UTS UNIVERSITY OF TECHNOLOGY SYDNEY

Design of millimeter-wave transmitter in silicon-based technologies

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Under the supervision of Dr. Forest ZHU and Dr. Yang YANG

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ABSTRACT

Nowadays, with rapid advances being made in wireless communications, the demand for high-performance radio frequency (RF) transmitters has risen dramatically. An increasing number of challenges are evident for radio frequency integrated circuit (RFIC) designers while the operational frequency is being pushed to millimeter-wave (mmWave). The transmitter is an electronic device that can be used to send radio signals. A typical transmitter may contain many components, such as an RF power amplifier and a switch. The efficiency of the transmitter can significantly guide the performance of the whole wireless system. For this reason, it is necessary for RFIC researchers to propose more efficient designs. Therefore, in this thesis, the design methodologies of a high-performance mmWave power amplifier and two silicon-based single-pole double-throw (SPDT) switches are presented.

The first approach is used to design a symmetrical 90 GHz single-pole double-throw switch in CMOS Technology. To improve the power-handling capability of bulk CMOS-based single-pole double-throw (SPDT) switch, a novel design approach that combines both power dividing and impedance transformation techniques is used to improve 1-dB compression point (P1dB). The SPDT switch is implemented in a 55nm bulk CMOS technology and achieves a measured P1dB of 15 dBm and an insertion loss of 3.5 dB and an isolation of 17 dB. The die area is only 0.14 mm^2.

In the second work, to further improve the power-handling capability of the SPDT switch, a 90-GHz asymmetrical SPDT switch is designed. Taking advantage of utilizing a unique passive ring structure, the fundamental limitation for P1dB due to reduced threshold voltage is overcome. The design has achieved an IL of 3.2 dB and 3.6 dB in Transceiver (TX) and Receiver (RX) mode, respectively. Moreover, more than 20 dB isolation is obtained in both modes. The P1dB is 19.5dBm. The die area of this design is only 0.26 mm^2.

In the third work, a wideband millimeter-wave (mm-Wave) power amplifier (PA) is designed. To ensure the designed PA has sufficient output power and good power-added efficiency (PAE), a balanced amplifier (BA) architecture is used. A prototype PA is fabricated in a 0.13-μm SiGe HBT technology. Supplied by 5V power, the PA can provide more than 15 dBm saturated output power between 85-100 GHz that is equivalent to more than 16% fractional bandwidth. The peak PAE is better than 14% within this frequency range. Including all pads, the die area is only 0.6 mm × 0.9 mm.

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LIST OF PUBLICATIONS

Journal Publications

1. **L. Chen**, L. Chen, Z. Ge, Y. Sun, T. J. Hamilton and X. Zhu, "A 90-GHz Asymmetrical Single-Pole Double-Throw Switch With >19.5-dBm 1-dB Compression Point in Transmission Mode Using 55-nm Bulk CMOS Technology," in **IEEE Transactions on Circuits and Systems I: Regular Papers**, doi: 10.1109/TCSI.2021.3106231.
2. **L. Chen**, Z. Ge, L. Chen, Y. Sun and X. Zhu, "Design of Millimeter-Wave Asymmetrical Single-Pole Double-Throw Switch with Enhanced 1-dB Compression Point in 55-nm Bulk CMOS Technology" in **IEEE Transactions on Circuits and Systems I: Regular Papers** (*under review*)

Conference Publications

1. L. Chen, L. Chen, Z. Ge, F. Meng and X. Zhu, "A W-band Power Amplifier with 15-dBm Psat and 14% PAE in 0.13-μm SiGe HBT Technology," **2021 IEEE MTT-S International Wireless Symposium (IWS)**, 2021, pp. 1-3, doi: 10.1109/IWS52775.2021.9499688.
2. **L. Chen**, L. Chen, Z. Ge. R. Gómez-Garcia and X. Zhu, " Design of Passive-Inspired Millimetre-Wave Integrated Devices in Low-Cost Bulk CMOS Technology," 2021 Asia-Pacific Microwave Conference (APMC), 2021 (**accepted**)

Co-Authored Journal publications

1. Z. Ge, **L. Chen**, R. Gómez-García and X. Zhu, "Millimeter-Wave Wide-Band Bandpass Filter in CMOS Technology Using a Two-Layered Highpass-Type Approach with Embedded Upper Stopband," in **IEEE Transactions on Circuits and Systems II: Express Briefs**, doi: 10.1109/TCSII.2021.3064387.
2. Z. Ge, **L. Chen**, L. Yang, R. Gómez-García and X. Zhu, "On-Chip Millimeter-Wave Integrated Absorptive Bandstop Filter in (Bi)-CMOS Technology," in **IEEE Electron Device Letters**, vol. 42, no. 1, pp. 114-117, Jan. 2021, doi: 101109/LED.2020.3036036.