

# Contents

|          |                                                                     |           |
|----------|---------------------------------------------------------------------|-----------|
| <b>1</b> | <b>Introduction</b>                                                 | <b>1</b>  |
| 1.1      | Goal of the work . . . . .                                          | 3         |
| 1.2      | Structure of this thesis . . . . .                                  | 3         |
| 1.3      | Transmitter and transmitter frontend . . . . .                      | 5         |
| 1.4      | Contribution of this work . . . . .                                 | 7         |
| <b>2</b> | <b>Transmitter Design</b>                                           | <b>9</b>  |
| 2.1      | Conventional transmitter topologies . . . . .                       | 9         |
| 2.2      | Digital-centric transmitter topologies . . . . .                    | 11        |
| 2.3      | RFDAC-based structure . . . . .                                     | 12        |
| 2.4      | Conventional $\Delta\Sigma$ -based topologies . . . . .             | 13        |
| 2.5      | Increased phase $\Delta\Sigma$ modulators . . . . .                 | 17        |
| 2.6      | Polar $\Delta\Sigma$ -based transmitter . . . . .                   | 20        |
| 2.7      | Pulse width and position modulation . . . . .                       | 21        |
| <b>3</b> | <b>Baseband chain for digital-centric transmitters</b>              | <b>25</b> |
| 3.1      | Particular aspects of digital-centric transmitters . . . . .        | 25        |
| 3.2      | Interpolation and asynchronous clock domain conversion . . . . .    | 27        |
| 3.2.1    | Reconfigurable virtual oversampling FIR filter . . . . .            | 28        |
| 3.2.2    | FIR filter form . . . . .                                           | 31        |
| 3.2.3    | Synchronisation . . . . .                                           | 31        |
| 3.2.4    | Implementation . . . . .                                            | 33        |
| 3.3      | Fractional oversampling and interpolation . . . . .                 | 38        |
| 3.3.1    | Oversampling implementation . . . . .                               | 39        |
| 3.4      | Reconfigurable $\Delta\Sigma$ resolution enhancing filter . . . . . | 46        |
| 3.4.1    | $\Delta\Sigma$ modulator structure . . . . .                        | 47        |
| 3.4.2    | $\Delta\Sigma$ modulator implementation . . . . .                   | 48        |
| 3.5      | Summary on baseband preprocessing . . . . .                         | 52        |

|          |                                                                               |           |
|----------|-------------------------------------------------------------------------------|-----------|
| <b>4</b> | <b>Mixed-signal RF blocks and transmitter frontends</b>                       | <b>55</b> |
| 4.1      | Quadphase low-pass $\Delta\Sigma$ modulator transmitter frontend .            | 55        |
| 4.1.1    | Conventional $\Delta\Sigma$ modulator topologies . . . . .                    | 56        |
| 4.1.2    | Quadphase $\Delta\Sigma$ modulator topology . . . . .                         | 59        |
| 4.1.3    | Full-custom quadphase $\Delta\Sigma$ modulator implementa-<br>tions . . . . . | 62        |
| 4.2      | Direct RF pulse-width and -position modulation frontend                       | 68        |
| 4.2.1    | PWPM transmitter frontend topology . . . . .                                  | 70        |
| 4.2.2    | PWPM transmitter frontend implementation . . .                                | 72        |
| 4.2.3    | PWPM transmitter frontend results and conclusion                              | 80        |
| 4.3      | Cascaded digital phase modulator . . . . .                                    | 87        |
| 4.3.1    | Implementation of phase merge cells . . . . .                                 | 90        |
| <b>5</b> | <b>Conclusions and Outlook</b>                                                | <b>99</b> |
| 5.1      | Conclusions . . . . .                                                         | 99        |
| 5.2      | Outlook . . . . .                                                             | 102       |

## Appendix

|                              |              |
|------------------------------|--------------|
| <b>Bibliography</b>          | <b>A iii</b> |
| <b>List of Figures</b>       | <b>A ix</b>  |
| <b>List of Abbreviations</b> | <b>A xi</b>  |
| <b>Curriculum Vitæ</b>       | <b>A xv</b>  |