

CONTENTS

| | |
|--|-----------|
| ABSTRACT (CHINESE) | i |
| ABSTRACT (ENGLISH) | iii |
| ACKNOWLEDGEMENT | vi |
| CONTENTS | vii |
| TABLE CAPTIONS | x |
| FIGURE CAPTIONS | xi |
| | |
| CHAPTER 1 INTRODUCTION | 1 |
| 1.1 BACKGROUND | 1 |
| 1.2 REVIEW ON ARCHITECTURES OF CMOS WIRELESS RECEIVER | 2 |
| 1.2.1 Heterodyne Receiver | 2 |
| 1.2.2 Direct-Conversion (Homodyne, Zero-IF) Receiver | 3 |
| 1.2.3 Image-Reject Receiver | 5 |
| 1.2.4 Wideband-IF Receiver | 6 |
| 1.2.5 Low-IF Receiver | 7 |
| 1.2.6 Double-Quadrature Receiver | 8 |
| 1.3 ORGANIZATION OF THIS THESIS | 9 |
| | |
| CHAPTER 2 THE DESIGN OF ACTIVE POLYPHASE FILTER | 19 |
| 2.1 INTRODUCTION | 19 |
| 2.2 MODEL FOR THE ACTIVE POLYPHASE FILTER | 22 |
| 2.3 CIRCUIT DESIGNS | 25 |
| 2.3.1 The Circuit Design of Wideband Active Polyphase Filter | 25 |
| 2.3.2 The Simulation Results of Active Polyphase Filter | 29 |
| 2.3.3 Layout Consideration | 31 |

| | | |
|------------------|---|-----|
| 2.3.4 | The Circuit Design of 1-V Wideband Active Polyphase Filter | 32 |
| 2.4 | EXPERIMENTAL RESULTS | 32 |
| 2.5 | SUMMARY | 34 |
| | | |
| CHAPTER 3 | A 5-GHZ DOUBLE-QUADRATURE RECEIVER FRONT-END FOR IEEE 802.11A WIRELESS LOCAL-AREA NETWORK APPLICATIONS | 58 |
| 3.1 | INTRODUCTION | 58 |
| 3.2 | SYSTEM DESCRIPTION AND CALCULATIONS | 60 |
| 3.2.1 | System Description | 60 |
| 3.2.2 | System Calculations | 61 |
| 3.2.2.A | Noise Figure | 61 |
| 3.2.2.B | CP1dB and IIP3 | 63 |
| 3.2.2.C | Image Rejection Ratio | 64 |
| 3.2.2.D | Phase Noise | 66 |
| 3.3 | Model for the double-quadrature receiver | 67 |
| 3.4 | CIRCUIT DESIGNS | 70 |
| 3.4.1 | Low-Noise Amplifier (<i>LNA</i>) | 70 |
| 3.4.2 | RF Quadrature Generator (<i>RF-QG</i>) | 71 |
| 3.4.3 | Double-Quadrature Mixers (<i>DQ-Mixers</i>) and Quadrature Voltage-Controlled Oscillator (<i>QVCO</i>) | 74 |
| 3.4.4 | Active Polyphase Filter | 76 |
| 3.4.5 | Overall Circuit | 77 |
| 3.5 | EXPERIMENTAL RESULTS | 78 |
| 3.6 | SUMMARY | 81 |
| | | |
| CHAPTER 4 | A 1-V 2.4-GHZ DOUBLE-QUADRATURE | 112 |

RECEIVER FRONT-END FOR LOW-VOLTAGE APPLICATIONS

| | | |
|---|--|-----|
| 4.1 | INTRODUCTION | 112 |
| 4.2 | CIRCUIT DESIGNS | 114 |
| 4.2.1 | Low-Noise Amplifier (<i>LNA</i>) | 114 |
| 4.2.2 | RF Quadrature Generator (<i>RF-QG</i>) | 116 |
| 4.2.3 | Quadrature Voltage-Controlled Oscillator (<i>QVCO</i>) | 118 |
| 4.2.4 | Double-Quadrature Mixers (<i>DQ-Mixers</i>) | 119 |
| 4.3 | EXPERIMENTAL RESULTS | 120 |
| 4.3.1 | 1-V 2.4-GHz Low-Noise Amplifier | 120 |
| 4.3.2 | 1-V 2.4-GHz Double-Quadrature Receiver | 121 |
| 4.4 | SUMMARY | 122 |
| CHAPTER 5 CONCLUSIONS AND FUTURE WORKS | | 141 |
| 5.1 | MAIN RESULTS OF THIS THESIS | 141 |
| 5.2 | FUTURE WORKS | 143 |
| REFERENCES | | |
| VITA | | |
| PUBLICATION LIST | | |

