

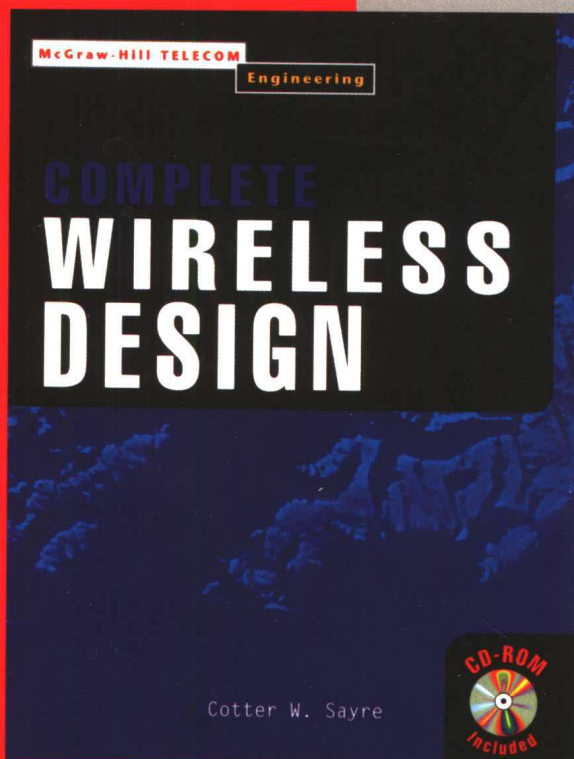


内附光盘

国外大学优秀教材 —— 通信系列 (影印版)

Cotter W. Sayre

完整无线设计



清华大学出版社

国外大学优秀教材 —— 通信系列（影印版）

完整无线设计

Complete Wireless Design

Cotter W. Sayre

清华大学出版社
北京

Cotter W. Sayre
Complete Wireless Design
EISBN: 0-07-137016-1

Copyright © 2001 by The McGraw-Hill Companies, Inc.

Original language published by The McGraw-Hill Companies, Inc. All Rights reserved. No part of this publication may be reproduced or distributed by any means, or stored in a database or retrieval system, without the prior written permission of the publisher.

Authorized English language edition jointly published by McGraw-Hill Education (Asia) Co. and Tsinghua University Press. This edition is authorized for sale only to the educational and training institutions, and within the territory of the People's Republic of China (excluding Hong Kong, Macao SAR and Taiwan). Unauthorized export of this edition is a violation of the Copyright Act. Violation of this Law is subject to Civil and Criminal Penalties.

本书英文影印版由清华大学出版社和美国麦格劳-希尔教育出版(亚洲)公司合作出版。此版本仅限在中华人民共和国境内(不包括中国香港、澳门特别行政区及中国台湾地区)针对教育及培训机构之销售。未经许可之出口,视为违反著作权法,将受法律之制裁。

未经出版者预先书面许可,不得以任何方式复制或抄袭本书的任何部分。

北京市版权局著作权合同登记号 图字:01-2004-4496

版权所有,翻印必究。举报电话:010-62782989 13801310933
本书封面贴有 McGraw-Hill 公司防伪标签,无标签者不得销售。

图书在版编目(CIP)数据

完整无线设计 = Complete Wireless Design / 塞伊尔(Sayre, C. W.)著. —影印本. —北京:清华大学出版社, 2004.12

(国外大学优秀教材——通信系列(影印版))

ISBN 7-302-10286-4

I. 完… II. 塞… III. 无线电通信—高等学校—教材—英文 IV. TN92

中国版本图书馆 CIP 数据核字(2004)第 143573 号

出版者:清华大学出版社

<http://www.tup.com.cn>

社总机:(010) 6277 0175

地址:北京清华大学学研大厦

邮编:100084

客户服务:(010) 6277 6969

责任编辑:田志明

印刷者:北京密云胶印厂

装订者:三河市春园印刷有限公司

发行者:新华书店总店北京发行所

开本:185×235 印张:35.125

版次:2004年12月第1版 2004年12月第1次印刷

书号:ISBN 7-302-10286-4/TN·229

印数:1~3000

定价:59.00元(含光盘)

本书如存在文字不清、漏印以及缺页、倒页、脱页等印装质量问题,请与清华大学出版社出版部联系调换。联系电话:(010) 62770175-3103 或 (010) 62795704

