Considerations for High-Speed Configurable-bandwidth Time-interleaved Digital Delta-Sigma Modulators
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Introduction
The high demand of more and more performant mobile communication systems has determined a shift from analog to digital processing in transmitter architectures, in order to overcome associated challenges, such as high data rates, configurability for multi-standard, area and power consumption reduction.

Our research is currently focused on power efficient digital transmitter architectures based on Delta-Sigma Modulation. The final objective is to implement an integrated circuit with low power consumption that can be used for mobile devices.

Delta-Sigma Modulation enables Digital RF
Delta-Sigma Modulation is based on 3 main concepts:
- Quantization: Approximation with a certain resolution
  - Ex: 1-bit quantization: 2 possible values “0” or “1”
  - final answer: \( y = 0.55 \)
- Oversampling
  - Increasing the sampling frequency n-times
  - Easiest: repeat each value (n-1) times
  - Used to locally reduce noise
- Noise shaping
  - Function for noise reduction in the band of interest
  - Increase Signal-to-Noise Ratio
  - Disadvantage: Higher out-of-band noise

In order to increase the operating frequency, we have studied Time-interleaving in Delta-Sigma Modulators i.e. different number of modulators working in parallel at lower frequencies, to obtain a high-frequency output.

Thesis Objectives
- Design a time-interleaved Delta-Sigma Modulator as part of a digital transmitter system.
- Validate functionality through system-level simulations.
- Define circuit specifications.
- Design and fabricate a prototype chip.
- Perform measurements and validate performance.

Delta-Sigma Modulator Design
The modulator is designed with optimized coefficients in order to provide bandwidth configurability for increased performance in mobile communication systems. Finally, this translates to increased Signal-to-Noise Ratio with respect to the targeted signal bandwidth.

Methodology and results
- Study Delta-Sigma Modulator architectures and Time-Interleaving Methods
- System-level simulations and Critical path analysis in order to optimize for high-frequency operation
- First prototype on FPGA Development Board to verify functionality
- The proposed implementation is synthesizable with automatic design tools, thus reducing complexity of the integration phase
- The results show that time-interleaving can be successfully applied to Delta-Sigma Modulators, either to increase operating frequency, or to reduce consumption for a desired operating mode

Acquired skills and research challenges
Acquired skills:
State of the art research, mathematical modeling, system design and specification, scientific communication and publishing.

Ongoing Research challenges:
Circuit design and fabrication, IC Measurement