TABLE CAPTIONS

| | | |
|-----------|--|-----|
| Table 1.1 | Comparison of receiver architectures | 12 |
| Table 2.1 | Dimensions of Devices in Constant-Gm Bias Circuit and Polyphase Filter. | 35 |
| Table 2.2 | Simulated NF and $IIP3$ Characteristics of Different Gain Distributions in the Four-Stage Active Polyphase Filter. | 36 |
| Table 2.3 | Measured Characteristics of the Active Polyphase Filter. | 37 |
| Table 2.4 | Comparison Between the Recently Proposed Polyphase Filter. | 38 |
| Table 3.1 | Rate-dependent Parameters in IEEE 802.11a | 83 |
| Table 3.2 | The Input Blocking Defined in HIPERLAN2 (f_C : carrier frequency) | 84 |
| Table 3.3 | Device Parameters of the 5-GHz DQR | 85 |
| Table 3.4 | Measured Results of the 5-GHz Double-Quadrature Receiver. | 86 |
| Table 3.5 | Performance Summaries of the Recently Proposed CMOS Double-Quadrature receiver and 5GHz Receivers. | 87 |
| Table 4.1 | Device Parameters of the 1-V Double-Quadrature Receiver. | 124 |
| Table 4.2 | Experimental Results of LNA and 1-V Double-Quadrature Receiver | 125 |

FIGURE CAPTIONS

| | | |
|----------|--|----|
| Fig. 1.1 | Block diagram of the heterodyne receiver. | 13 |
| Fig. 1.2 | Block diagram of the direct-conversion receiver. | 14 |
| Fig. 1.3 | Two sources of DC offsets in the direct-conversion receiver. | 14 |
| Fig. 1.4 | Block diagram and the spectral flow of Hartley image-reject receiver. | 15 |
| Fig. 1.5 | Block diagram and the spectral flow of Weaver image-reject receiver. | 16 |
| Fig. 1.6 | Block diagram of the wideband-IF receiver. | 17 |
| Fig. 1.7 | Block diagram of the low-IF receiver. | 18 |
| Fig. 1.8 | Spectral flow of the low-IF receiver. | 18 |
| Fig. 2.1 | Signal flowgraph for realizing a single-stage complex filter. | 39 |
| Fig. 2.2 | Transfer curves of $ H(s) $ versus frequency. | 40 |
| Fig. 2.3 | Simulated IRR_{PPF} values (indicated on the curves) of one-stage polyphase filter at $\omega = \omega_p$ with gain and pole frequency variations. | 41 |
| Fig. 2.4 | Required stage versus achievable IRR_{PPF} within the rejection band. | 42 |
| Fig. 2.5 | (a) Circuit of LHF . (b) Differential type of LHF and its equivalent functionality block $LHFD$. (c) Block diagram of $H(s)$. | 44 |
| Fig. 2.6 | Circuit of constant-gm bias. | 45 |
| Fig. 2.7 | HSPICE simulated transfer curve and IRR_{PPF} of the one-stage CMOS polyphase filter ($\omega_p = 24.5\text{MHz}$). | 46 |
| Fig. 2.8 | HSPICE simulated IRR variations of the one-stage CMOS polyphase filter with four corners (FF, FS, SF, and SS) of | 47 |

| | | |
|-----------|--|----|
| | MOS device models. | |
| Fig. 2.9 | HSPICE simulated IRR variations of the one-stage CMOS polyphase filter in the temperature between 0° and 80° . | 47 |
| Fig. 2.10 | HSPICE simulated transfer curve and IRR_{PPF4} of the four-stage CMOS polyphase filter. | 48 |
| Fig. 2.11 | HSPICE simulated IRR variations of the four-stage CMOS polyphase filter with four corners (FF, FS, SF, and SS) of MOS device models. | 49 |
| Fig. 2.12 | HSPICE simulated IRR variations of the four-stage CMOS polyphase filter in the temperature between 0° and 80° . | 49 |
| Fig. 2.13 | Floor planning of the one-stage polyphase filter. | 50 |
| Fig. 2.14 | Low-voltage version of LHF . | 51 |
| Fig. 2.15 | HSPICE simulated transfer curve and IRR_{PPF4} of the low-voltage four-stage CMOS polyphase filter. | 52 |
| Fig. 2.16 | Die micrograph of fabricated four-stage polyphase filter in $0.25\text{-}\mu\text{m}$ CMOS technology. | 53 |
| Fig. 2.17 | Measured IRR_{PPF4} of fabricated four-stage polyphase filter in $0.25\text{-}\mu\text{m}$ CMOS technology. | 54 |
| Fig. 2.18 | Measured quadrature output signals when 20-MHz differential signals are applied. | 55 |
| Fig. 2.19 | Two-tone test for $f1 = 19.5\text{MHz}$ and $f2 = 20.5\text{MHz}$. | 56 |
| Fig. 2.20 | Measured $IIP3$ of fabricated four-stage polyphase filter in $0.25\text{-}\mu\text{m}$ CMOS technology. | 57 |
| Fig. 3.1 | Allocated frequency of wireless LAN IEEE 802.11a. | 88 |
| Fig. 3.2 | Determination of $IIP3$ in a communication system. | 89 |
| Fig. 3.3 | Noises and image interferers at the input and output of the receiver. | 90 |
| Fig. 3.4 | The Required IRR_{DQR} in different NF_{CIR} to achieve the data rate of 54Mbits/s. | 90 |

