SOFTWARE RADIO ARCHITECTURE

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Object-Oriented Approaches to Wireless Systems Engineering

Joseph Mitola III
Consulting Scientist

A Wiley-Interscience Publication
JOHN WILEY & SONS, INC.
New York · Chichester · Weinheim · Brisbane · Singapore · Toronto

Published simultaneously in Canada.

Library of Congress Cataloging-in-Publication Data:

Mitola, Joseph
Software Radios: wireless architectures for the 21st century/Joseph Mitola III.
p. cm.
"A Wiley-Interscience publication."
ISBN 0-471-38492-5 (Cloth: alk. paper)
1. Cellular telephones. 2. Radio frequency modulation—Computer programs. 3. Digital to analog converters. I. Title.

TK6570.M6 M55 2000
621.3845′6—dc21 00-027758

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

For Lynné

... for Barb & Max

and Dad and Mom
and my Mentors
and the "Alpha's"

"In the Public Interest"

CONTENTS

PREFACE

The purpose of this text is to show how to integrate the analog RF and digital aspects of radio with the rapidly emerging large-scale object-oriented software technology needed for open-architecture software-defined radio (SDR).

This is therefore a systems engineering text. It is not a design text. This book will not help you design a better filter for a specific SDR. It will, however, help you make better decisions about how to partition the end-to-end system filtering requirements. It will help you allocate the critical functions of dynamic range and processing capacity in such a way that the filter's design constraints are well founded and that the hardware platform, firmware, and software support the filtering requirements of the software radio. This book will also give you quantitative criteria for deciding whether to host that filter in an analog package, digitally on an applications-specific integrated circuit (ASIC), or in software on the latest digital signal processing (DSP) chip. In addition, if the filter is to be implemented in software, this book will give you the skills to ensure that the software is well structured and performs robustly—even when many tasks are competing for processing resources. The appropriate host for such a filter changes over time. Commercial filter ASICs may become obsolete as DSP processing capacity increases, changing the systems-level tradeoffs. As needs, technology, and team expertise evolve, the effective choice will also change. The effective choice also changes as a function of the top-down design constraints placed on the radio system by the economics of the marketplace and by the larger systems architecture. And the effective choice may be to not implement the filter per se at all, but to procure it as part of an off-the-shelf subsystem. As we migrate to systems on a chip, this means the filter may entail intellectual property that has to be partitioned and protected, and yet has to be leveraged by the rest of the system. A sound systems-level architecture facilitates this process, while an inferior architecture inhibits it. The reduced time to market and cost efficiency of such buy-versus-make choices also require balancing the capabilities and design constraints given competing technical and economic constraints.

Software-radio is therefore an interdisciplinary technology, so this is an interdisciplinary text. The radio-oriented chapters are written for people with strong software background but little background in radio engineering. Software radio is about wideband radio frequency (RF) hardware that is given its "personality" by software. Therefore, the software people have to understand the RF hardware and air interface standards to the degree set forth in this

text in order to function effectively on an interdisciplinary team. Similarly, the software-oriented chapters are written for people with strong background in RF, analog radio, or DSP but little background with large-scale software. And software radio is increasingly about complex, large-scale software. One of the revolutionary aspects of software radio is that knowing how to code a radio algorithm in C on a DSP just doesn't give a software engineer the core skills needed to contribute effectively to software radio architecture. In fact, that experience becomes a liability if it causes one to minimize the importance of the new large-scale software engineering methods like CORBA.

In addition, European readers will have to be patient with the tutorial material on SDL, the ITU-standard Specification and Description Language. In teaching the software radios course on which this book is based, I have found that US engineers make little use of formal methods for specifying radio functions. ETSI's emphasis on formal methods and the widespread use of SDL in support of European standards-setting process has not reached across the Atlantic yet. As a result, U.S. practitioners of radio engineering often try to do with pencil and paper what their European counterparts do on a computer—define new air interface standards. This text's treatment of UML extends the SDL material.

This text has several companions. The first is the Special Issue of the IEEE *Journal on Selected Areas in Communication on Software Radios*, published in April 1999 by the IEEE (New York). This *JSAC* is a surrogate graduate-level text. As such, it addresses related graduate-level research topics including mathematical structure of the software radio, virtual radios, advanced digital filter ASICs, smart antennas, and other advanced techniques. The IEEE Press Compendium *Software Radio Technology* by Mitola and Zvonar extends the JSAC with both earlier and more recent technical papers. Prof. Friedrich Jondral's course text in German (U. Karlsruhe) relates fundamental digital radio to SDR.

The dedication of this text to the "public interest" envisions the resulting *affordable*, robust, high-quality radio services as beneficial to the public interest. If coalition partners can cooperate better using software radios in peacekeeping roles, then that serves the public interest. If governments can acquire radio platforms at lower and more predictable cost, then that makes resources available for other public priorities. The focus of this text is the architecture. In this text, architecture is defined as the consistent set of functions, components, and design rules that promote open-architecture evolution of complex radio systems.

The book is organized for ease of access by a variety of readers. Chapters 1–3 provide the high-level background needed for a general understanding of how software radio fits in the larger telecommunications technology. Systems engineers and program mangers should have a solid grasp of chapters 4 and 5 in order to lead architecture evolution. Program managers and software engineers need to pay particular attention to the discussion of complexity drivers. Like any other software-intensive project, software radios are subject to sub-

tle changes of the scope of the software. These chapters attempt to forewarn and thus forearm the team against factors that can drive software complexity and processing requirements out of the bounds of time, personnel, or processing capacity available on the project. The chapters on subsystems (6–12) focus on the requirements that software radio brings to the hardware and software segments. The software-oriented chapters are designed to be useful to hardware-oriented readers and the hardware-oriented chapters are designed to be useful to software-oriented readers. Sufficient basics on signal processing are included to provide a relatively self-contained treatment. The concluding chapters (13–16) provide examples of how to apply software radio architecture to create robust yet affordable multiband multi-mode communications systems.

I really enjoy interacting with those of you who are out there creating SDR systems and propelling the software radio evolution forward. Since you have purchased this text, you probably would like to use the knowledge you gain. A few spreadsheet design tools can help with some important aspects of that task. These are the software radio spreadsheets. You get access to them via the author's software radios web site. The URL is http://ourworld.compuserve.com/homepages/jmitola. The site is for folks who purchased this text. By following the instructions on the site, you can get access to the design aids. I also welcome questions from readers about this text, or anything in the area of software radio technology.

Best regards,

JOE MITOLA