Hindawi
International Journal of Antennas and Propagation
Volume 2020, Article ID 4387494, 3 pages
https://doi.org/10.1155/2020/4387494

Editorial

Advanced Simulation Methods of Antennas and Radio Propagation for 5G and Beyond Communications Systems

Marko Sonkki,[1] **Eva Antonino-Daviu**,[2] **Danping He**,[3] **and Sami Myllymäki**[4]

[1]*Centre for Wireless Communications, University of Oulu, Oulu, Finland*
[2]*Electromagnetic Radiation Group, Universidad Politecnica de Valencia, Valencia, Spain*
[3]*State Key Lab of Rail Traffic and Control Safety, Beijing Jiaotong University, Beijing, China*
[4]*Microelectronics Research Unit, University of Oulu, Oulu, Finland*

Correspondence should be addressed to Marko Sonkki; marko.sonkki@gmail.com

Received 17 February 2020; Accepted 18 February 2020; Published 27 June 2020

Nowadays, high data rates can be provided by optical fibres as defined in the IEEE 802.3ba-2010 standard. The question is how to bring such a data rate over a wireless link between an indoor base station and a mobile device where 1000-fold growth data transfer is expected till 2020 [1] and 5000-fold growth by the year 2030 [2]. The IEEE 802.11.n standard for wireless local area networks (WLANs) can provide data rates up to 600 MBit/s, whereas the IEEE 802.11ac D standard defines data rates up to 7 GBit/s. For future wireless communications systems (5G and beyond), more than 100 GBit/s data rates are desired, giving huge challenges for the systems' design. These kinds of data speeds have been so far demonstrated only in laboratory conditions [3].

Wireless networks beyond 5G (fifth-generation) and 6G (sixth-generation) are expected to provide a performance targeting up to Tbps data rates. It is supporting a large scale of novel usage scenarios and applications with high reliability, almost zero response time, and higher frequencies. Virtual presence, 3D printing, cyber physical systems, intelligent transport, and Industry 4.0 are only a few examples of several possible use cases in order to enhance scalability, flexibility, and efficient resource allocation. These approaches do not tackle the fundamental performance limitations such as the available bandwidth, transmission and processing delay, cost, and energy consumption. To break these barriers in networks beyond 5G, resources, technologies, and research towards new technological concepts, components, architectures, and systems concepts are needed. Hence, innovative joint-investigation, assessment, and design of theoretical models, aligned and supported by experimental parameter evaluation/estimation and validation, are required.

In the future, the access to high-speed Internet is a crucial advantage in the global competition for industry sites and highly qualified human resources. Terahertz (THz) links, as a wireless backhaul extension of the optical fiber [4], are important to guarantee high-speed Internet access everywhere. Moreover, the increasing number of mobile and fixed users in the private, industrial, and service sectors will require hundreds of Gbps communications between cell towers (backhaul) or between cell towers and remote radio heads (fronthaul).

As the application scenarios and requirements are more diverse in the 5G and beyond communications than before, not only the sub-6 GHz spectrum but also higher frequency bands including millimetre wave (mm-Wave) and THz bands are key enablers to satisfy the increasing data rate demands. Therefore, tremendous funding has been and will be investigating in this area. Researchers are active in sharing their knowledge to push the related technologies forward.

Accurate channel characterization and modelling are fundamental to evaluate the designed technologies and system performance. The evaluation of multiple-input multiple-output (MIMO) technology, various mobilities, propagation environments, and frequency bands are making this work more and more challenging [5]. The researchers are making efforts on both deterministic and stochastic channel models that support spatial consistency, dual mobility, and various propagation mechanisms. Ray tracing-(RT-) based deterministic modelling approach has demonstrated the advantage in predicting time-varying channel and MIMO channel for various frequency bands. The computational complexity and the utility of RT have been optimized by many efforts [6]. Stochastic models such as 3GPP-based QuaDRiGa (QUAsi Deterministic RadIo channel GenerAtor) model and COST2100 model support time-varying simulation like MIMO simulation as well. They are useful in non-site-specific statistical evaluation.

On the contrary, new 2D materials [7] and artificial materials [8] on mm-Wave and sub-THz wave together with new packaging and fabrication methods, components, and structures are becoming most commonly used on-chip packaged antenna arrays perspective. In addition, beyond small antenna arrays, there are massive matrix structures such as plasmonic antenna arrays [9] utilizing millions elements enabling together with 2D materials and artificial materials opening available new kind of THz electronic packaging alternatives.

Moreover, new advanced antenna systems, such as very large antenna arrays, will be required to overcome the very high path loss over the radio channel. The antennas in an mm-Wave and THz band need to support a very large bandwidth from several GHz up to a few THz [9], for example, sub-THz band communication systems at 300. GHz can provide a relative bandwidth of 10% at the centre frequency, i.e., in the order of 30 GHz.

The very large bandwidth opens the door to a variety of applications, which demand ultrahigh data rates, and allows the development of novel applications in classical networking scenarios as well as in new nanoscale communication approach. Some of these applications can already be foreseen, and others will undoubtedly emerge as technology progresses [10].

