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Spatial fading channel emulation for over-the-air testing of millimeter-wave radios: concepts and experimental validations

Key words: Spatial channel model; Over-the-air (OTA) testing; Wireless cable method; Multi-probe anechoic chamber (MPAC) method; FR2 validation

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Motivation

- Millimeter-wave (mmWave) new radio (NR) testing will move exclusively to over-the-air (OTA) radiated modes using device antennas as the direct interface with the test system.
- It is of great importance to optimize and validate the device performance in real-world conditions, i.e., under faded and subject to interference channel conditions with multiple cells, users, and radio access technologies.
- It would be desirable to develop cost-effective OTA testing methodologies in laboratory conditions, which makes it possible to achieve virtual field testing purposes of mmWave devices in realistic conditions.

Main idea

- In this work, the main focus is on spatial fading channel emulation for the OTA testing of mmWave radios and its validation in a practical FR2 anechoic chamber.
- We experimentally validate the wireless cable method and the multi-probe anechoic chamber (MPAC) method in a practical setup for mmWave NR testing.
- Two simple strategies to achieve wireless cable connection for mmWave radios, i.e., using antenna polarization discrimination and pattern discrimination, are proposed.

Wireless cable method

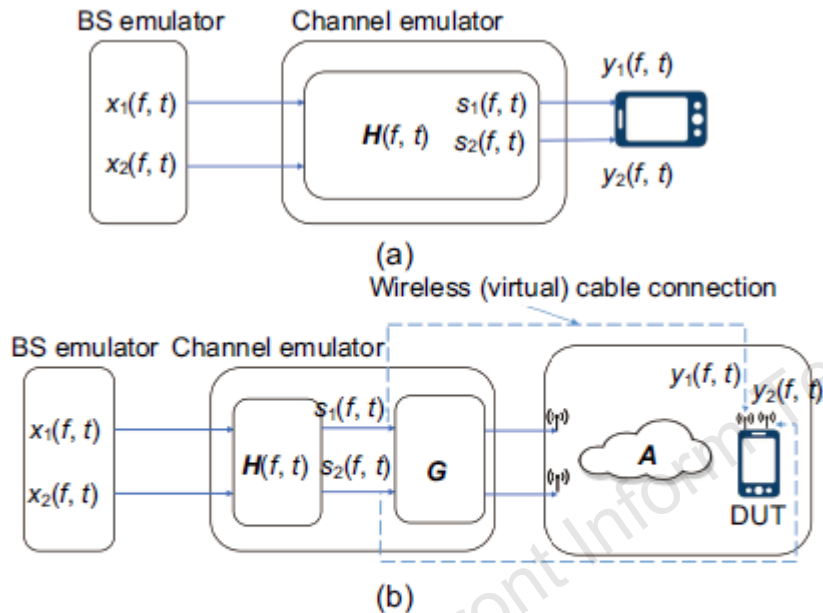
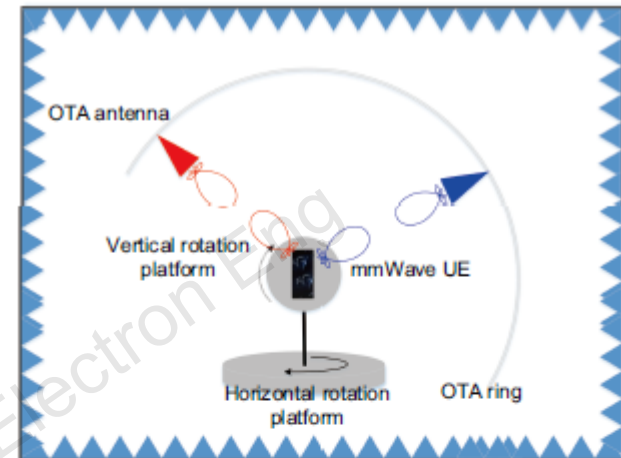
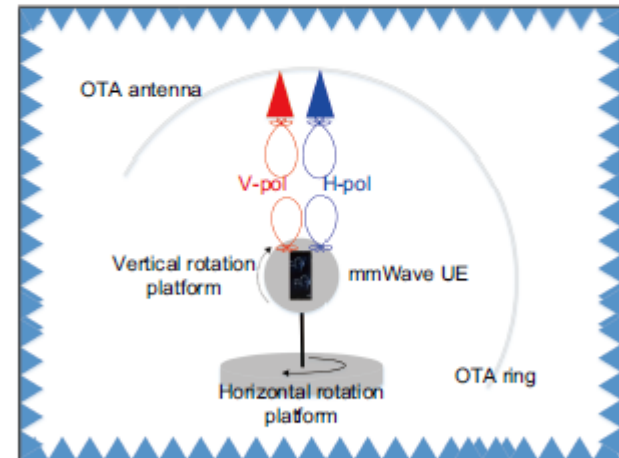


