

# Lecture Notes in Electrical Engineering

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Wynand Lambrechts · Saurabh Sinha

# Millimeter-wave Integrated Technologies in the Era of the Fourth Industrial Revolution

Wynand Lambrechts  
University of Johannesburg  
Johannesburg, Gauteng, South Africa

Saurabh Sinha  
University of Johannesburg  
Johannesburg, Gauteng, South Africa

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# Preface

The Fourth Industrial Revolution (Industry 4.0) will take advantage of ubiquitous connectivity to grow economies. There is a vast difference between the telecommunications infrastructure of developed countries and that of emerging markets; emerging markets often lack broadband Internet infrastructure. A sustainable solution is required to bridge the digital divide and enable emerging markets to participate in Industry 4.0. Such a solution, however, has numerous facets and requires introducing technology that is sustainable and future-proof and ensures scalable, feasible, and affordable access. Unfortunately, globally, the cost of accessing broadband Internet in unequal markets remains high, with current solutions reaching their thresholds in terms of available bandwidth on the mass consumer level.

Spectrum demand and allocation in emerging markets often lag behind what is happening in developed countries and expensive to (unfairly) maximize profit for local regulators and frequently for local governments as well. Arguments typically refer to the limited amount of available spectrum, which is true of current-generation networks. However, millimeter-wave (mm-Wave) frequencies (30—300 GHz) offer unprecedented amounts of bandwidth for wireless broadband connectivity. Built on the premise of mm-wave connectivity is the fifth-generation (5G) networks, a clear contender to spearhead connectivity for Industry 4.0, also in emerging markets.

This book focuses on researching the capabilities of mm-wave-based 5G networks, specifically for emerging markets. The technology is researched from several perspectives, including technological advantages and disadvantages, as well as its unique characteristics to offer scalable and affordable connectivity to grow emerging economies. In the current information age, bringing connectivity to as many people as possible (ideally everyone) boosts socioeconomic benefits through innovation in science and technology, with the common goal of bringing about positive change in the lives of individuals. The importance of connectivity has recently been further emphasized with the global pandemic, COVID-19, forcing millions of people to adopt an online approach to conduct business and communicate with one another.

The research presented in this book is structured to investigate not only the economic benefits of mm-wave and 5G. It also gives a strong theoretical background on the underlying technologies required to realize transmitters and receivers that are capable of operating at extremely high frequencies. The technical contribution of this book is in its presentation of electronic subsystem analysis and review of high-frequency active circuits that are capable of operating at mm-wave frequencies. These subsystems include frequency mixers, oscillators, low-noise amplifiers, and power amplifiers. To implement feasible future-generation technologies and ensure future-proof infrastructure that is easily expandable, it is of the utmost importance to understand the principles that influence the integrity of transmitted information. This book researches the importance of identifying, describing, and analyzing technology from a purely technological standpoint, but equally so, acknowledges and investigates the challenges in introducing such technologies into emerging markets.

A detailed investigation of techniques to introduce mm-wave 5G networks to emerging markets is presented in the latter part of this book. As the digital service sector evolves, certain key characteristics remain universal, such as adequate digital infrastructure, technology-literate end users, innovative skilled entrepreneurs, and business environments that encourage creative thinking. A core characteristic and major advantage of 5G are its potentially dynamic pricing and low dependence on the infrastructure of previous-generation wireless networks. This book aims to investigate these features thoroughly and provide potential solutions to introduce 5G, possibly in a staggered approach, to emerging markets. In emerging markets, the complexity and challenges of distributing critical products and services in significantly unequal markets are much higher. Governments have been forced to innovate policies and strategies to achieve the successful distribution of products and services to poor households and rural areas. 5G is a future-proof and sustainable technology with numerous advantages not associated with previous-generation mobile technologies that offer governments and local entrepreneurs a means to innovate modern policies and strategies to bridge the digital divide.

The primary audience of this book is learners in the fields of engineering and information technology who want to identify and act upon ways of advancing connectivity in emerging markets and rural areas by bringing high-bandwidth, low-latency mobile connectivity to individuals through future-proof technologies. The audience is presented with an introduction to the role of mm-wave and 5G in Industry 4.0, followed by a theoretical background on mm-wave circuit design, and finally, an in-depth investigation into potential solutions to prepare emerging markets to participate in Industry 4.0 through mm-wave broadband connectivity.

## **Acknowledging the Technical Peer-Review Process**

The authors would like to recognize the support of the numerous technical reviewers, as well as language and graphics editors, who have participated in the development of this research contribution. We value the system of scholarly peer review and the perspective that this adds to the production of research text that augments the body of scientific knowledge.

Johannesburg, South Africa

Wynand Lambrechts  
Saurabh Sinha

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## About the Authors

**Dr. Wynand Lambrechts**, SMIEEE, obtained his B.Eng., M.Eng., and Ph.D. degrees in electronic engineering from the University of Pretoria (UP), South Africa. He achieved his M.Eng. with distinction. He has authored two publications in peer-reviewed journals and has presented at various local and international conferences. Wynand is the lead author on four books; in the fields on sustainable energy and in microelectronic engineering, published by international publishers. He has co-authored four contributing chapters in other books in the fields of green energy and technology and the Fourth Industrial Revolution. He previously held a position as an electronic engineer at Denel Dynamics, a state-owned company in South Africa. He is currently employed by SAAB Grintek Defence (SGD) and is also serving as a part-time research associate at the University of Johannesburg (UJ), South Africa.

**Prof. Saurabh Sinha**, Ph.D.(Eng), Pr. Eng., SMIEEE, FSAIEE, FSAAE, MASSAf. Prof. Sinha obtained his B. Eng. (with distinction), M. Eng. (with distinction), and Ph.D. degrees in electronic engineering from the University of Pretoria (UP). As an established researcher, rated by the National Research Foundation (NRF), he has authored or co-authored over 130 publications in peer-reviewed journals and at international conferences. He served UP for over a decade; his last service being as the director of the Carl and Emily Fuchs Institute for Microelectronics, Department of Electrical, Electronic and Computer Engineering. On October 1, 2013, he was appointed as an executive dean of the Faculty of Engineering and the Built Environment (FEBE) at the University of Johannesburg (UJ). As of December 1, 2017, he is the UJ deputy vice-chancellor: Research and Internationalization. Among other leading roles, he also served the IEEE as a board of director and IEEE vice-president: Educational Activities.