MR. ZIHANG SONG | MR. HAORAN QI | DR. VEDAPRABHU BASAVARAJAPPA | PROF. YUE GAO
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The Challenge

The evolution of wireless communication in millimeter-wave (mmWave) frequencies delivers strong request to real-time wideband spectrum sensing (WSS) techniques. The GHz bandwidth operation brings a natural push for wider bandwidth hardware components, especially higher sampling rate analog-to-digital converters (ADCs) to allow for electromagnetic spectrum surveillance, dynamic access, and co-existence of mobile, satellite and radar applications. However, the cost, complexity, and energy consumption of Nyquist-rate ADCs are very challenging in practice for real-time WSS implementations in mmWave frequencies.

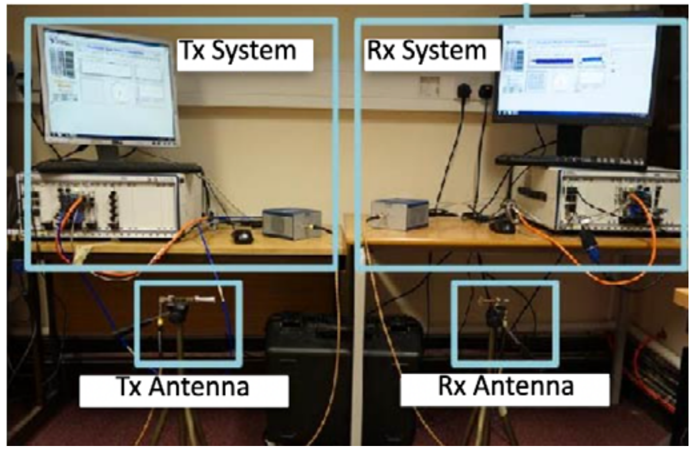
The Solution

The National Instruments (NI) mmWave transceiver system (MTS) is configured as Tx and Rx, respectively. Symbols modulated by 64-QAM and Verizon 5G OFDM waveform spanning the bandwidth of 100 MHz are transmitted with multiple component carriers. The baseband complex signal with 2 GHz bandwidth are sampled by a Nyquist ADC at the passive receiver.

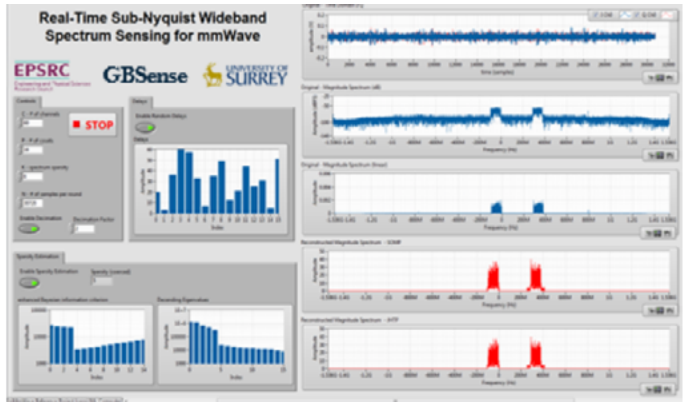
Using LabVIEW development tools, the behaviour of compressed samplers is implemented in parallel at the baseband processing FPGA module to improve efficiency and low latency. Low-complexity compressive recovery algorithms are developed on the host controller which process the real-time compressed data from the processing FPGA. Feasibility of the proposed sub-Nyquist spectrum sensing framework is successfully validated on real-time mmWave signals. Numerical evaluation is also carried out regarding the noise performance and detection probability under various conditions.

Next Steps

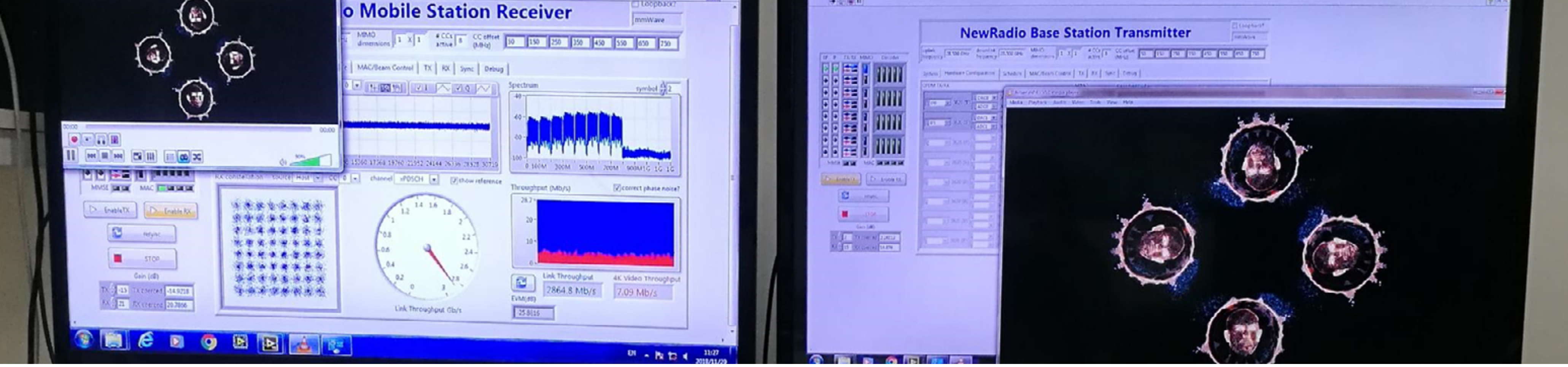
With the compressive sensing framework validated by NI MTS, integrated hardware and novel sub-Nyquist sampling algorithms can be designed accordingly, which could be applied in machines and devices in future mobile and satellite systems.