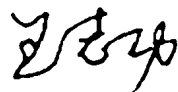
Complete Wireless Design

影印版序

近十多年来,以无线电波为媒体的移动通信、无线局域网等技术和产业呈爆炸式发展。无线系统特别是其中的射频电路设计成为世界范围内炙手可热的专业。一大批电子信息专业学生和技术人员渴求获得无线有关的知识、技术和经验。本书正是为适应这种需求而撰写的全面讨论无线设计的专业书。既可作为本科生的教学参考书,也可作为工程师和业余爱好者的自学教材。

本书分为十章。第一章简单介绍无线电的基本元器件和基础知识。基本元器件包括电阻、电容、电感和变压器等无源元件、二极管和三极管等半导体器件和微带线,基础知识包括传输线、S 参数和电波传播等。第二章介绍幅度调制、频率调制、单边带调制和数字调制,调制器与解调器集成电路设计。第三章讨论各种放大器的设计,包括小信号放大器、大信号放大器、微波单片放大器(MMIC)、宽带放大器、音频放大器与可变增益放大器(VGA)等,讨论了放大器偏置以及放大器的耦合与去耦等问题。第四章讨论压控振荡器(VCO)、LC 振荡器和晶体振荡器的设计。第五章讨论锁相环(PLL)和直接数字频率合成器的设计。第六章讨论集总参数、分布参数、双频、晶体、声表面波(SAW)、有源和可调谐等各种滤波器设计。第七章讨论有源和无源混频器设计。第八章讨论倍频器、射频开关、自动增益控制、衰减器、平衡非平衡转换(Balun)、分波器/合波器,电源和方向耦合器等一系列射频微波系统支持电路的设计。第九章讨论接收机和发射机的设计、链路的性能预算与完整系统的设计。第十章讨论器件与系统噪声、电磁干扰、射频电路底板设计、软件无线电、混合集成电路、直接变换接收机、原型机设计、天线、射频接头,无线设计软件、美国联邦通信委员会(FCC)的无线设备管理法等一系列无线电相关知识以及语音处理、自动频率控制和静噪电路等几种关联电路。本书带有一张光盘,刻录有一种称之为 Puff 的射频电路 CAD 软件。附录 A 给出了 Puff 的使用说明。

本书的特点是:代替众多复杂的数学推导过程,给出了一系列简明的计算公式;避免了纯粹的理论叙述,给出了大量的设计实例;从系统、电路、器件到测试和设计工具,内容全面,通俗易懂。可以相信,这本专著影印本的出版发行对我国移动通信、微波通信、卫星通信和无线局域网等射频电路与系统的人才培养和工程设计都将产生有益的帮助。



2004 年 12 月于东南大学

*To my lovely wife Linda, without whom this book
would not have been possible.*

Preface

Complete Wireless Design gives the reader a solid grounding in the latest radio-frequency (RF) design methods and communication circuits employed in today's wireless equipment and systems, and will assist any engineer, technician, or ham, to design—down to the circuit level—anything from a basic two-way radio to the wireless receivers and transmitters of a digital communications system.

Included with the book is a free and complete copy of Caltech's Puff RF/microwave circuit simulation software, along with Sonnet Lite's electromagnetic simulator, Agilent's AppCad RF design software, and National's PLL design programs.

Unlike many wireless books, *Complete Wireless Design* does not simply present predesigned circuits and expect readers to modify them in some haphazard fashion for their own wireless applications, nor does this book present overly complex equations for the design of wireless circuits and systems, which most readers, even engineers, would have difficulty understanding, much less applying. Instead, *Complete Wireless Design* allows the reader, using simple algebra, to design cutting-edge oscillators, amplifiers, mixers, filters, phase-locked loops (PLLs), frequency multipliers, RF switches, microstrip elements, automatic gain control (AGC) loops, power splitters, attenuators, and duplexers easily and quickly. This book will also explain the practical aspects of designing with radio-frequency integrated circuits (RFICs) and monolithic microwave integrated circuits (MMICs); and how to perform all the necessary calculations for impedance matching, perform wireless link analyses, complete a frequency plan, and integrate a complete communications system. The book covers vital high speed and circuit design issues as well.

