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Article / Book Information

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Category(English)	Doctoral Thesis
種別(和文)	論文要旨
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（博士課程）
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論 文 要 旨

THESIS SUMMARY

専攻： Department of	電子物理工学　　　専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of　（学術）
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

This dissertation presents a study of millimeter-wave transceiver targeting high data rate by improving spectrum efficiency with high linearity and high-order modulation scheme in CMOS technology.

The dissertation starts from CMOS millimeter-wave devices modeling and wireless transceiver system analysis. Passive and active devices modeling and characterization is usually required for highly accurate design at millimeter-wave frequencies. For a given channel bandwidth, the communication data rate can be increased by using high-order modulation schemes, which require high system linearity.

The power amplifier design has a dominant effect on wireless transceiver system linearity. The power amplifier is designed to handle large output power before emitted from transmitter antenna, the higher linear output power leads to the longer communication distance. To achieve a high linearity with adequate gain on the millimeter-wave power amplifier design, optimized transistor and output transformer are utilized. The power combined solution is provided by using modeled transmission line to further improve output power and overall linearity. Designed for 5G New Radio 28GHz and 39GHz bands, a 28 GHz power amplifier and a 39 GHz power amplifier are introduced. By using high quality factor 1:1 ratio transformer and high-accuracy output matching technique, the proposed 28 GHz power-combining PA achieves 20.2dBm PSAT and 11.4dBm output power with 2500MHz 64QAM modulated signal. A single path 39 GHz PA with transmitter/receiver switch is proposed, it achieves 15.5 dBm PSAT and 8.6 dBm output power with 3000MHz 64QAM modulated signal.

Due to relatively higher free-space path loss (FSPL) at millimeter-wave frequencies, it is necessary to overcome high FSPL when establishing a long distance millimeter-wave wireless link. The link distance can be enhanced by further improving transmitter output power, however, the power amplifier designed in CMOS has a limited performance due to the technology limitation and feasibility. The phased-array architecture with controlled sub-array element can enhance the transceiver signal strength therefore enhance the link distance. Targeting several hundred meter millimeter-wave link distance, the estimated array element for transmitter is over 1000. Highly accurate sub-array element phase and gain control are required for high quality beamforming. 28GHz and 39GHz phased-array transceiver are implemented with the characteristic of high linearity. The measured 1-channel transmitter peak error vector magnitude (EVM) for 28GHz transceiver and 39GHz transceiver are -37dB and -34dB, respectively. The measured 1-channel receiver peak signal to noise and distortion ratio (SNDR) for 28GHz transceiver and 39GHz transceiver are 39dB and 40dB, respectively. Built-in phase gain calibration mechanisms are proposed to enhance the beamforming quality. The proposed phase gain calibration extracts the phase and gain information in each sub-array transmitter and receiver path. An analog-to-digital convertor (ADC) and a phase-to-digital convertor (PDC) are used for gain and phase quantization. The built-in calibration has a measured accuracy of 0.08-degree RMS phase error and 0.01-dB RMS gain error. Thanks to the highly-accurate phase gain control, the 8TX-8RX phased-array transceiver module 1-m OTA measurement supports 5G NR 400MHz 256QAM OFDMA modulation with -30.0dB EVM. The 64-element transceiver has a EIRP MAX of 53dBm.

Furthermore, for indoor high data rate high portability wireless, a novel BPOOK modulation is proposed to realize the ultra low power consumption with improved spectrum efficiency. Conventionally, to realize a low power wireless transceiver at millimeter-wave frequencies, the on-off-keying (OOK) modulation is used due to its simplicity. However, the OOK modulation has the intrinsic issues of low spectrum efficiency and high LO feedthrough (LOFT). In order to solve the issues in OOK modulation, a binary-phase-OOK (BPOOK) is proposed. The BPOOK wireless transceiver transmits radio frequency (RF) signal with amplitude modulated on and off by input baseband data, and meanwhile phase is changing between 0° and 180°. The BPOOK transceiver achieves doubled spectral efficiency compared with on-off keying (OOK) modulation and binary-phase-shift keying (BPSK) modulation. It also cancels the intrinsic LOFT in the OOK modulation. The 60GHz BPOOK transceiver achieves 3.0Gb/s data rate while consuming a power of 100mW. The 60GHz BPOOK transceiver is compliant with spectrum mask in IEEE 802.11ad standard.

At last, this dissertation concludes the millimeter-wave transceiver design towards high data rate by improving spectrum efficiency with proposed high linearity power amplifier, high accuracy phased-array transceiver and spectrum efficient BPOOK modulation scheme. Future researches are also discussed in the end of the dissertation.

備考 ： 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1copy of 800 Words (English).