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mmWave Massive MIMO Vehicular Communications

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Preface

The automobile industry is currently shifting from “driving by humans” to “driving by intelligence.” Such a transformative evolution is primarily propelled by fast-increasing onboard sensors, with which the vehicles are gaining unprecedented degrees of intelligence. Numerous sensors will inevitably bring in massive sensory data, making reliable and swift information transfer an urgent and crucial issue. Existing wireless solutions include DSRC and LTE-V2X, both permitting low-volume message delivery. However, due to the limited bandwidth, they are still far from meeting the Gbps-level data rate regulated by the automobile industry. The current limitation inevitably motivated the exploration of the mmWave band, where vast spectrum resources are available for high-speed information transfer. Besides the bandwidth merit, mmWave’s inherent short wavelength allows a natural combination with massive MIMO for higher diversity and multiplexing gain. In theory, alternating the operating frequency does not need to change the wireless regime, but the fact is that many implementing concerns, such as power consumption and hardware expenditure, prohibit mmWave systems from inheriting classic fully-digital transceivers. Instead, an economical yet restricted structure, namely the hybrid beamformer, comes into practical use. In conjunction with the higher signal dimensions and complicated channel environments, the compromised hardware architecture requires a paradigm-shifting design to underpin mmWave communication. Against this background, this book will showcase a comprehensive picture regarding advanced mmWave massive MIMO techniques, hoping to provide promising physical-layer solutions to vehicular communications in the 5G and Beyond era.

The book is organized as follows. Chapter 1 overviews vehicular communications and elaborates the necessity of mmWave technologies. Chapter 2 introduces state-of-the-art mmWave channel modeling, with space-time-frequency and non-stationary features taken into account. Based on the insights from channel modeling, Chap. 3 presents an efficient channel estimator dedicated to mmWave transceivers with hybrid structures, which is capable of combating doubly selective massive MIMO mmWave channels. The obtained channel state information opens the door to a generic mmWave multi-user transceiver design, with the detailed strategies presented in Chap. 4. Driven by the pursuit of lower error rate and higher energy efficiency, Chaps. 5 and 6 explore the potential use of index modulation in hybrid mmWave systems. Although both chapters will deal with the doubly selective channels, Chap. 5 focuses on the uplink multi-user access, whereas Chap. 6 spotlights on downlink multi-user transmission. Despite our best effort, the above content covers just a tip of the iceberg of mmWave vehicular communication. Thus, some open problems and promising directions will be discussed at the end of each chapter for future studies.

This book is mainly oriented to researchers, graduated students, and professors relevant to this field. Nevertheless, it also serves as a great introduction to state-of-the-art mmWave vehicular communications for those outside this field but aspire to pursue new interdisciplinary directions.

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Contents

Acronyms

3GPP	The 3rd Generation Partnership Project
ADC	Analog-to-Digital Converter
APEP	Average Pairwise Error Probability
APS	Analog Phase Shifter
BER	Bit Error Rate
BS	Base Station
CDL	Clustered Delay Line
CP	Cyclic Prefix
CS	Compressed Sensing
D2D	Device-to-Device
DAC	Digital-to-Analog Converter
DSRC	Dedicated Short-Range Communications
FFT	Fast Fourier Transform
GMD	Geometric Mean Decomposition
GPS	Global Positioning System
IFFT	Inverse Fast Fourier Transform
IM	Index Modulation
ITS	Intelligent Transportation System
IV	Internet of Vehicles
LTE	Long-Term Evolution
MIMO	Multiple-Input Multiple-Output
MS	Mobile Station
NMSE	Normalized Mean Square Error
NR	New Radio
OFDM	Orthogonal Frequency Division Multiplexing
OMP	Orthogonal Matching Pursuit
PSD	Power Spectrum Density
QoS	Quality of Service
RF	Radio Frequency
RSU	Roadside Unit
SM	Spatial Modulation

SNR	Signal-to-Noise Ratio
SVD	Singular Value Decomposition
TDL	Tapped Delayed Line
UE	User Equipment
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
VANET	Vehicular Ad hoc Network
VCN	Vehicular Communication Network