Cotter W. Sayre

Acknowledgments

The author wishes to thank the following individuals for their assistance and contributions in giving permission to reproduce the enclosed RF software, as well as the software documentation:

David Rutledge of Caltech University, along with Richard Compton, Scott Wedge, and Andreas Gerstlauer, for the linear circuit simulator *PUFF*.

Dr. James C. Rautio, president of Sonnet Software, for the EM simulator *Sonnet Lite em*.

Christopher A. Schell, senior engineer at National Semiconductor, for *Codeloader* and *EasyPLL*.

Robert L. Myers, AppCad Program Manager, for Agilent's *AppCad*.

国外大学优秀教材——通信系列(影印版)

Mc
Graw
Hill Education

完整无线设计

Cotter W. Sayre

PUFFRF/Microwave电路仿真软件
Sonnet Lite电磁仿真软件
National's PLL设计程序
Agilent's AppCad电路设计程序

配书
(CD-ROM)
版权所有
侵权必究

技术支持: hull@tup.tsinghua.edu.cn

ISBN 7-89494-643-5



清华大学出版社
<http://www.tup.com.cn>

2004.12

Contents

Preface xi

Chapter 1. Wireless Essentials	1
1.1 Passive Components at RF	1
1.1.1 Introduction	1
1.1.2 Resistors	2
1.1.3 Capacitors	2
1.1.4 Inductors	4
1.1.5 Transformers	7
1.2 Semiconductors	9
1.2.1 Introduction	9
1.2.2 Diodes	10
1.2.3 Transistors	17
1.3 Microstrip	26
1.3.1 Introduction	26
1.3.2 Microstrip as Transmission Line	27
1.3.3 Microstrip as Equivalent Components	28
1.4 Transmission Lines	38
1.4.1 Introduction	38
1.4.2 Transmission Line Types	38
1.4.3 Transmission Line Issues	39
1.5 S-Parameters	39
1.5.1 Introduction	39
1.5.2 S-Parameter Measurement	43
1.6 Propagation	48
1.6.1 Introduction	48
1.6.2 Multipath	48
 Chapter 2. Modulation	 51
2.1 Amplitude Modulation	51
2.1.1 Introduction	51
2.1.2 Fundamentals	51
2.1.3 Power Measurement	56
2.1.4 Disadvantages	57

2.2 Frequency Modulation	57
2.2.1 Introduction	57
2.2.2 Fundamentals	57
2.2.3 FM and AM Comparisons	62
2.3 Single-Sideband Modulation	62
2.3.1 Introduction	62
2.3.2 Fundamentals	63
2.3.3 Modulation	64
2.3.4 Output Power	65
2.4 Digital Modulation	66
2.4.1 Introduction	66
2.4.2 Types of Digital Modulation	66
2.4.3 Power and Digital Signals	70
2.4.4 Digital Modulation Issues	72
2.5 Designing with Modulator/Demodulator I.C.s	81
2.5.1 Introduction	81
2.5.2 Designing with the RFMD RF2703	83
2.6 Digital Test and Measurement	86
2.6.1 Introduction	86
2.6.2 Common Digital Tests and Measurements	87
 Chapter 3. Amplifier Design	 99
3.1 Small Signal Amplifiers	111
3.1.1 Introduction	111
3.1.2 Amplifier Design with S-Parameters	112
3.1.3 Vector Algebra	121
3.1.4 Matching Networks	126
3.2 Large Signal Amplifiers	151
3.2.1 Introduction	151
3.2.2 Amplifier Design with Large Signal Series Equivalent Impedances	155
3.3 Amplifier Biasing	158
3.3.1 Introduction	158
3.3.2 Bias Designs	173
3.4 MMICs	187
3.4.1 Introduction	187
3.4.2 MMIC Biasing	188
3.4.3 MMIC Coupling and Decoupling	191
3.4.4 An MMIC Amplifier Circuit	192
3.4.5 MMIC Layout	193
3.5 Wideband Amplifier	194
3.5.1 Introduction	194
3.5.2 Design of Wideband Amplifiers	198
3.6 Parallel Amplifier	199
3.6.1 Introduction	199
3.6.2 Design of a Parallel MMIC Amplifier	201
3.7 Audio Amplifiers	202
3.7.1 Introduction	202
3.7.2 Design of an IC Audio Amplifier	203

