論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	A Study of 300GHz-Band CMOS Phased-Array Transceiver System for High Data Rate Wireless Communication
著者(和文)	ABDOIbrahim Imad Ibrahim
Author(English)	Ibrahim Imad Abdo
出典(和文)	学位:博士(学術), 学位授与機関:東京工業大学, 報告番号:甲第12155号, 授与年月日:2021年12月31日, 学位の種別:課程博士, 審査員:岡田 健一,髙木 茂孝,徳田 崇,廣川 二郎,伊藤 浩之,SONG Ho-Jin
Citation(English)	Degree:Doctor (Academic), Conferring organization: Tokyo Institute of Technology, Report number:甲第12155号, Conferred date:2021/12/31, Degree Type:Course doctor, Examiner:,,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	電気電子 系 電気電子 コース	申請学位（専攻分野）： Academic Degree Requested	博士 (学術) Doctor of
学生氏名： Student's Name	IBRAHIM IMAD IBRAHIM ABDO	指導教員（主）： Academic Supervisor(main)	岡田 健一
		指導教員（副）： Academic Supervisor(sub)	

要旨（英文 800 語程度）
Thesis Summary (approx.800 English Words)

This dissertation presents a study of 300GHz-band CMOS transceiver and phased-array systems based on subharmonic mixing. The 300GHz band is one of the main candidates for the next generation of wireless communication systems (6G) due to the wide available bandwidth, which is capable of much higher data rate. Many applications are expected to utilize the 300GHz-band such as wireless data centers, AR/VR applications, 4k uncompressed video streaming, inter-chip communication, and so on. This thesis covers the design details of the transceiver RF front-end including the mixers, LO chain components, and the PCB implementation for the phased-array system.

Using the CMOS process to build 300GHz-band transceivers is an attractive option considering the low cost and the compatibility with the digital integrated circuits. However, the main obstacle resides in the low maximum oscillation frequency (f_{max}) of the CMOS transistors which barely exceeds 300GHz for small transistor sizes. As a result, the implementation of reliable power amplifiers (PAs) and low noise amplifiers (LNAs) is quite difficult and still not demonstrated well in the literature. Most of the recent works eliminate the RF amplifiers and adopt the mixer-last transmitter (TX), mixer-first receiver (RX) architecture instead. The design using the mentioned architecture is still challenging considering that the linearity and noise requirements of the mixers are very critical. In addition, the free space path loss of the 300GHz-band is approximately 20dB higher than the loss of the currently popular 5G bands around 30GHz, making it more difficult to achieve the required signal-to-noise-ratio (SNR) for a long-distance high-data-rate wireless link. Overcoming the SNR degradation may cause a drastic increase in the area and the power consumption, so careful design and implementation techniques are necessary.

Two 300GHz-band transceiver systems are discussed in this thesis; a low-power transceiver with a single mixing path, and a phased-array transceiver with output power improvement and image rejection techniques. The low-power transceiver utilizes a subharmonic mixer with novel circuit techniques to provide the suitable system performance and to meet the link budget requirements. The subharmonic mixer is chosen in this work to reduce the LO frequency and the design complexity. Other parts such as the LO chain components are also designed using special circuit techniques to reduce the overall power consumption. The transceiver proposed in this thesis achieves a 34Gb/s maximum data rate over a 1cm distance while consuming 0.41W from a 1V supply. Compound semiconductor (InP) PAs and LNAs are added to the system to study the hybrid-transceiver option, and as a result, the maximum data rate is improved to 56Gb/s with higher order modulations such as 64QAM becoming usable as well.

The phased-array transceiver utilizes the subharmonic mixer with a bi-directional architecture. The TX mode is based on the outphasing technique to improve the average output power while canceling the LO feedthrough, and the RX mode adopts the Hartley architecture to cancel any undesired image signals. The RX mode can be also configured to provide LO feedthrough cancellation since the mixer-first receivers usually suffer from the LO emission issues due to the absence of the LNA. Thanks to the bi-directional operation, the TX and the RX share the antenna, and that makes it easier to implement a phased-array due to the small chip size. A one-dimensional stacked Vivaldi antenna array is adopted in this work to realize half-wavelength spacing between the antenna elements, and a measured beam range from -18 degrees to 18 degrees is achieved by the implemented array. The maximum data rate of the TX mode is 52Gb/s and the maximum data rate of the RX mode is 36Gb/s.

Apart from the systems mentioned above, the thesis also explores frequency multiplication techniques at mm-wave frequencies due to their critical role in sub-THz systems in general. The frequency multipliers

must provide high output power at the desired frequency while suppressing the other undesired harmonics so that the number of the following buffering stages can be minimized. Such a target is not easy to achieve when the required output frequency is in the sub-THz region. Hence, several novel techniques that utilize the transmission line characteristics and the even/odd modes are proposed in this thesis to reduce the transceiver system total area and power consumption.

The introduced systems are implemented in 65nm CMOS technology and the effectiveness of the proposed techniques was verified in clean-room and over-the-air measurements. The future directions and the possible improvements on the 300GHz-band phased-array transceiver systems are briefly presented in the last chapter of this thesis.