Fig. 1 Illustration of the conducted cable setup (a) and the wireless cable setup for mobile handsets supporting 2×2 MIMO systems (b)

BS: base station; MIMO: multiple-input multiple-output



(a)



(b)

Fig. 3 Illustration for achieving wireless cable connection via antenna pattern discrimination (a) and antenna polarization discrimination (b)

mmWave: millimeter-wave; OTA: over-the-air; UE: user equipment

Wireless cable method

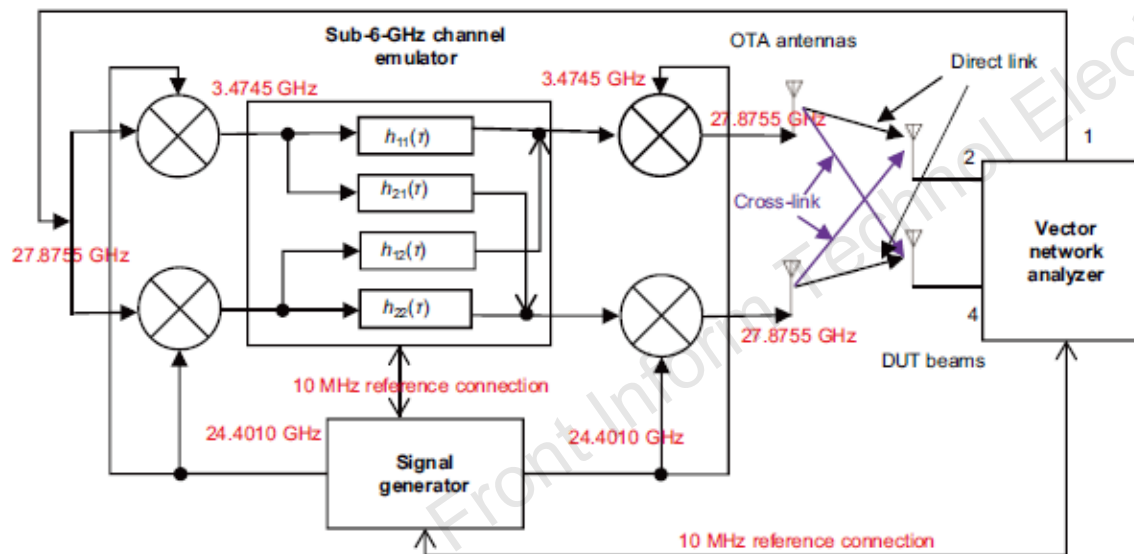


Fig. 4 System diagram for the wireless cable method validation setup

DUT: device under test; OTA: over-the-air. References to color refer to the online version of this figure