3.8 VGA Amplifiers	204
3.8.1 Introduction	204
3.8.2 Design of VGA Amplifiers	204
3.9 Coupling/Decoupling of Amplifiers	206
3.9.1 Introduction	206
3.9.2 Design of Decoupling/Coupling Circuits	207
 Chapter 4. Oscillator Design	 213
4.1 Oscillator Simulation	216
4.1.1 Introduction	216
4.1.2 Open-Loop Design	216
4.2 VCO and LC Oscillators	224
4.2.1 Introduction	224
4.2.2 Types of <i>LC</i> Oscillators	224
4.2.3 Designing <i>LC</i> Oscillators and VCOs	227
4.2.4 Testing <i>LC</i> Oscillators	236
4.2.5 <i>LC</i> and VCO Oscillator Issues	236
4.3 Crystal Oscillators	240
4.3.1 Introduction	240
4.3.2 Types of Crystal Oscillators	242
4.3.3 Designing Crystal Oscillators	244
4.3.4 Crystal Oscillator Issues	249
4.3.5 Testing and Optimizing Crystal Oscillators	251
 Chapter 5. Frequency Synthesizer Design	 253
5.1 Phase-Locked Loops	253
5.1.1 Introduction	253
5.1.2 Designing Phase-Locked Loops	258
5.2 Direct Digital Synthesis	266
 Chapter 6. Filter Design	 271
6.1 Lumped Filters	278
6.1.1 Introduction	278
6.1.2 Types of Lumped Filters	279
6.1.3 Image-Parameter Design	280
6.2 Distributed Filters	290
6.2.1 Introduction	290
6.2.2 Types of Distributed Filters	292
6.2.3 Distributed Filter Design	293
6.2.4 Distributed Filter Issues	298
6.3 Diplexer Filters	299
6.3.1 Introduction	299
6.3.2 Diplexer Design	300
6.4 Crystal and SAW Filters	301
6.4.1 Introduction	301
6.4.2 Crystal and SAW Filter Issues	302

6.5 Active Filters	304
6.5.1 Introduction	304
6.5.2 Active Filter Design	305
6.6 Tunable Filters	307
6.6.1 Introduction	307
6.6.2 Tunable Filter Design	307
 Chapter 7. Mixer Design	 313
7.1 Passive Mixers	314
7.1.1 Introduction	314
7.1.2 Types of Passive Mixers	315
7.1.3 Passive Mixer Design	317
7.1.4 Passive Mixer Issues	319
7.2 Active Mixers	324
7.2.1 Introduction	324
7.2.2 Types of Active Mixers	324
7.2.3 Designing Active Mixers	327
7.2.4 Active Mixer Issues	331
 Chapter 8. Support Circuit Design	 333
8.1 Frequency Multipliers	333
8.1.1 Introduction	333
8.1.2 Frequency Multiplier Design	337
8.1.3 Frequency Multiplier Issues	340
8.2 RF Switches	342
8.2.1 Introduction	342
8.2.2 RF Switch Design	343
8.2.3 RF Switch Issues	348
8.3 Automatic Gain Control	349
8.3.1 Introduction	349
8.3.2 Automatic Gain Control Design	351
8.3.3 Automatic Gain Control Issues	356
8.4 Attenuators	357
8.4.1 Introduction	357
8.4.2 Fixed Attenuator Design	357
8.4.3 Variable-Attenuator Design	358
8.5 Baluns	360
8.5.1 Introduction	360
8.5.2 Balun Design	361
8.6 Splitters/Combiners	362
8.6.1 Introduction	362
8.6.2 Splitter and Combiner Design	362
8.7 Power Supplies	365
8.7.1 Introduction	365
8.7.2 Types of Power Supply Regulators	370
8.7.3 Regulator Design	373
8.8 Directional Couplers	377
8.8.1 Introduction	377
8.8.2 Directional Coupler Design	378