MMWAVE TRANSCEIVER SYSTEM SETUP FOR GBSENSE



VIRTUAL CONTROL & MONITORING PANEL FOR PROPOSED SUB-NYQUIST SPECTRUM SENSING SCHEME



Sensing and Communication Converged System for Autonomous Vehicles

Joint sensing and communications system using mmWave spectrum to overcome challenges for V2X

BEIJING UNIVERSITY OF POSTS AND TELECOMMUNICATIONS (BUPT) KEY LABORATORY OF UNIVERSAL WIRELESS COMMUNICATIONS | MINISTRY OF EDUCATION | QIXUN ZHANG | ZHIYONG FENG

The Challenge

To improve the safety of autonomous vehicles, with the deployment of various sensors (e.g., optical cameras, LiDAR, mmWave radar, ultrasonic sensors, etc.), the low latency multiple sensing information convergence from different vehicles is a challenging problem. Motivated by the large bandwidth and high resolution features of the mmWave spectrum band, we propose the novel idea of joint sensing and communication system design for the high bandwidth and low latency information convergence using mmWave spectrum band. The key challenges are as follows.

- Fast beam steering and beam tracking for mobile mmWave communication
- Robust mmWave broadband transmission in mobile scenario
- Joint system design and optimization for sensing and communication

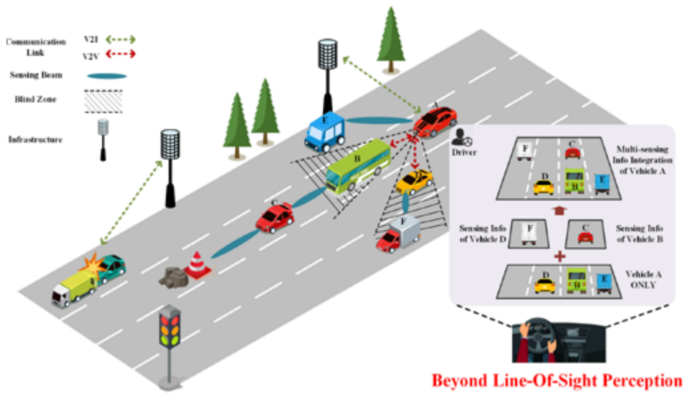
The Solution

A hardware testbed for sensing and communication converged system is designed and developed based on 5G New Radio NI mmWave Transceiver System at Ka mmWave band.

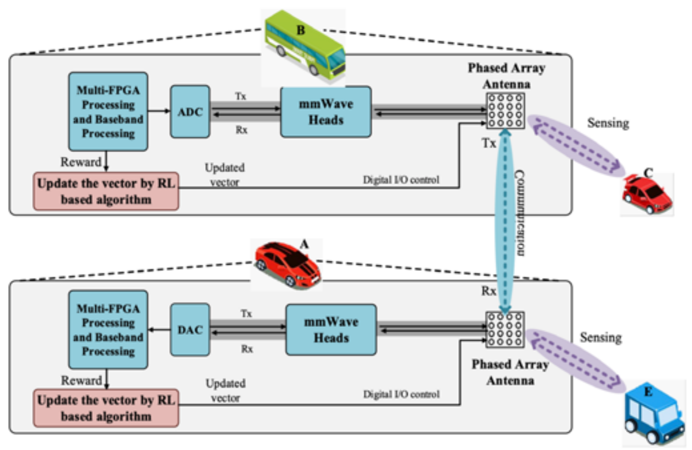
- Fast beam steering and machine learning based beam tracking algorithms for the mobility scenario
- Data-driven based Doppler shift estimation and compensation utilizing maximum likelihood estimation (MLE) for the mobile broadband communication
- Game theory based dynamic time allocation optimization scheme for joint sensing and communication frame structure design

Next Steps

- Intelligent beam control algorithms for autonomous vehicles
- Real-time safety related sensing information integration for autonomous vehicles



SENSING AND COMMUNICATION CONVERGED NETWORK SCENARIO FOR AUTONOMOUS VEHICLES



SENSING AND COMMUNICATION CONVERGED PLATFORM DESIGN