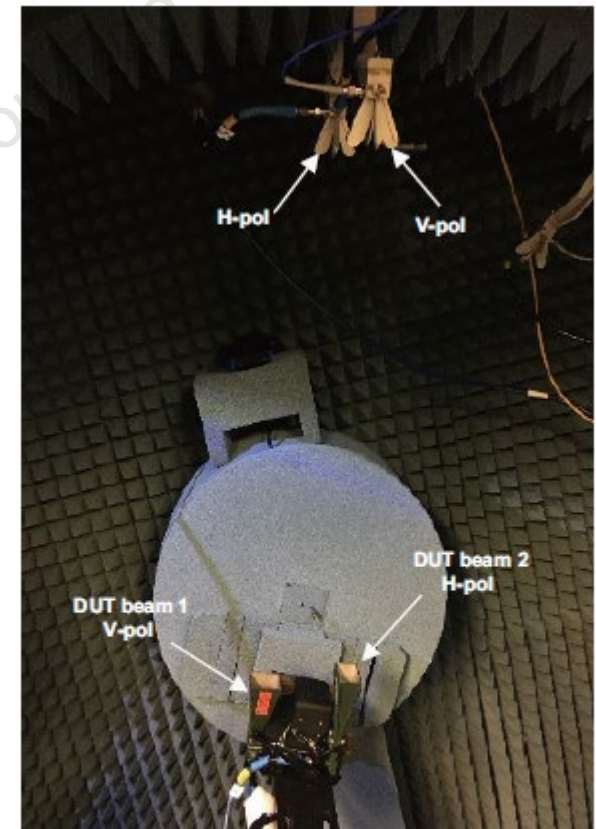


Fig. 5 Measurement setup for the wireless cable method using the polarization discrimination scheme
DUT: device under test; OTA: over-the-air; V-pol: vertical polarization; H-pol: horizontal polarization

Wireless cable method

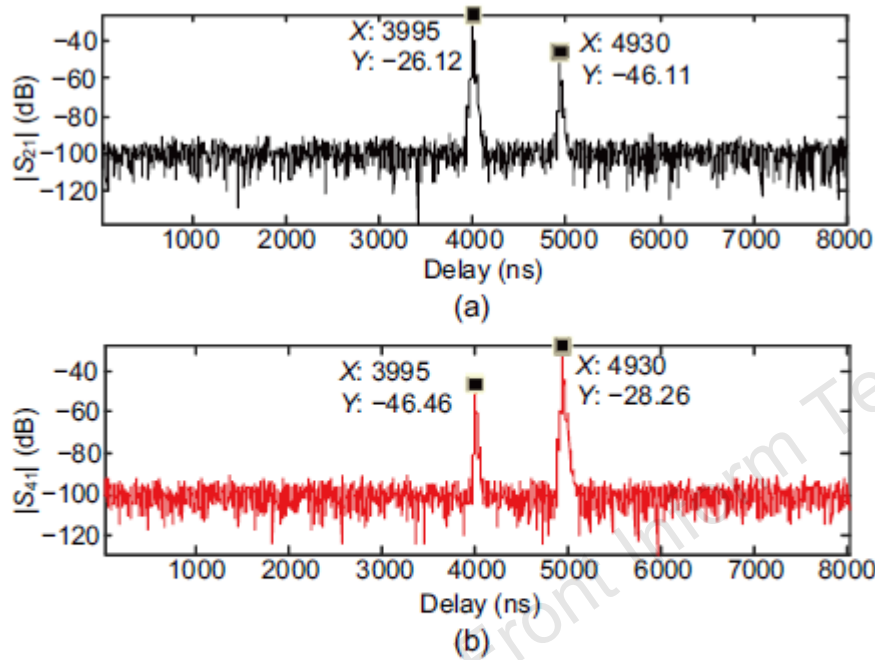


Fig. 7 Measured CIRs for the first (S_{21}) and second (S_{41}) DUT antennas using the polarization discrimination scheme

CIR: channel impulse response; DUT: device under test

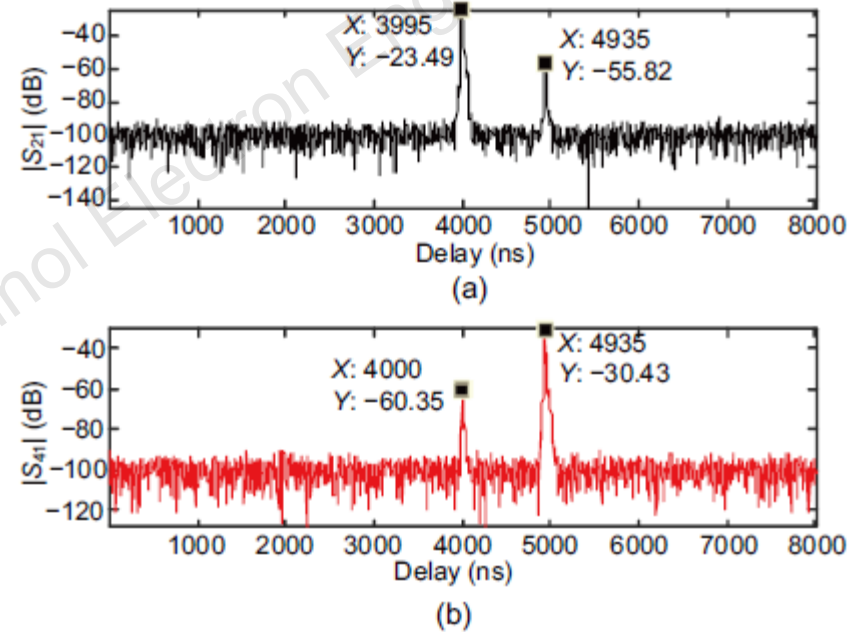


Fig. 8 Measured CIRs for the first (S_{21}) and second (S_{41}) DUT antennas using the beam pattern discrimination scheme

