ACSP · Analog Circuits And Signal Processing

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Software Radio

Sampling Rate Selection, Design and Synchronization

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"O frati," dissi "che per cento milia
perigli siete giun ti a l'occidente,
a questa tanto picciola vigilia
d'i nostri sensi ch' del rimanente
non vogliate negar l'esperienza,
di retro al sol, del mondo sanza gente.
Considerate la vostra semenza:
fatti non foste a viver come bruti,
ma per seguir virtute e canoscenza."

A. Dante, Inferno, Canto XXVI

Preface

Software Radio (SR) is one of the most important emerging technologies for the future of wireless communication services. By moving radio functionality into software, it promises to give flexible radio systems that are multi-service, multi-standard, multi-band, reconfigurable and reprogrammable by software.

Today's radios are matched to a particular class of signals that are well defined by their carrier frequencies, modulation formats and bandwidths. A radio transmitter today can only up convert signals with well-defined bandwidths over defined center frequencies, while, on the other side of the communication chain, a radio receiver can only down convert well-defined signal bandwidths, transmitted over specified carrier frequencies.

The challenge is to remove such constraints and design systems that can be used as universal platforms that can adapt themselves to specific situations. We would like to have a single transmitter that is able to up convert signals independently of their bandwidth, modulation format and carrier frequency. For every transmission, we would like to detect an available, wide enough, spectral hole which is arbitrarily located in the radio spectrum, and to transmit the signal without changing the hardware platform of the transmitter and receiver devices. In order to achieve this goal, the radio devices have to be software-based and their hardware platform has to be reduced to a minimum. The devices have to be reconfigurable and the signal digitization has to occur as close as possible to the antenna. Such a radio will make possible the dynamic spectrum management ensuring the optimal use of this precious resource.

This book is derived from the Ph.D. thesis of one of the authors, and thus it aggregates the studies, the deductions, the mathematical derivations and the scientific results achieved during a 4-year long period of research activity. It does not have the intention of providing a detailed overview of the current state of the art on software radio technology, nor it is intended as a textbook. It examines specific aspects connected with the realization of software radios discussing some of, what the writers believe to be, the most critical issues connected with it, and thus this book necessarily reflects the biased view of its authors. Specifically the book addresses the following issues: proper low-sampling rate selection in the multi-band

received signal scenario, architecture design for both software radio receiver and transmitter devices and radio synchronization. This book also addresses other issues that the authors' recent research work has approached (timing jitter modeling, time interleaved analog to digital converter and spectral analysis).

A scientific approach is followed everywhere which maintains the mathematic formulations to an acceptable level for a reader that has an average signal processing background. This book is aimed at a research community that is interested in further development of efficient algorithm implementations.

The authors tried to do their best for explaining all the concepts as clearly as possible, trying also to avoid losing the details in the description. Many figures and block diagrams have been included for simplifying the understanding process. At the end of every reasoning and mathematical derivation, simulation results are provided in order to confirm the effectiveness of the proposed theories, while many references are given at the end of every chapter for those who would like to enrich their knowledge on the topics.

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Organization of Book

This book is composed of five main chapters.

Chapter 1 provides the basics on software defined radio (SDR) and discusses its benefits pointing out the current state of the technology. This chapter also clarifies the differences between software defined radio, software radio and adaptive intelligent software radio (AISR), better known as cognitive radio (CR).

Chapter 2 introduces the sampling rate selection issue explaining the key reasons that motivate the use of low-rate sampling techniques in digital signal processor based architectures. This chapter provides a new computational formula for selecting the appropriate low-sampling rate in the case of multi-band signals. Theoretical results are confirmed through Matlab simulations. In this chapter the authors also give a new model for describing the frequency selective effect of the timing jitter affecting the analog to digital converters (ADCs) along with an effective and easy to implement solution for semi-blindly correcting time and gain mismatches in a two-channel time interleaved ADC (TI-ADC) operating on communication signals (Hermitian symmetric signals centered at intermediate frequency).

Chapter 3 faces the problem of designing a software defined radio architecture, both for the transmitter and the receiver. A software defined radio transmitter must be able to simultaneously up convert signals with variable bandwidths and randomly located center frequencies while a software defined radio receiver must be able to simultaneously detect and down convert them. In this chapter the authors present implementable back-end structures for both the SDR transmitter and receiver. The polyphase up and down converter channelizer engines are at the core of the proposed designs. That is the motivation for which this chapter also provides the basics of multirate signal processing with particular attention to the derivation of the standard polyphase down converter channelizer.

In Chap. 4 three octave processors for constant-Q spectrum analyzer are presented. Spectrum analyzers are indispensable for software radios. In fact an adaptive intelligent software radio transmitter must be able to optimize the utilization of the available radio spectrum; in order to achieve this goal it needs to know where the

white spaces are located. On the other side, the receiver needs to know the carrier frequencies of the information signals and their bandwidths in order to demodulate them properly.

Chapter 5 faces the synchronization issue in digital radios. After providing an introduction of this topic, this chapter presents a new blind time, frequency and phase synchronization algorithm for a software defined radio receiver operating on quadrature amplitude modulated (QAM) signals. The algorithm is based on information-theoretic criteria.

Contents