URSI AP-RASC 2019, New Delhi, India, 09 - 15 March 2019

Overview of Radio Propagation Models for 5G and beyond

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The demand for mobile connectivity is continuously increasing, and by 2020, mobile and wireless communications will serve not only very dense populations of mobile phones and nomadic computers, but also the expected multiplicity of devices and sensors located in machines, vehicles, health systems and city infrastructures. The fifth (and beyond) generation of radio communication networks (5G, 5G+) are expected to implement technologies for supporting wireless connectivity for any rates, type of communicating units, and scenario. Whereas spectral and spatial efficiency are key challenges, in addition to constraints such as energy consumption, latency, mobility, adaptability, heterogeneity, coverage and reliability, the multi-dimensional radio channel remains central in such contexts. Multiple antenna systems (MIMO), interference recognition and management as well as cooperation among separate network nodes are inherently multi-dimensional techniques and should always be designed with a proper knowledge not only of the channel, but also of the interference. In addition, the use of higher frequency ranges (cm- and mm-waves) is investigated to address the spectrum shortage. Finally, new environments are emerging with the application of the wireless Internet of Things (IoT) in several areas.

This communication aims to provide an overview of the latest trends in radio propagation, in particular in the context of upcoming 5G communication networks. Going from recent radio channel measurements to current modeling techniques, the communication will include an overview of channel modeling activity within COST CA15104 (IRACON) action. Recent results in peer-to-peer, multi-link, vehicular and millimeter wave propagation will be described. Future research topics will eventually be briefly outlined.

With regard to cellular communications**,** advanced models, such as WINNER and the COST family of models [1-2] have recently been extended by the QuaDRiGa project [3] as well as the current IRACON action: the main extensions brought by these recent models deal with spatial consistency as well as massive MIMO aspects.

So far, experimental and ray-tracing results have pointed out that the mm-wave channel is typically characterized by a very limited number of strong specular reflections [4]. The issue is therefore not as much a path-loss or fading problem (as classically studied below 6 GHz), but more the space-time dynamics of these sparse multipaths, which is critical in terms of beamforming and beam tracking. The impact of human shadowing is also critical and often neglected by mm-wave models.

As far as mobile-to-mobile scenarios are concerned, results for peer-to-peer indoor communication channels [5] have shown that flexible fading distributions can be used to represent time-varying statistics as the indoor nodes move even over short distances. Further results will deal with car-to-car and car-to-pedestrian scenarios.

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2. L. Liu et al., "The COST 2100 MIMO channel model," *IEEE Wireless Comm. Mag.*, **19**, 6, pp. 92-99, December 2012.

3. S. Jaeckel, L. Raschkowski, K. Börner and L. Thiele, "QuaDRiGa: A 3-D multicell channel model with time evolution for enabling virtual field trials," *IEEE Trans. Antennas Propagat.*, **62**, 6, pp. 3242-3256, June 2014.

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5. E. Vinogradov, , *et al.*, "*Physical-statistical modeling of dynamic indoor power delay profiles*," *IEEE Trans. Wireless Commun.*, 16 (10), pp. 6493-6502, October 2017.