

Preface

Today's electronic communication possibilities and applications are endless. However, only 150 years ago, the concept of the telephone was unknown. The history of electronic communication begins in the nineteenth century with the telegraph, and a couple of years later, the telephone. At the end of the same century, the foundations of wireless electronic communication were established. In the beginning, these electronic systems were bulky and impractical due to large components like vacuum tube amplifiers. Thanks to the invention of the transistor and the integrated microprocessor, these communication systems could be miniaturized and integrated into portable systems that we all use today, like smartphones, laptops, and tablets.

History has also taught us that the demand for data rate over wireless channels rapidly increases, from several kilobits per second in the early 1990s to hundreds of megabits in today's high-speed wireless links. But even these high-speed links cannot support the applications of the (near) future like wireless uncompressed (ultra) high-definition video streaming or gigabit wireless LAN, for which data rates in the order of 10 Gb/s and even higher are required. Therefore, new solutions have to be developed to support these high-data-rate links, today and in the future. One of the most promising solutions is to shift the wireless carrier frequency from the currently used microwave bands (e.g., 2.4, 5 GHz) toward the millimeter-wave frequency spectrum (60, 85, 94, 120 GHz), where high modulation bandwidths are available, which can support gigabit-per-second wireless data streaming.

This work focuses on the development of circuit and system design techniques for millimeter-wave wireless communication systems above 90 GHz and fabricated in nanometer-scale CMOS technologies. The scaling of CMOS technologies over the past decades has led to transistors with gate lengths in the nanometer scale range. Thanks to this scaling, the speed of the MOS transistors has also increased to a maximum frequency of oscillation above 300 GHz for the latest technology nodes. So CMOS has become a millimeter-wave technology, but with the great advantage of high integration capabilities.

Although the speed of the CMOS transistors has increased, the target operation frequency of the circuits in this work (above 90 GHz) is still close to the technology's maximum frequency of oscillation. So coping with a low power gain is one of the

major design challenges in CMOS at millimeter-wave frequencies. Also, the transistors tend to show inherent potential unstable behavior, which makes multistage amplifier and system design a real challenge. Furthermore, the metal stack of CMOS technologies is not optimized for the design of high-frequency passives, which will result in a decreased performance of traditional matching circuit topologies. At the system level, problems like the implementation of the millimeter-wave chip interface and bandwidth and linearity requirements of the ADCs, DACs, and up- and downconversion circuits emerge.

These problems are addressed in several chip implementations in which circuit- and system-level solutions are proposed and implemented. Capacitive neutralization is extensively applied to improve the gain and stability properties of the transistors in multistage differential W-band CMOS amplifiers. The adoption of transformers and differential slow-wave transmission lines in the impedance matching networks resulted in small chip footprints, while improving the performance of the amplifiers even more. High gains ranging from 11 up to 18 dB and high output powers up to 8 dBm were measured, which confirms the efficiency of the adopted circuit design techniques.

A combination of two stability analysis techniques is also proposed to accurately predict the common-mode and differential-mode stability behaviors of multistage amplifiers. On the one hand, pole–zero stability analysis, which is excellent to predict the frequencies of possible oscillations and their dependency of one single design parameter is used. On the other hand, K-factor and stability circle-based analysis is adopted to get better insight in the load and source impedances causing possible unstable behavior. Combining both techniques has led to a robust stability analysis technique which not only makes it possible to identify the cause of the oscillation and its frequency but also gives better insight in possible stabilization solutions.

New digital modulation system topologies are proposed for fully integrated F-band and D-band transmitters. These direct carrier modulator topologies result in a relaxation of the requirements of the upconverter and allow to omit wideband, high-speed digital-to-analog converters. In addition, the design complexity of these systems can be considerably reduced. An F-band ASK transmitter supporting data rates up to 5 Gb/s and a 120-GHz, 10-Gb/s PSK transmitter will be discussed. The design and performance of a fully integrated 120-GHz Star-QAM transmitter, which combines both modulation techniques of the previously mentioned transmitters, capable of supporting a 10-Gb/s wireless data link, is also one of the topics in this book. The integration of a frequency generator, modulator, power amplifier, baseband circuits, and bondwire antenna has led to a fully integrated solution which solves the problem of millimeter-wave interfacing, and hereby closes the gap between a laboratory chip solution and a real-life application.

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