Chapter 9. Communication Systems Design	379
9.1 Receivers	379
9.1.1 Introduction	379
9.1.2 Receiver Design	380
9.1.3 Receiver Issues	388
9.2 Transmitters	389
9.2.1 Introduction	389
9.2.2 Transmitter Design	390
9.3 Link Budgets	393
9.3.1 Introduction	393
9.3.2 Link Budget Design	394
9.3.3 Will It Work?	397
9.4 The Complete System	401
9.4.1 Introduction	401
9.4.2 Wireless System Design	401
9.4.3 System Design with RFICs	406
9.4.4 System Issues	409
 Chapter 10. Wireless Issues	 413
10.1 Noise in Components and Systems	413
10.2 Electromagnetic Interference	414
10.2.1 Introduction	414
10.2.2 Designing for EMI Suppression	414
10.3 Wireless Board Design	417
10.3.1 Introduction	417
10.3.2 Board Materials	417
10.3.3 Board Layout	419
10.3.4 Board Design Issues	425
10.4 Software Radio	429
10.4.1 Introduction	429
10.4.2 Software Radio Designs	429
10.5 Hybrid Circuits	431
10.5.1 Introduction	431
10.5.2 Board and Conductor Materials	432
10.6 Direct-Conversion Receivers	433
10.6.1 Introduction	433
10.6.2 Direct-Conversion Issues	434
10.7 Prototyping	435
10.7.1 Introduction	435
10.7.2 Prototyping Considerations	435
10.8 Antennas	436
10.8.1 Introduction	436
10.8.2 Common Antenna Types	439
10.8.3 Antenna Issues	441
10.9 RF Connectors	442
10.9.1 Introduction	442
10.9.2 Types of RF Connectors	442
10.10 Wireless Design Software	443

10.10.1 Introduction	443
10.10.2 RF Programs	443
10.10.3 RF Software Issues	445
10.11 FCC Equipment Authorizations	448
10.11.1 Introduction	449
10.11.2 Wireless Equipment Law	449
10.12 Support Circuits	449
10.12.1 Introduction	451
10.12.2 Circuits	451
 Appendix A. Puff Manual	 459
 Appendix B. Useful Tables	 519
 Glossary	 523
 Bibliography	 539
Index	543

Wireless Essentials

A firm understanding of how passive and active components function at high frequencies, as well as a strong grasp of the fundamental concepts of lumped and distributed transmission lines, S -parameters, and radio-frequency (RF) propagation, is essential to successful circuit design.

1.1 Passive Components at RF

1.1.1 Introduction

At radio frequencies, lumped (physical) resistors, capacitors, and inductors are not the “pure” components they are assumed to be at lower frequencies. As shown in Fig. 1.1, their true nature at higher frequencies has undesirable resistances, capacitances, and inductances—which must be taken into account during design, simulation, and layout of any wireless circuit.

At microwave frequencies the lengths of all component leads have to be minimized in order to decrease losses due to lead inductance, while even the board traces that connect these passive components must be converted to transmission line structures. *Surface mount devices* (SMDs) are perfect for decreasing this lead length, and thus the series inductance, of any component (Fig. 1.2), while the most common transmission line structure is *microstrip*, which maintains a 50-ohm constant impedance throughout its length—and without adding inductance or capacitance.

As the frequency of operation of any wireless circuit begins to increase, so does the requirement that the actual physical structure of all of the lumped components themselves be as small as possible, since the part’s effective frequency of operation increases as it shrinks in size: the smaller package lowers the harmful distributed reactances and series or parallel resonances.


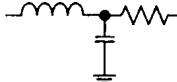
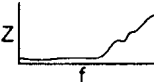
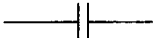
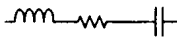
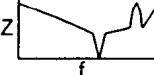

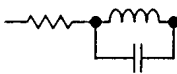
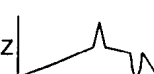

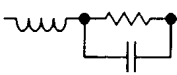
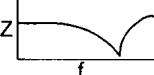
COMPONENT	LF BEHAVIOR	HF BEHAVIOR	RESPONSE
WIRE			
CAPACITOR			
INDUCTOR			
RESISTOR			

Figure 1.1 A component's real-life behavior at high frequencies (HF) and low frequencies (LF).

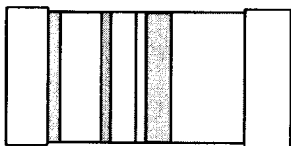


Figure 1.2 A surface mount resistor.

