

国外电子与通信教材系列

英文版

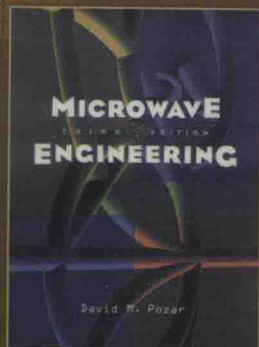


# 微波工程

(第三版)

Microwave Engineering

Third Edition



[美] David M. Pozar 著



电子工业出版社

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# 微波工程 (第三版) 英文版

## Microwave Engineering, Third Edition

本书改编自 David M. Pozar 所著的 *Microwave Engineering, Third Edition* 一书, 删除了原书中介绍铁氧体元件理论与设计的第 9 章, 以及分析微波系统的第 13 章, 因为这两章的内容介绍较为简单, 且市面上有专著论述。第 1 章至第 4 章介绍了电磁场的基本理论和电路理论, 第 5 章至第 11 章利用相关的概念阐明了各种微波电路和器件。在基本理论方面, 本书介绍了经典的电磁场理论, 叙述了现代微波工程中常用的分布电路和网络分析方法。在微波电路和器件方面, 增加了平面结构元件和集成电路的设计、振荡器的相位噪声、晶体管功率放大器、非线性效应以及当今微波工程师经常使用的工具等内容。在每章结尾提供了习题, 并在书末提供了部分习题的答案, 可供教师选用和学生自测。

### 本书新特性

- 内容得到了更新和修改: 第三版在容性耦合谐振腔滤波器、射频 MEMS、晶体管功率放大器、晶体管振荡器、倍频器、振荡器的相位噪声以及 FET 混频器方面提供了新内容
- 很多例题包含有理论与设计: 所有例题均展示了典型问题是如何求解的、典型设计是如何进行的以及典型元件的设计是如何完成的
- 习题广泛多样性: 所有习题 (其中很多是新的或经修改的) 既有理论又有设计内容
- 对微波工程如何做和为什么做两者进行了讨论
- 网上的其他资源: 本书的网站中包括有来自马萨诸塞大学的实验室实验手册以及用 Ansoft 公司的 SERENADE Microwave CAD 软件包编写的有关本书中一些例题和习题的文件

本书的习题解答手册可通过 Wiley 的如下网站为得到授权的老师提供, 同时老师和学生也可通过该网站免费获得许多例题和习题中使用的数据文件: [www.wiley.com/college/pozar](http://www.wiley.com/college/pozar)。



**David M. Pozar:** 美国马萨诸塞大学电气与计算机工程教授, IEEE 会士, 多个期刊的主编、副主编。在天线与射频领域出版专著、教材多本, 发表论文多篇, 同时在教学与科研领域多次获奖。目前的研究方向为天线与射频电路设计、超宽带无线通信、微带天线与相控阵天线等。