As the next generation wireless communication devices rely on MIMO technology to provide enhanced data rates, the antenna design becomes even more challenging task in any communication scenario. The theory of characteristic modes (TCM) provides some insight into the design and analysis of complex antenna systems. Characteristic modes are a set of orthogonal real modes that can be computed numerically for open electromagnetic problems. Since they are obtained in the absence of excitation, the radiating potential of any structure can be evaluated prior to the selection of excitation method. TCM is also finding its way into the design of antennas for a variety of modern applications, such as RFID, cognitive radio, UWB systems, full-duplex communications, Internet of Things (IoT), but also to a massive-MIMO antenna design by allowing to excite different modes in a single element, and, thus, decreasing the size of an array with a sophisticated feed network [11].

This special issue collects eight papers concerning various aspects of 5G and beyond system approaches. Two papers deal with radio channel measurement and modelling and two channel characterization by using ray tracing, while three papers are concerned with antennas and one with OTA (over-the-air) test measurements by combining radio channel and antenna topics together under the system level.

One paper dealing with OTA measurements for the 5G systems written by Xin et al. proposes OTA test setup for mm-Wave massive MIMO equipment using the cascaded amplitude and phase modulation (APM) network and channel emulator. Compared with the existing test setup with mechanical switch, the test setup enables more accurate reconstruction of the radio channel environment under the multiprobe anechoic chamber (MPAC) setup without increasing the number of channel emulators (CEs) allowing a lower cost test system. The constructed MPAC testing setup for mm-Wave and massive MIMO equipment is composed of an anechoic chamber, a sectored probe wall containing a number of probes, an APM network, a fading channel emulator, and a user emulator (UE), and the simulation results are compared with the test setup.

Two papers are focusing on RT at mm-Waves, where the first one is written by Xiong et al. The paper studies wireless channel characteristics of the three-dimensional (3D) model of high-speed railway station (HSR) at the 37.0–42.5 GHz band. Key parameters such as path-loss exponent, shadow fading factor, delay spread, Rician K-factor, angular spread, power angle spectrum, and spatial correlation are extracted and investigated. These channel characteristics are proposed for the selection of antenna arrays and the design of future 5G communication networks in the railway environment.

The other ray tracing paper written by Wang et al. discusses the characteristics of vehicle-to-infrastructure (V2I) channels simulated and extracted for the urban environment in Seoul. Simulations at the 23 GHz band with 1 GHz bandwidth in a realistic V2I urban environment are performed by a calibrated RT simulator to complement these missing characteristics, e.g., directionality and blockage. The path loss, shadow factor, Rician K-factor, root-mean-square (RMS) delay spread, and angular spreads are characterized from the calibrated RT simulation results, which gives a better understanding of the propagation channel for designing vehicular radio technologies and a communication system in a similar environment. The extracted parameters can be input to the channel generator, like QuaDRiGa or Metis, to generate similar channels, which can be used to evaluate or verify the performance of the system- or link-level design.

Two papers are related to channel measurements and characterization. The first paper, written by Zhu et al., develops a general 3D nonstationary vehicle-to-vehicle (V2V) channel model, which is based on the traditional geometry-based stochastic models (GBSMs) and the twin-cluster approach. In contrast to the traditional models, the new model is characterized by 3D scattering environments, 3D antenna arrays, and 3D arbitrary trajectories of both terminals and scatterers with provided channel parameters. The statistical properties, i.e., spatial-temporal correlation function (STCF) and Doppler power spectrum density (DPSD) are delivered a well. Simulation results demonstrated that the proposed model agrees with the theoretical and measured results, which verifies the theoretical derivations and channel model.

The other channel measurement paper is written by Zhong et al. where measurements are performed on the outdoor-to-indoor (O2I) propagation channels at 3.5, 4.9, and 28 GHz simultaneously by using a multiband channel sounder. The captured path loss distribution and angular power arrival profiles were presented with measured penetration loss at 28 GHz through different kinds of glass windows. The glass windows presented in the paper introduced the penetration loss of 3 to 12 dB which was considered acceptable for mm-Wave O2I coverage. The low-emissivity (low-E) windows, assumed to be used more in the future, introduced 10 dB additional loss compared to glass window. The measurement results will help to analyse the O2I coverage at mm-Waves, which is important when designing and developing the future 5G network.

Finally, three antenna papers are focusing on 5G systems, which two are for mm-Wave and one for 6 GHz by exciting multiple modes. The first mm-Wave paper is written by Jian et al., and it is focusing on wideband circularly polarized (CP) microstrip antenna consisting a central patch and a microstrip line radiator. The CP radiation is achieved by loading a rectangular slot on the ground plane. To improve the 3 dB axial ratio bandwidth (ARBW), two symmetric parasitic rectangular patches, paralleled to a central patch and a slit, are positioned to load the central patch. The measured impedance bandwidth for of the proposed antenna is from 22.8 to 33.8 GHz, and the simulation result shows that the 3 dB ARBW is from 28.77 to 33.5 GHz within the impedance bandwidth. The peak gain of the antenna is approximately 5 dBic within 3 dB ARBW.