CIR: channel impulse response; DUT: device under test

MPAC method

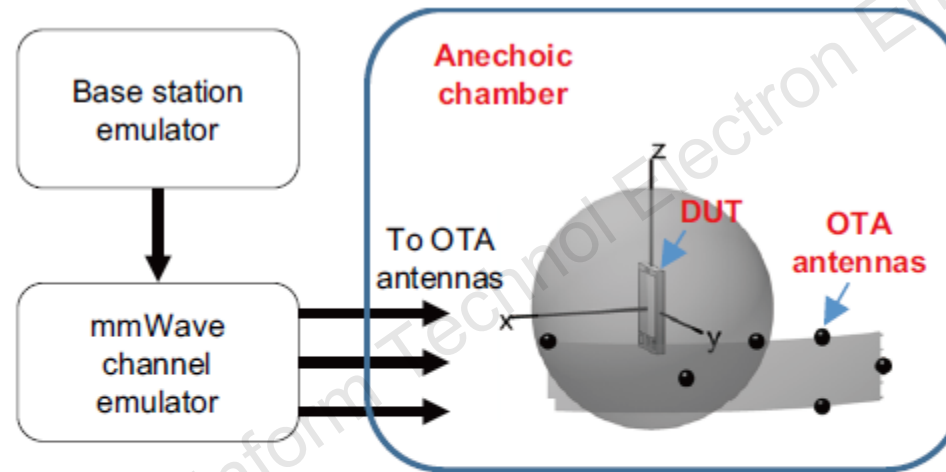


Fig. 9 MPAC system layout for OTA testing of an FR2 MIMO device

DUT: device under test; FR: frequency range; MIMO: multiple-input multiple-output; mmWave: millimetre-wave; MPAC: multi-probe anechoic chamber; OTA: over-the-air

