Digital Calibration of Analog, Mixed-Signal and Radio-Frequency Systems

Pietro Monsurrò

10 hours, 2 credits

Seminar room at second floor of DIET Department, Via Eudossiana 18, 00184, Rome, Italy

Course Objectives

Trends in analog and digital technologies allow system designers to shift more functions from the analog / mixed-signal / radio-frequency sections to the digital section. Higher flexibility and modularity of digital solutions, rapidly increasing digital processing power and power efficiency, and growing analog limitations (gain, mismatches…) in advanced CMOS processes have expanded the domain of digital processing.

Digital calibration is the use of digital techniques to improve the performance of analog / mixed-signal / radio-frequency systems. Examples of systems whose performance can be improved through digital processing are analog-to-digital converters, power amplifiers, I/Q mixers, whole receivers, transmitters, or entire systems such as direction-finding receivers, beam-formers, etc.

By its nature, digital calibration requires multiple interdisciplinary skills: circuit and system design, block and system modeling, statistical estimation theory, digital signal processing, digital design, adaptive filtering techniques, and poses new trade-offs from an engineering point of view.

The goal of the course is to introduce the idea of digital calibration, describe its most common applications, and explain the theoretical instruments required to understand and design these systems.

Program

Lecture #1 (February 9th, 14:00 – 15:30) – The idea of digital calibration; the three steps of digital calibration: modeling, estimation and correction; background and foreground estimation; trends in digital and analog technologies; modularity and flexibility; accuracy, complexity, speed trade-offs; benefits of digital calibration; examples of systems which can be calibrated.

Lecture #2 (February 12th, 14:00 – 15:30) – ADC specifications and performance limitations; the architecture of pipeline ADCs; errors in pipeline ADCs; calibration through injection of random sequences; split-ADC and colored random sequences; modeling mixed-signal systems; limitations in switches and OTAs; nonlinear calibration of ADCs.

Lecture #3 (February 14th, 14:00 – 15:30) – Time-interleaved ADCs; the Papoulis model and multi-rate signal processing; errors in time-interleaved ADCs; calibration techniques; the speed/accuracy/complexity trade-off; bandwidth expansion techniques; asynchronous time-interleaving.

Lecture #4 (February 16th, 14:00 – 15:30) – System-level calibration; linear and nonlinear models; Volterra models; a priori and a posteriori model restrictions; system identification; nonlinear intersymbol interference, effect of interferers and jammers, constellation distortion; SNR, THD and dynamic range; calibration of power amplifiers; calibration of receivers.

Lecture #5 (February 19th, 14:00 – 15:30) – Estimation of error models; background and foreground techniques; adaptive filtering; the LMS algorithm; the RLS algorithm; design trade-offs; fast RLS algorithms; the FWL RLS algorithm; the RBLS algorithm.

Final exam

Pass/fail exam. Discussion of a scientific paper related to the course.

Course material

Course slides. Research papers.