| | | |
|-----------|---|-----|
| Fig. 3.5 | Block diagram of double-quadrature receiver (<i>DQR</i>). | 91 |
| Fig. 3.6 | Signal spectra in the <i>DQR</i> (a) before the downconversion and (b) after the downconversion. | 92 |
| Fig. 3.7 | Simulated noise figure versus gate-width of the input transistor of the <i>LNA</i> . | 93 |
| Fig. 3.8 | Circuit diagram of the low-noise amplifier (<i>LNA</i>). | 94 |
| Fig. 3.9 | RLC phase shifter. | 95 |
| Fig. 3.10 | Circuit diagram of the RF quadrature generator (<i>RF-QG</i>). | 95 |
| Fig. 3.11 | Simulated amplitude errors and <i>ISR</i> at the outputs of the <i>RF-QG</i> . | 96 |
| Fig. 3.12 | Circuit diagram, which combines the functions of <i>Mixer1</i> and <i>Mixer3</i> in Fig. 3.5. | 97 |
| Fig. 3.13 | Circuit diagram of quadrature voltage-controlled oscillator (<i>QVCO</i>). | 98 |
| Fig. 3.14 | Block diagram of current reuse structure. | 99 |
| Fig. 3.15 | Block diagram of the four-stage active polyphase filter. | 100 |
| Fig. 3.16 | HSPICE simulated transfer curve and IRR_{PPF4} of the four-stage active polyphase filter. | 101 |
| Fig. 3.17 | HSPICE simulated <i>IRR</i> variations of the four-stage active polyphase filter with four corners (FF, FS, SF, and SS) of MOS device models. | 102 |
| Fig. 3.18 | HSPICE simulated <i>IRR</i> variations of the four-stage CMOS polyphase filter in the temperature between 0° and 80°. | 102 |
| Fig. 3.19 | Complete circuit diagram of the 5-GHz double-quadrature receiver | 103 |
| Fig. 3.20 | Die micrograph of the fabricated CMOS double-quadrature receiver. | 104 |
| Fig. 3.21 | Measured S_{11} . | 105 |
| Fig. 3.22 | Measured tuning range of quadrature VCO. | 106 |

| | | |
|-----------|--|-----|
| Fig. 3.23 | Output spectrum of the <i>DQR</i> | 107 |
| Fig. 3.24 | Measured results concerning <i>CP1dB</i> and <i>IIP3</i> . | 108 |
| Fig. 3.25 | Measured frequency response and <i>IRR_{DQR}</i> of fabricated 5-GHz CMOS <i>DQR</i> . | 109 |
| Fig. 3.26 | Results of 30-times Monte-Carlo simulations for <i>DQ-Mixers</i> | 110 |
| Fig. 3.27 | Results of 30-times Monte-Carlo simulations for <i>DQ-Mixers</i> | 111 |
| Fig. 4.1 | Circuit diagram of the designed individual low-noise amplifier (<i>LNA</i>). | 126 |
| Fig. 4.2 | Simulated impedance at the coupled-source node of differential low-noise amplifiers (<i>LNAs</i>) with (a) MOS current source and (b) LC-tank. | 127 |
| Fig. 4.3 | RLC phase shifter. | 128 |
| Fig. 4.4 | Circuit diagram of the RF quadrature generator (<i>RF-QG</i>). | 128 |
| Fig. 4.5 | Simulated amplitude errors and the corresponding image rejection of the 1-V <i>RF-QG</i> | 129 |
| Fig. 4.6 | Circuit diagram of the quadrature voltage-controlled oscillator (<i>QVCO</i>). | 130 |
| Fig. 4.7 | Circuit diagram, which combines the functions of <i>Mixer1</i> and <i>Mixer3</i> in Fig. 3.5. | 131 |
| Fig. 4.8 | Die micrograph of the fabricated <i>LNA</i> in 0.25- μ m CMOS technology. | 132 |
| Fig. 4.9 | Measured <i>S₂₁</i> of 1-V 2.4-GHz low-noise amplifier | 133 |
| Fig. 4.10 | Measured common-mode gain of 1-V 2.4-GHz low-noise amplifier | 134 |
| Fig. 4.11 | Measured noise figure of 1-V 2.4-GHz low-noise amplifier | 135 |
| Fig. 4.12 | Measured <i>IIP3</i> of 1-V 2.4-GHz low-noise amplifier | 136 |
| Fig. 4.13 | Die micrograph of the fabricated <i>DQR</i> in 0.25- μ m CMOS | 137 |

technology

| | | |
|-----------|--|-----|
| Fig. 4.14 | Output spectrum of the <i>DQR</i> | 138 |
| Fig. 4.15 | Measured <i>IIP3</i> of the <i>DQR</i> | 139 |
| Fig. 4.16 | Measured image rejection ratio of the <i>DQR</i> | 140 |