MPAC method

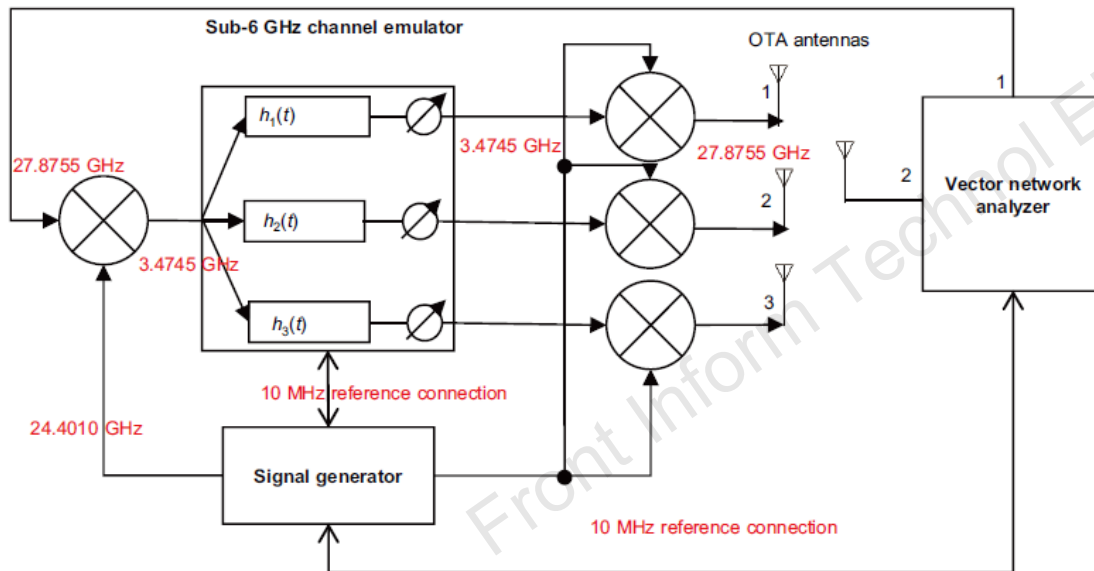


Fig. 10 System diagram for the SS-MPAC setup

OTA: over-the-air; SS-MPAC: simple sectored multi-probe anechoic chamber

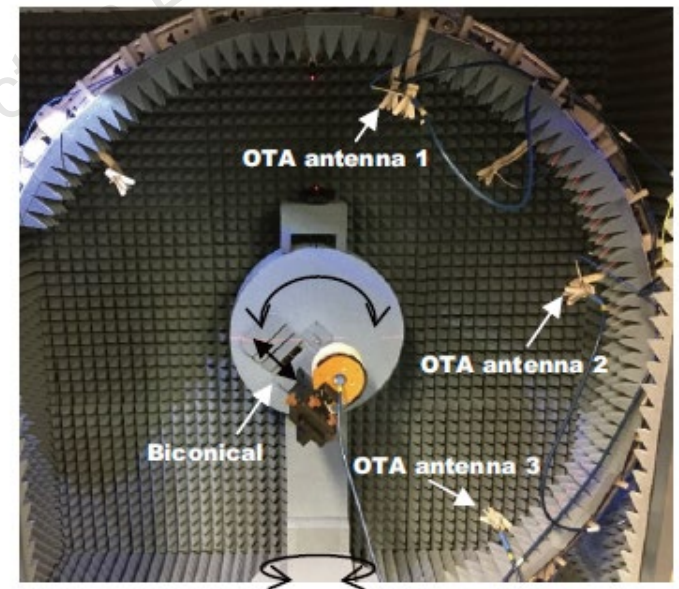


Fig. 11 System diagram for the MPAC setup

MPAC: multi-probe anechoic chamber; OTA: over-the-air

MPAC method

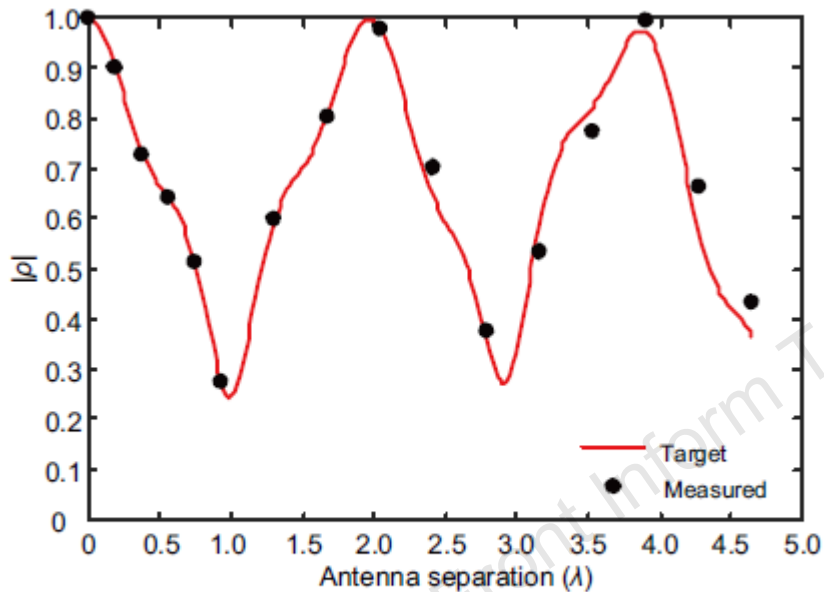


Fig. 12 Measured and target spatial correlation in the MPAC setup

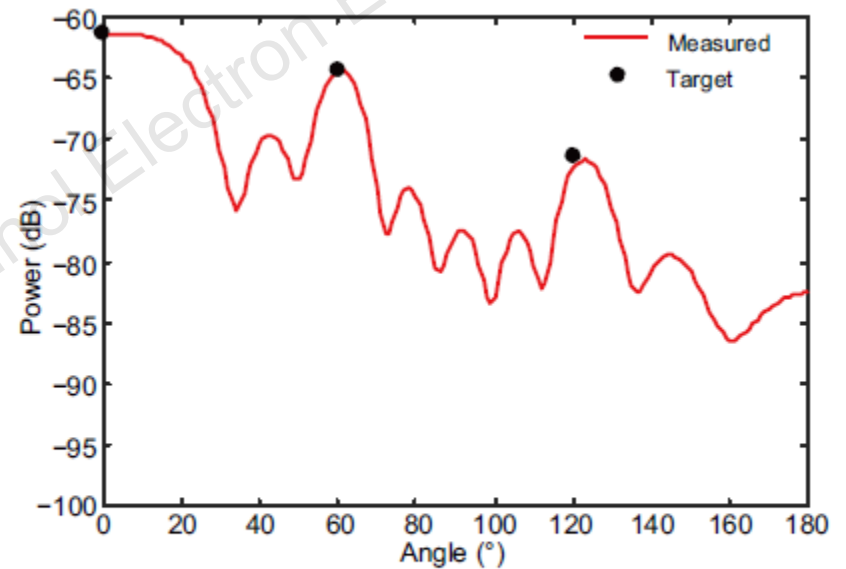
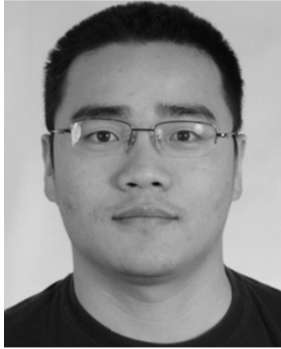


Fig. 13 Measured and target power angular spectrum in the MPAC setup

MPAC: multi-probe anechoic chamber

Conclusions

- Two OTA methods, namely, the wireless cable method and the MPAC method, have been investigated for mmWave radios with preliminary experimental results.
- Three strategies to achieve wireless cable connection have been discussed, i.e., transfer function matrix calibration, polarization discrimination, and antenna pattern discrimination. It is shown in the preliminary measurement results at around 28 GHz that an isolation more than 20 dB and 30 dB can be achieved for the wireless cable method using polarization discrimination and antenna pattern discrimination, respectively.
- The spatial correlation and PAS have also been investigated for a simple MPAC setup in the FR2 chamber. Excellent agreement between the measurement results and the target values is achieved in terms of spatial correlation and PAS, which validates the effectiveness of the MPAC method in the mmWave bands.



Wei FAN received his BS degree from the Harbin Institute of Technology, Harbin, China, in 2009, the MS degree (Hons.) from the Politecnico di Torino, Turin, Italy, the MS degree (Hons.) from the Grenoble Institute of Technology, Grenoble, France, in 2011, and the PhD degree from Aalborg University, Aalborg, Denmark, in 2014. In 2011, he was with