1.1.2 Resistors

As shown in Fig. 1.3, a resistor's actual value will begin to decrease as the frequency of operation is increased. This is caused by the distributed capacitance that is always effectively in parallel with the resistor, shunting the signal around the component; thus lowering its effective value of resistance. As shown in the figure, this distributed capacitance is especially problematic not only as the frequency increases, but also as the resistance values increase. If the resistor is not of the high-frequency, thin-film type, a high-value resistor can lose much of its marked resistance to this capacitive effect at relatively low microwave frequencies. And since the series inductance of the leads of the surface-mount technology resistor are typically quite low, the added reactive effect is negligible in assisting the resistor in maintaining its marked resistance value.

1.1.3 Capacitors

Capacitors at RF and microwave frequencies must be chosen not only for their cost and temperature stability, but also for their ability to properly function at these high frequencies. As shown in Fig. 1.1, a capacitor has an undesired lead inductance that begins to adversely change the capacitor's characteristics as

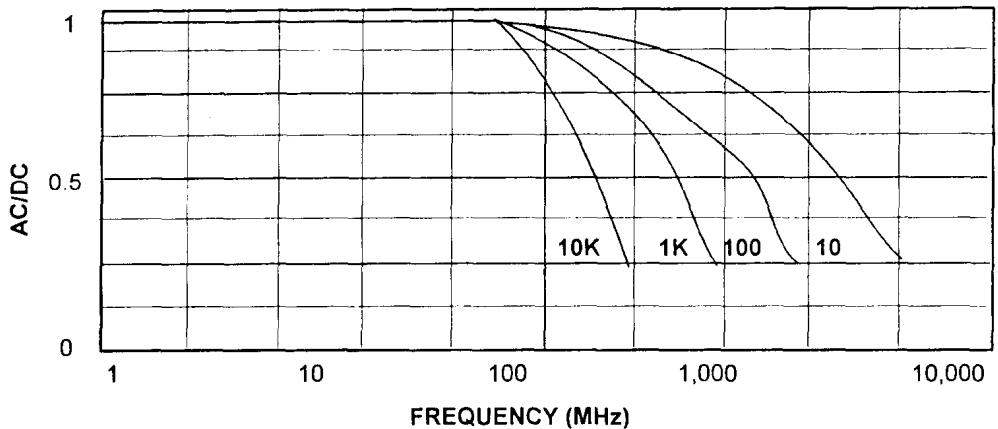


Figure 1.3 Ratio of an SMD resistor's resistance at DC to its resistance at AC for increasing frequencies.

the frequency is increased. This effect is most pronounced if the lead inductance resonates with the capacitance of the physical capacitor, resulting in a series resonance—or a total reactance of nearly *zero* ohms (resonating a capacitor can also be purposeful: a *j0 capacitor* is the type that becomes series resonant at the frequency of interest by resonating its own parasitic inductance with its own small value of marked capacitance, which creates a very low series impedance, perfect for coupling and decoupling at very high frequencies). Above this series resonant frequency the capacitor itself will actually become more inductive than capacitive, making it quite important to confirm that the circuit's design frequency will not be over the series resonance of the capacitor. This is vital for coupling and decoupling functions, while a capacitor for tuned circuits should have a series resonance comfortably *well above* the design frequency. The higher the value of the capacitor, the lower the frequency of this series resonance—and thus the closer the capacitor is to its inductive region. Consequently, a higher-value capacitor will demonstrate a higher inductance, on average, than a smaller value capacitor. This makes it necessary to compromise between the capacitive reactance of the capacitor in coupling applications and its series resonance. In other words, a coupling capacitor that is expected to have a capacitive reactance at the frequency of interest of 0.1 ohm may actually be a much poorer choice than one that has a capacitive reactance of 5 ohms—unless the capacitor is chosen to operate as a *j0* type.

Only certain capacitor classifications are able to function at both higher frequencies *and* over real-life temperature ranges while maintaining their capacitance tolerance to within manageable levels. The following paragraphs discuss the various capacitor types and their uses in wireless circuits:

Electrolytic capacitors, both aluminum and tantalum, are utilized for very low frequency coupling and decoupling tasks. They have poor *equivalent series resistance* (ESR) and high DC leakage through the dielectric, and most are