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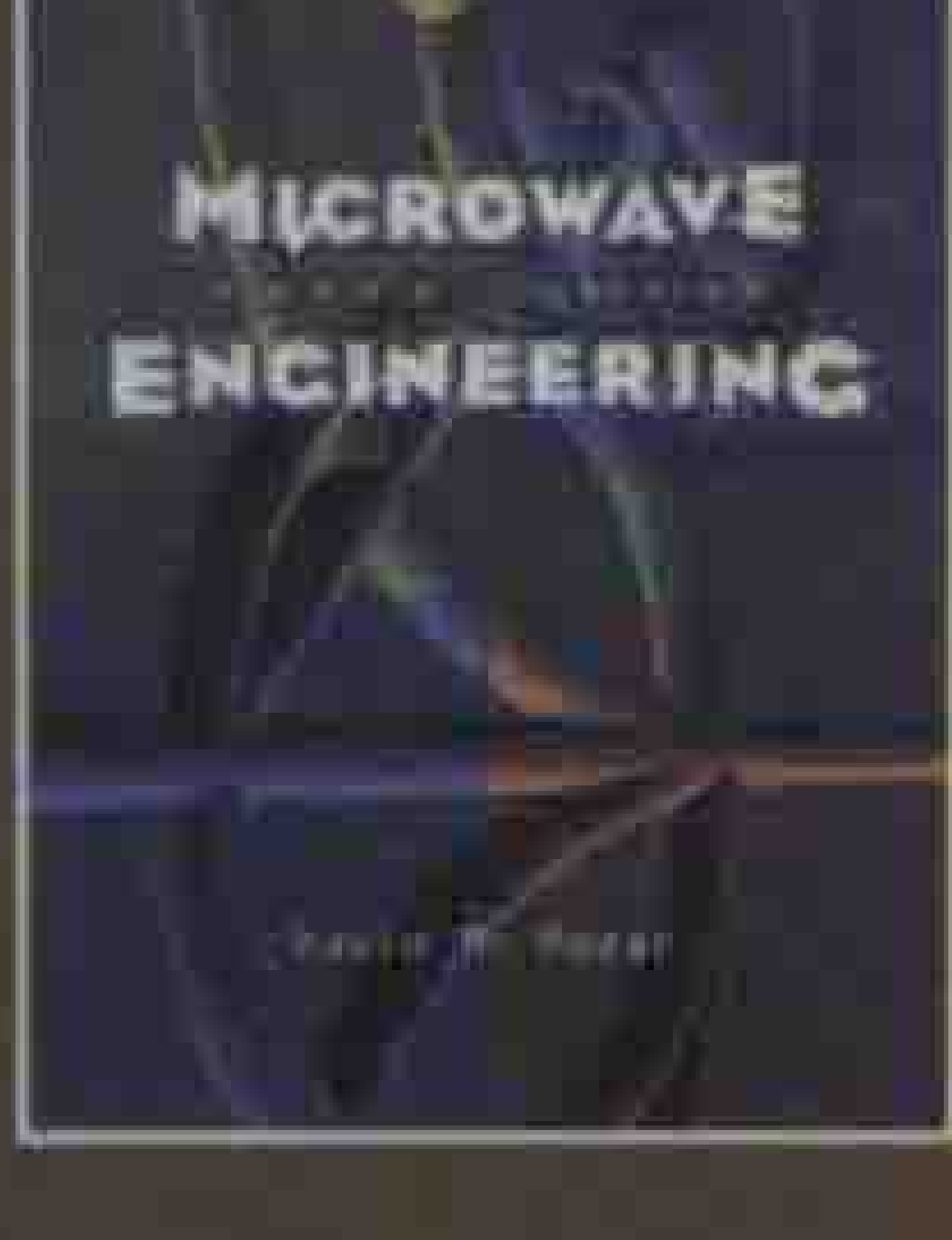
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北京 · BEIJING

## 内 容 简 介

本书改编自 David M. Pozar 所著的 *Microwave Engineering, Third Edition* 一书, 删除了原书中介绍铁氧体元件理论与设计的第 9 章, 以及分析微波系统的第 13 章, 因为这两章的内容介绍较为简单, 且市面上有专著论述。第 1 章至第 4 章介绍了电磁场的基本理论和电路理论, 第 5 章至第 11 章利用相关的概念阐明了各种微波电路和器件。在基本理论方面, 本书介绍了经典的电磁场理论, 叙述了现代微波工程中常用的分布电路和网络分析方法。在微波电路和器件方面, 增加了平面结构元件和集成电路的设计、振荡器的相位噪声、晶体管功率放大器、非线性效应以及当今微波工程师经常使用的工具等内容。在每章结尾提供了习题, 并在书末提供了部分习题的答案, 可供教师选用和学生自测。

该书可作为高年级本科生或研究生的微波工程教材, 也可作为微波电路及器件研制和开发的工程技术人员参考书。

David M. Pozar: **Microwave Engineering, Third Edition.**

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## 序

2001年7月间,电子工业出版社的领导同志邀请各高校十几位通信领域方面的老师,商量引进国外教材问题。与会同志对出版社提出的计划十分赞同,大家认为,这对我国通信事业、特别是对高等院校通信学科的教学工作会很有好处。

