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Wireless Off-body Channel Analysis and Sparse Modeling

Pengfei Cui

School of Communication and Computation
Faculty of Engineering & IT
University of Technology Sydney
NSW - 2007, Australia

University of Technology Sydney

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CERTIFICATE OF ORIGINAL AUTHORSHIP

I, *Pengfei Cui* declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the *School of Communication and Computation*, *Faculty of Engineering & IT* at the University of Technology Sydney.

This is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution. I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of the requirements for a degree at any other academic institution except as fully acknowledged within the text. This thesis is the result of a Collaborative Doctoral Research Degree program with Nanjing University of Posts and Telecommunications.

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Publications

The following papers have been written based on the materials presented in this thesis.

Journal Papers :

1. **Peng-fei Cui**, J. Andrew Zhang, Wen-Jun Lu, Y. Jay Guo, and HongBo Zhu. Statistical sparse channel modeling for measured and simulated wireless temporal channels. *IEEE Transactions on Wireless Communications*, Sep. 2019.

2. **Peng-fei Cui**, Yu Yu, Wen-Jun Lu, Yang Liu, and Hong-Bo Zhu. Measurement and modeling of wireless off-body propagation characteristics under hospital environment at 6-8.5 GHz. *IEEE Access*, 5:10915–10923, 2017.

3. **Peng-fei Cui**, Wen-Jun Lu, Yu Yu, B. Xue, and Hong-Bo Zhu. Off-body spatial diversity reception using circular and linear polarization: measurement and modeling. *IEEE Communications Letters*, 22(1):209–212, Jan. 2018.

4. Yu Yu, **Peng-fei Cui**, Wen-Jun Lu, Yang Liu, and HongBo Zhu. Off-body radio channel impulse response model under hospital environment: measurement and modeling. *IEEE Communications Letters*, 20(11):2332–2335, Nov. 2016.

5. Jun She, Wen-Jun Lu, Yang Liu, **Peng-fei Cui**, and HongBo Zhu. An experimental massive mimo channel matrix model for hand-held scenarios. *IEEE Access*, 7:33881–33887, 2019.

Conference Papers :

1. **Peng-fei Cui**, J. Andrew Zhang, Wen-jun Lu, Y. Jay Guo, and Hong-bo Zhu. Influence of human body on massive MIMO indoor channels. In *2019 IEEE 89th Vehicular Technology Conference (VTC2019-Spring)*, pages 1–6, June 2018.

2. **Peng-fei Cui**, J. Andrew Zhang, Wen-jun Lu, Y. Jay Guo, and Hong-bo Zhu. Sparse channel modeling using multi-measurement vector compressive sensing. In *2018 IEEE Global Communications Conference (GLOBECOM)*, pages 1–6, Dec 2018.

3. **Peng-fei Cui**, Yu Yu, Yang Liu, Wen-jun Lu, and Hong-bo Zhu. Body obstruction characteristics for off-body channel under hospital environment at 6-8.5 ghz. In *2016 IEEE International Conference on Ubiquitous Wireless Broadband (ICUWB)*, pages 1–4, Oct 2016.

4. **Peng-fei Cui**, Yu Yu, Yang Liu, Wen-jun Lu, and Hong-bo Zhu. Joint rls and lms adaptive equalization for indoor wireless communications under staircase environments. In *2015 International Conference on Wireless Communications Signal Processing (WCSP)*, pages 1–5, Oct 2015.

5. Yu Yu, **Peng-fei Cui**, Jun She, Yang Liu, Xi Yang, Wen-Jun Lu, Shi Jin, and Hong-Bo Zhu. Measurement and empirical modeling of massive MIMO channel matrix in real indoor environment. In *2016 8th International Conference on Wireless Communications Signal Processing (WCSP)*, pages 1–5, Oct 2016.

6. Jun She, Chen Gao, Yu Yu, **Peng-fei Cui**, Wen-jun Lu, Shi Jin, and Hong-bo Zhu. Measurements of massive MIMO channel in real environment with 8-antenna handset. In *2017 9th International Conference on Wireless Communications and Signal Processing (WCSP)*, pages 1–4, Oct 2017.

Contents

List of Figures

List of Tables

Abstract

The successful application of very rapidly growing wearable devices relies on the research on the propagation characteristics of off-body channels which plays a key role in connecting the wireless body area network and cellular network, WiFi and other local area networks. This thesis concentrates on the bottleneck problems of the measurement, analysis and modeling of the off-body propagation characteristics. A large number of measurement investigations have been carried out to solve the thorny problem of complicated and changeable scenes of off-body channel and heavy fading caused by adjacent humans. These activities include different transmission schemes, different influence factors, and typical changeable configurations. Then, in this study, the systematic analysis of the measured big channel datasets are conducted based on traditional large/small scale propagation analysis methods and compressive sensing based sparse channel analysis methods.

The first part of the thesis discusses the measurement and analysis of typical off-body channel types including single input single output (SISO), diversity reception and multiple input multiple output (MIMO). A two-factor integrated path loss model with variable body worn locations and variable access point (AP) height is proposed to improve the power management and link budgeting ability in off-body scenarios. A highly robust circularly polarized spatial diversity off-body scheme is made up and validated to tackle the heavy fading problem. In addition, the influences of humans including both hand-held effect and body obstruction effect on off-body transmission angular spectrum and capacity are estimated.

In the second part of the thesis, the novel compressive sensing based sparse channel analysis methods are proposed to deal with the modeling problems of off-body temporal channels with complex multipath components. The channel impulse response (CIR) models of SISO and MIMO channels based on single measurement vector (SMV) and multi-measurement vector (MMV-CS) compressive sensing methods respectively are established.

Finally, according to the off-body link types, the propagation characteristics, sparse analysis and modeling methods are integrated into several channel simulators with friendly GUI interface, whose source codes are shared on gitHub. Those models and simulators are expected to be used in theoretical analysis and engineering practice for the coverage planning, link simulation, algorithm design, and performance validation.