University of Victoria | Graduate Studies

Notice of the Final Oral Examination for the Degree of Doctor of Philosophy

of

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"Antenna Designs and Channel Modeling for Terahertz Wireless Communications"

Department of Electrical and Computer Engineering

Friday, October 21, 2016
9:00 A.M.
Engineering and Computer Science Building
Room 468

Supervisory Committee:
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Dr. Jens Bornemann, Department of Electrical and Computer Engineering, UVic (Co-Supervisor)
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Dr. David Capson, Dean, Faculty of Graduate Studies

Abstract

In this dissertation, channel modeling for Terahertz (THz) channels and designs of nano devices for THz communications are studied. THz communication becomes more and more important for future wireless communication systems that require an ultra high data rate, which motivates us to propose new nano device designs based on graphene and new system models for the THz channel. Besides, the multiple-input multiple-output (MIMO) antenna technique is well known to increase the spectral efficiency of a wireless communications system. Considering THz channels' particular characteristics, MIMO systems with reconfigurable antennas and distributed antennas are proposed. We compare the differences between MIMO systems in the GHz and THz bands, and highlight the benefits of using multiantennas in the THz band.

The work on nano device designs provides two antenna designs with single walled carbon nanotubes (SWCNTs) and graphene nano ribbon (GNR). First, we analyse the spectral efficiency of an SWCNT bundled dipole antenna based MIMO system in the Terahertz band. Two scenarios are considered: the large scale MIMO and the conventional scale MIMO. It is found that, in order to get the maximum spectral efficiency, the CNT bundle size should be optimized to obtain a tradeoff between the antenna efficiency and the number of antennas for a given area. We also discuss the random fluctuation in the bundle size during the CNT bundled antenna fabrication which reduces the system spectral efficiency. Then, we propose reconfigurable directional antennas for THz communications. The beamwidth and direction can be controlled by the states of each graphene patch in the antenna, and the states can be easily configured by changing the electrostatic bias voltage on each element.

The work on reconfigurable MIMO system proposes a new antenna array design for MIMO in the THz band. First, the path loss and reflection models of the THz channel are discussed. Then, we combine the graphene-based antenna and the THz channel model and propose a new MIMO antenna design. The radiation directions of the transmit antennas can be programmed dynamically, leading to different channel state matrices. Finally, the path loss and the channel capacity are numerically calculated

and compared with those of the GHz channel. The results show that for short range communications, the proposed MIMO antenna design can enlarge the channel capacity by both increasing the number of antennas and choosing the best channel state matrices.

The work on MIMO channels proposes a statistical model for the MIMO channel with rough reflection surfaces in the THz Band. First, our analysis of scattering from a rough surface indicates that the reflection from a single surface can be a cluster of rays. Secondly, a new MIMO model for THz communications is proposed. In this model, the number of multipaths is highly dependent on the roughness of the reflecting surfaces. When the surface is ideally smooth, the MIMO channel is sparse and as a result, the capacity is sub-linear with the MIMO scale. On the other hand, when the surface is rough, more degrees of freedom are provided by the scattered rays. Finally, channel capacities with different surface roughness are numerically calculated and compared between different MIMO scales. The results show that in contrast to the GHz range, large scale THz multiple antennas may not provide as much multiplexing gain. Therefore, it is necessary to determine the antenna scale according to the actual propagation environment.

The work on distributed antenna systems (DAS) proposes a new DAS model in the THz band. First, the model of DAS in the THz frequency is discussed, which has fewer multipaths than that in the GHz band. Then, we analyze the characteristics of the DAS model and point out that the channel is very sparse if the number of antennas on the base station (BS) is very large. Besides, we provide reasons for the fact that DAS can have a large number of degrees of freedom. We compare the capacities of MIMO systems with DAS and without DAS. The results show that for THz channels, increasing the number of antenna units (AUs) is much more important than increasing the number of antennas in one AU. Finally, we propose an antenna selection and precoding scheme which has very low complexity.