Chapter 1
Radio Channel Modeling and Propagation Prediction for 5G Mobile Communication Systems

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ABSTRACT

5G mobile communication networks are emerging in order to cover the extreme needs for high data rates for delivering multimedia data to mobile communication users. The required bandwidth may be found if millimeter wave bands are fully employed for the establishment of such cellular systems. In this Book Chapter the propagation issues for 5G mobile communication systems are rigorously analyzed and presented. Firstly, the most popular scenarios and architectures of the next generation mobile systems are described and the channel models utilized for the evaluation of physical layer techniques (air interface are given. Secondly, the channel effects are described, i.e. effects due to local environment of the transceivers, atmospheric effects and their combination and the state of the art on the modeling of these effects is analytically presented. Finally, future directions for the propagation and channel model prediction for the next generation mobile communication systems -5G millimeter wave cellular systems are analyzed. Open issues and technical challenges of millimeter wave (mmWave) 5G cellular systems are finally described.

INTRODUCTION

The great success of the mobile data and multimedia communication services lead the advancement from 3G to 4G mobile communication systems, in order to increase the data rate to end users. However, the increase of traffic in the mobile communications network due to the need of access to data communications anywhere and anytime and the growth of demand of high data rates drove the research to the development and design of next generation mobile communication systems.

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The fifth generation (5G) mobile communication systems have already been under research through European Commission projects and various national projects in Korea, U.S.A and other countries. A number of European projects, such as 5GNOW, MiWEBA, MiWaveS, and METIS, have been recently issued for the development of the future generation of mobile communications. Furthermore, many IEEE magazines and Journals have dedicated issues on the 5G paradigm, e.g. Thomson et al. (2014), Ghosh et al. (2014), showing that there is a number of challenges in all the layers of the network.

The 5G technology, will not only give higher data rates to mobile handhelds, but also will try to incorporate devices with no human intervention and enable the so-called Machine-to-Machine Communications, making a further step to the Internet of Things (Boccardi et al., 2014). More particularly, for the latter issue of M2M communications, as this is explained in (Boccardi et al., 2014), there are at least three key requirements: a) massive number of connected devices, b) very high link reliability, c) low latency and real-time operation. Therefore, 5G will have to address the various data rates for the communication. One of the most significant issues of the operation of 5G mobile communication systems is the spectrum which will be used for the links. Although, cognitive radio techniques can be proven useful tools in order to exploit effectively the used of below 3GHz bands. There is a large amount of spectrum available at mmWave spectrum. Therefore potential bands for 5G spectrum are: the 28 GHz band (27.5-29.5 GHz), the 38 GHz band (36-40 GHz), the 60 GHz band (57-64 GHz), the E-band (71-76 GHz and 81-86 GHz) and finally, the W band (92-95 GHz), as proposed in Ghosh et al. (2014).

The first research studies and results for 5G cellular networks are in Xu et al. (2000), Rappaport et al. (2013a), and Rappaport et al. (2013b) and have shown that wireless communication systems at frequency bands above 30 GHz will be able to give the appropriate bandwidth for the realization of the new generation of mobile systems. More particularly, for an outdoor scenario and for access or fronthaul links, a frequency between 28 and 40 GHz will be the best candidate for operation of the systems, while for an indoor scenario (small cell or "femto-cell"), the 60 GHz band is usually considered. The 60 GHz band can be also utilized for short-range outdoor hot-spots (up to 50 m). Finally, for the backhaul of the link, the most probable frequency bands to be used are these above 70 GHz.

A great difference between the conventional frequency bands, i.e. less than 3 GHz operating frequency, with the mmWave bands is the propagation of the signals. Signals transmitted in frequency bands less than 10 GHz do not experience any significant impact from the atmosphere in comparison to the mmWave bands. Therefore, in 5G systems, the atmospheric environment shall be taken into account and must be combined with the effects of local environment of the transceivers. The effects of the atmosphere can be summarized in the attenuation due to precipitation, atmospheric gases, such as oxygen attenuation and water vapor, and the scintillation of signal amplitude due to turbulence. In the local environment effects the multipath propagation is included, as well as the shadowing effects and the large scale effects, such as the free space loss. Furthermore, even the losses due to the local environment cannot be considered the same with the conventional bands. Moreover, the foliage attenuation and the building penetration losses for an outdoor-to-indoor scenario are also different with comparison to these of the sub-3 GHz bands. Therefore, the propagation channel effects must be modeled via a thorough theoretical analysis and experimentation.

In this Book Chapter, firstly, we analyze the possible scenarios for 5G networks. Secondly, a state of the art and a thorough research on the literature for models aiming to capture the channel effects on 5G mobile communication systems and mmWave bands will be given. Although, the state of the art on channel models for 5G communica-

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