教材建设是高校教学建设的主要内容之一。编写、出版一本好的教材,意味着开设了一门好的课程,甚至可能预示着一个崭新学科的诞生。20世纪40年代MIT林肯实验室出版的一套28本雷达丛书,对近代电子学科、特别是对雷达技术的推动作用,就是一个很好的例子。


我国领导部门对教材建设一直非常重视。20世纪80年代,在原教委教材编审委员会的领导下,汇集了高等院校几百位富有教学经验的专家,编写、出版了一大批教材;很多院校还根据学校的特点和需要,陆续编写了大量的讲义和参考书。这些教材对高校的教学工作发挥了极好的作用。近年来,随着教学改革不断深入和科学技术的飞速进步,有的教材内容已比较陈旧、落后,难以适应教学的要求,特别是在电子学和通信技术发展神速、可以讲是日新月异的今天,如何适应这种情况,更是一个必须认真考虑的问题。解决这个问题,除了依靠高校的老教师和专家撰写新的符合要求的教科书外,引进和出版一些国外优秀电子与通信教材,尤其是有选择地引进一批英文原版教材,是会有好处的。

一年多来,电子工业出版社为此做了很多工作。他们成立了一个“国外电子与通信教材系列”项目组,选派了富有经验的业务骨干负责有关工作,收集了230余种通信教材和参考书的详细资料,调来了100余种原版教材样书,依靠由20余位专家组成的出版委员会,从中精选了40多种,内容丰富,覆盖了电路理论与应用、信号与系统、数字信号处理、微电子、通信系统、电磁场与微波等方面,既可作为通信专业本科生和研究生的教学用书,也可作为有关专业人员的参考材料。此外,这批教材,有的翻译为中文,还有部分教材直接影印出版,以供教师用英语直接授课。希望这些教材的引进和出版对高校通信教学和教材改革能起一定作用。

在这里,我还要感谢参加工作的各位教授、专家、老师与参加翻译、编辑和出版的同志们。各位专家认真负责、严谨细致、不辞辛劳、不怕琐碎和精益求精的态度,充分体现了中国教育工作者和出版工作者的良好美德。

随着我国经济建设的发展和科学技术的不断进步,对高校教学工作会不断提出新的要求和希望。我想,无论如何,要做好引进国外教材的工作,一定要联系我国的实际。教材和学术专著不同,既要注意科学性、学术性,也要重视可读性,要深入浅出,便于读者自学;引进的教材要适应高校教学改革的需要,针对目前一些教材内容较为陈旧的问题,有目的地引进一些先进的和正在发展中的交叉学科的参考书;要与国内出版的教材相配套,安排好出版英文原版教材和翻译教材的比例。我们努力使这套教材能尽量满足上述要求,希望它们能放在学生们的课桌上,发挥一定的作用。

最后,预祝“国外电子与通信教材系列”项目取得成功,为我国电子与通信教学和通信产业的发展培土施肥。也恳切希望读者能对这些书籍的不足之处、特别是翻译中存在的问题,提出意见和建议,以便再版时更正。



中国工程院院士、清华大学教授  
“国外电子与通信教材系列”出版委员会主任



## 出版说明

进入21世纪以来,我国信息产业在生产和科研方面都大大加快了发展速度,并已成为国民经济发展的支柱产业之一。但是,与世界上其他信息产业发达的国家相比,我国在技术开发、教育培训等方面都还存在着较大的差距。特别是在加入WTO后的今天,我国信息产业面临着国外竞争对手的严峻挑战。

作为我国信息产业的专业科技出版社,我们始终关注着全球电子信息技术的发展方向,始终把引进国外优秀电子与通信信息技术教材和专业书籍放在我们工作的重要位置上。在2000年至2001年间,我社先后从世界著名出版公司引进出版了40余种教材,形成了一套“国外计算机科学教材系列”,在全国高校以及科研部门中受到了欢迎和好评,得到了计算机领域的广大教师与科研工作者的充分肯定。