Intel Mobile Communications, Aalborg, as a research intern. He conducted a three-month internship at Anite Telecoms Oy, Oulu, Finland, in 2014. He is currently an associate professor with the Antennas Propagation and Millimeter-wave Systems Section, Aalborg University. His current research interests include over-the-air testing of multiple antenna systems, radio-channel sounding, modeling, and emulation.



Lassi Hentilä was born in Oulu, Finland, in 1978. He received his MS degree in electrical engineering and telecommunications from the University of Oulu, Oulu, in 2004. He was with the Centre for Wireless Communications, University of Oulu, from 2001 to 2004. In 2004, he moved to Elektrobit, Oulu, where he was involved in radio propagation, radio-channel measurements and modeling, and MIMO OTA research and standardization, and participated in the European IST-WINNER Projects (WINNER I, WINNER II, and WINNER+). In 2013, he moved to Anite Telecoms Oy, Oulu, where he was a MIMO OTA specialist. In 2016, he moved to Keysight Technologies Finland Oy, Oulu, as a part of the acquisition of Anite Telecoms Oy, where he currently develops OTA solutions for 5G base station and mobile station testing.



Pekka Kyösti received his MS degree in mathematics and his Dr.Tech. degree in telecommunications from the University of Oulu, Oulu, Finland. From 1998 to 2002, he was with Nokia Networks, Espoo, Finland. From 2002 to 2016, he was with Elektrobit, Oulu, and Anite Telecoms Oy, Oulu. Since 2002, he has been involved in radio channel measurements, estimation, and modeling. From 2008 to 2012, he was actively developing methods for MIMO over-the-air testing. He was moved to Keysight Technologies Finland Oy, Oulu, along the acquisition in 2016. He is currently involved in channel modeling for 5G systems with Keysight Technologies Finland Oy and the University of Oulu.