Another mm-Wave antenna written by Alves et al. presents a concept and development of two mechanically frequency-tunable horn filtennas (filter antenna). The design relies on the integration of a horn antenna with a mechanically tunable filter based on dual-post resonators. The proposed filtennas were manufactured and experimentally characterized. Measurements show that both filtennas have a tuning ratio approximately 1.37 with continuous adjustment. The first prototype operates from 2.56 to 3.50 GHz, whereas the second one has the bandwidth from 17.4 to 24.0 GHz. In addition, the higher frequency filtenna has been implemented in a 5.0-meter reach indoor environment, using a 16-QAM signal at 24 GHz. The configuration results, in terms of a root-mean-square error vector magnitude (EVMRMS) and antenna radiation efficiency, are 3.69% and 97.0%, respectively.

The third antenna paper written by Chen et al. presents a wideband differential-fed multimode microstrip patch antenna at 4.75–6.75 GHz band. Two symmetrical rectangular slots are cut on the radiating patch where the zero-current position of the TM30 mode excites another resonant slot mode. In addition, the slot length is enlarged to decrease the frequency of the slot mode with little effect on the TM30 mode. To further expand the impedance bandwidth, the width of the patch is reduced to increase the frequency of the TM12 mode, while having little influence on the TM30 and the slot modes. Additionally, a pair of small rectangular strips is adopted on the top of the feeding probes to achieve good impedance matching. Based on the arrangements, a broadband microstrip patch antenna with three in-band minima could be realized. The results show that the −10 dB impedance bandwidth of the antenna is extended to 35.8% with a stable radiation pattern.

Conflicts of Interest

The editors declare that they have no conflicts of interest regarding the publication of this special issue.

Acknowledgments

The guest editorial team would like to thank all the authors for their interest of selecting this special issue to publish their research results.

Marko Sonkki
Eva Antonino-Daviu
Danping He
Sami Myllymäki

References

[1] A. Osseiran, V. Braun, T. Hidekazu et al., "The foundation of the mobile and wireless communications system for 2020 and beyond: challenges, enablers and technology solutions," in *Proceedings of the IEEE 77th Vehicular Technology Conference (VTC Spring)*, pp. 1–5, Dresden, Germany, June 2013.

[2] European Project ICT-317669-METIS, "Deliverable D 8.4 METIS final project report," 2015, https://www.metis2020.com/documents/deliverables/.

[3] J. Vieira, K. Nieman, Z. Miers et al., "A flexible 100-antenna testbed for massive MIMO," in *Proceedings of the IEEE International Workshop Massive MIMO: Theory Practice*, pp. 287–293, Austin, TX, USA, December 2014.

[4] S.-H. Yang, M. R. Hashemi, C. W. Berry, and M. Jarrahi, "7.5% optical-to-terahertz conversion efficiency offered by photoconductive emitters with three-dimensional plasmonic contact electrodes," *IEEE Transactions on Terahertz Science and Technology*, vol. 4, no. 5, pp. 575–581, 2014.

[5] C.-X. Wang, J. Bian, J. Sun, W. Zhang, and M. Zhang, "A survey of 5G Channel measurements and models," *IEEE Communications Surveys & Tutorials*, vol. 20, no. 4, pp. 3142–3168, 2018.

[6] D. He, B. Ai, K. Guan, L. Wang, Z. Zhong, and T. Kürner, "The design and applications of high-performance ray-tracing simulation platform for 5G and beyond wireless communications: a tutorial," *IEEE Communications Surveys & Tutorials*, vol. 21, no. 1, pp. 10–27, 2019.

[7] E. Dadrasnia, H. Lamela, M. B. Kuppam, F. Garet, and J.-L. Coutaz, "Determination of the DC electrical conductivity of multiwalled carbon nanotube films and graphene layers from noncontact time-domain terahertz measurements," *Advances in Condensed Matter Physics*, vol. 2014, Article ID 370619, 6 pages, 2014.

[8] D. Ramaccia, A. Epstein, M. Barbuto, and S. Rudolph, "Metamaterials, metasurfaces, and artificial dielectrics: theory and applications to the next-generation telecommunication platforms," *International Journal of Antennas and Propagation*, vol. 2017, Article ID 4312542, 2 pages, 2017.

[9] I. F. Akyildiz and J. M. Jornet, "Realizing ultra-massive mimo (1024 × 1024) communication in the (0.06–10) terahertz band," *Nano Communication Networks*, vol. 8, pp. 46–54, 2016.

[10] I. F. Akyildiz, J. M. Jornet, and C. Han, "Terahertz band: next frontier for wireless communications," *Physical Communication*, vol. 12, pp. 16–32, 2014.

[11] D. Manteuffel and R. Martens, "Compact multimode multi-element antenna for indoor UWB massive MIMO," *IEEE Transactions on Antennas and Propagation*, vol. 64, no. 7, pp. 2689–2697, 2016.