引进和出版一些国外优秀电子与通信教材,尤其是有选择地引进一批英文原版教材,将有助于我国信息产业培养具有国际竞争能力的技术人才,也将有助于我国国内在电子与通信教学工作中掌握和跟踪国际发展水平。根据国内信息产业的现状、教育部《关于“十五”期间普通高等教育教材建设与改革的意见》的指示精神以及高等院校老师们反映的各种意见,我们决定引进“国外电子与通信教材系列”,并随后开展了大量准备工作。此次引进的国外电子与通信教材均来自国际著名出版商,其中影印教材约占一半。教材内容涉及的学科方向包括电路理论与应用、信号与系统、数字信号处理、微电子、通信系统、电磁场与微波等,其中既有本科专业课程教材,也有研究生课程教材,以适应不同院系、不同专业、不同层次的师生对教材的需求,广大师生可自由选择 and 自由组合使用。我们还将与国外出版商一起,陆续推出一些教材的教学支持资料,为授课教师提供帮助。

此外,“国外电子与通信教材系列”的引进和出版工作得到了教育部高等教育司的大力支持和帮助,其中的部分引进教材已通过“教育部高等学校电子信息科学与工程类专业教学指导委员会”的审核,并得到教育部高等教育司的批准,纳入了“教育部高等教育司推荐——国外优秀信息科学与技术系列教学用书”。

为做好该系列教材的翻译工作,我们聘请了清华大学、北京大学、北京邮电大学、南京邮电大学、东南大学、西安交通大学、天津大学、西安电子科技大学、电子科技大学、中山大学、哈尔滨工业大学、西南交通大学等著名高校的教授和骨干教师参与教材的翻译和审校工作。许多教授在国内电子与通信专业领域享有较高的声望,具有丰富的教学经验,他们的渊博学识从根本上保证了教材的翻译质量和专业学术方面的严格与准确。我们在此对他们的辛勤工作与贡献表示衷心的感谢。此外,对于编辑的选择,我们达到了专业对口;对于从英文原书中发现的错误,我们通过与作者联络、从网上下载勘误表等方式,逐一进行了修订;同时,我们对审校、排版、印制质量进行了严格把关。

今后,我们将进一步加强同各高校教师的密切关系,努力引进更多的国外优秀教材和教学参考书,为我国电子与通信教材达到世界先进水平而努力。由于我们对国内外电子与通信教育的发展仍存在一些认识上的不足,在选题、翻译、出版等方面的工作中还有许多需要改进的地方,恳请广大师生和读者提出批评及建议。

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## Preface

Because education should be the accumulation of understanding, not just an accumulation of facts, I have tried to write a textbook that emphasizes the fundamental concepts of electromagnetics, wave propagation, network analysis, and design principles as applied to modern microwave engineering. Although I have avoided the handbook approach, in which a large amount of information is presented with little or no explanation or context, a considerable amount of material in this book is related to the design of specific microwave circuits and components, for both practical and motivational value. I have tried to present the analysis and logic behind these designs so that the reader can see and understand the process of applying fundamental concepts to arrive at useful results. The engineer who has a firm grasp of the basic concepts and principles of microwave engineering, and has seen how these can be applied toward a specific design objective, is the engineer who is most likely to be rewarded with a creative and productive career.

Modern microwave engineering involves predominantly distributed circuit analysis and design, in contrast to the waveguide and field theory orientation of earlier generations. The majority of microwave engineers today design planar components and integrated circuits without direct recourse to electromagnetic analysis. Microwave computer-aided design (CAD) software and network analyzers are the essential tools of today's microwave engineer, and microwave engineering education must respond to this shift in emphasis to network analysis, planar circuits and components, and active circuit design. Microwave engineering will always involve electromagnetics (many of the more sophisticated microwave CAD packages implement rigorous field theory solutions), and students will still benefit from an exposure to subjects such as waveguide modes and coupling through apertures, but the change in emphasis to microwave circuit analysis and design is clear.

Microwave and RF technology is more pervasive than ever. This is especially true in the commercial sector, where modern applications include cellular telephony, personal communications systems, wireless local area data networks, millimeter wave collision avoidance vehicle radars, direct broadcast satellites for radio and television, global positioning systems, radio frequency identification tagging, ultra wideband radio and radar systems, and microwave remote sensing systems for the environment. Defense systems continue to rely heavily on microwave technology for passive and active sensing, communications, and weapons control systems. This state of affairs suggests that there will be no shortage of challenging problems in RF and microwave engineering in the foreseeable future, and a clear need for engineers having both an understanding of the fundamentals of microwave engineering as well as the creativity to apply this knowledge to problems of practical interest.

The success of the first two editions of *Microwave Engineering* has been gratifying. For this edition we solicited detailed feedback from teachers and readers for their thoughts about what topics should be deleted and added. There was almost no agreement on specific material to remove (it seemed that almost every topic in the book was being used by someone). There was, however, fairly uniform agreement in favor of more material on active circuit design and related topics. To this end we have increased the number of chapters from 12 to 13 and have added new material on noise, nonlinear effects, RF MEMs, diode and transistor device characteristics, transistor power amplifiers, FET mixers, transistor oscillators, oscillator phase noise, and frequency multipliers. Sections on intermodulation products, dynamic range, mixers, antennas, and receiver design have been completely rewritten. Numerous new or revised examples and problems have been added, with several of these related to practical design problems involving planar circuits and components. Another new feature of this edition is a list of *Answers to Selected Problems* at the end of the book. Topics that have been cut for this edition include the uniqueness theorem, Fabry-Perot resonators, electronic warfare, and some examples related to waveguides.

This text is written for a two-semester course in microwave engineering, for seniors or first-year graduate students. If students have a good background in undergraduate electromagnetics, the material in Chapters 1 and 2 can be reviewed fairly quickly. Students with less background should study this material in more detail. Chapters 3–11 can then be followed in sequence, but it is likely that the instructor will want to choose between a field theory emphasis, or more of a circuit design emphasis. Alternatively, it is possible to focus exclusively on microwave circuit design, avoiding the material on electromagnetic analysis.

Two important items that should be included in a successful course on microwave engineering are the use of computer-aided design (CAD) simulation software and a microwave laboratory experience. Providing students with access to CAD software allows them to verify results of the design-oriented problems in the text, giving immediate feedback that builds confidence and makes the effort more rewarding. Because the drudgery of repetitive calculation is eliminated, students can easily try alternative approaches and explore problems in more detail. The effect of line losses, for example, is explored in several examples and problems—this would be effectively impossible without the use of modern CAD tools. In addition, classroom exposure to CAD tools provides useful experience upon graduation. Most of the commercially available microwave CAD tools are very expensive, but several manufacturers provide academic discounts or free “student versions” of their products. Ansoft Corporation, for example, has a student version of their popular SERENADE package available for free download at their Web site ([www.ansoft.com](http://www.ansoft.com)).

A hands-on microwave instructional laboratory is expensive to equip but provides the best way for students to develop an intuition and physical feeling for microwave phenomena. A laboratory with the first semester of the course might cover the measurement of microwave power, frequency, standing wave ratio, impedance, and *S*-parameters, as well as the characterization of basic microwave components such as tuners, couplers, resonators, loads, circulators, and filters. Important practical knowledge about connectors, waveguides, and microwave test equipment will be acquired in this way. Alternatively, a more advanced laboratory session can consider topics such as noise figure, intermodulation distortion, and mixing. Naturally, the type of experiments that can be offered is heavily dependent on the test equipment that is available.

With this edition we are able to make available several resources for students and instructors on the Wiley Web site. A sample instructional laboratory manual, along with SERENADE circuit files for many of the problems and examples in the text, can be found at [www.wiley.com/college/pozar](http://www.wiley.com/college/pozar). An on-line solution manual for all problems in the

text is available to qualified instructors, who may apply for access through the Web site [www.wiley.com/college/pozar](http://www.wiley.com/college/pozar) and going to the Instructor's Companion Site.

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David M. Pozar  
Amherst, MA

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