国际知名大学原版教材——信息技术学科与电气工程学科系列 27

Satellite Communications
(Third Edition)

卫星通信（第3版）

Dennis Roddy

McGraw Hill

清华大学出版社

EISBN: 0-07-137176-1
Satellite Communications, Third Edition
Dennis Roddy

北京市版权局著作权合同登记号：图字：01-2002-5388

图书在版编目（CIP）数据

卫星通信/（加）罗迪著．—影印本．—北京：清华大学出版社，2002
书名原文：Satellite Communications
（国际知名大学原版教材——信息技术学科与电气工程学科系列）
ISBN 7-302-06170-X

Ⅰ．卫… Ⅱ．罗… Ⅲ．卫星通信－教材－英文 Ⅳ．TN927

中国版本图书馆 CIP 数据核字（2002）第 104956 号

出版者：清华大学出版社（北京清华大学学研大厦，邮编 100084）
http:// www.tup.tsinghua.edu.cn
印刷者：北京四季青印刷厂
发行者：新华书店总店北京发行所
开　本：787×960 1/16　**印张**：37
版　次：2003 年 1 月第 1 版　2003 年 1 月第 1 次印刷
书　号：ISBN 7-302-06170-X/TN・134
印　数：0001～5000
定　价：49.50 元

国际知名大学原版教材
——信息技术学科与电气工程学科系列

出　版　说　明

郑大钟
清华大学信息科学与技术学院

当前，在我国的高等学校中，教学内容和课程体系的改革已经成为教学改革中的一个非常突出的问题，而为数不少的课程教材中普遍存在“课程体系老化，内容落伍时代，本研层次不清”的现象又是其中的急需改变的一个重要方面。同时，随着科教兴国方针的贯彻落实，要求我们进一步转变观念扩大视野，使教学过程适应以信息技术为先导的技术革命和我国社会主义市场经济的需要，加快教学过程的国际化进程。在这方面，系统地研究和借鉴国外知名大学的相关教材，将会对推进我们的课程改革和推进我国大学教学的国际化进程，乃至对我们一些重点大学建设国际一流大学的努力，都将具有重要的借鉴推动作用。正是基于这种背景，我们决定在国内推出信息技术学科和电气工程学科国外知名大学原版系列教材。

本系列教材的组编将遵循如下的几点基本原则。(1) 书目的范围限于信息技术学科和电气工程学科所属专业的技术基础课和主要的专业课。(2) 教材的范围选自于具有较大影响且为国外知名大学所采用的教材。(3) 教材属于在近 5 年内所出版的新书或新版书。(4) 教材适合于作为我国大学相应课程的教材或主要教学参考书。(5) 每本列选的教材都须经过国内相应领域的资深专家审看和推荐。(6) 教材的形式直接以英文原版形式印刷出版。

本系列教材将按分期分批的方式组织出版。为了便于使用本系列教材的相关教师和学生从学科和教学的角度对其在体系和内容上的特点和特色有所了解，在每本教材中都附有我们所约请的相关领域资深教授撰写的影印版序言。此外，出于多样化的考虑，对于某些基本类型的课程，我们还同时列选了多于一本的不同体系、不同风格和不同层次的教材，以供不同要求和不同学时的同类课程的选用。

本系列教材的读者对象为信息技术学科和电气工程学科所属各专业的本科生，同时兼顾其他工程学科专业的本科生或研究生。本系列教材，既可采用作为相应课程的教材或教学参考书，也可提供作为工作于各个技术领域的工程师和技术人员的自学读物。

组编这套国外知名大学原版系列教材是一个尝试。不管是书目确定的合理性，教材选择的恰当性，还是评论看法的确切性，都有待于通过使用和实践来检验。感谢使用本系列教材的广大教师和学生的支持。期望广大读者提出意见和建议。

Satellite Communications

(Third Edition)

影印版序

自 1965 年世界上第一颗商用同步卫星成功发射以来，卫星通信因其覆盖面积大、组网灵活、机动性好、频带宽、容量大等特点，而得到长足的发展。现已成为一种不可或缺的、重要的通信手段。对于幅员辽阔的国家和低人口密度的地区，卫星通信更具有特殊的地位，是快捷、可靠的通信方式。在我国西部大开发中卫星通信必将发挥重要的作用。

目前，国内外全面论述卫星通信原理的书籍不多，Dennis Roddy 所著 Satellite Communications 一书最初是为加拿大 Lakehead 大学高年级本科生撰写的教材。自 1989 年第一次出版以来，在美国和加拿大被广为采用，已两次改版。这里影印的是 2001 年由 McGraw-Hill 出版的第三版。本书主要阐述卫星通信的基本原理，其内容覆盖：卫星轨道、电波传播、天线、卫星星体构造、地面站组成、调制方式、纠错编码、链路计算、卫星干扰、多址方式等。与第二版相比，第三版中加强了同步轨道、纠错编码、雨衰、码多分址、数字电视卫星直播、卫星移动通信等内容，特别是增加了卫星因特网的内容，全书篇幅由 516 页增加为 569 页。

本书结合实际系统论述概念和原理，实用性强，数学公式少，数学工具只是作为必不可少时的一种表达。每章后附有习题，其部分习题答案在附录 A 中给出。书后还给出了一些有价值的参考文献和有关卫星系统的网址。这些参考文献和网址对于打算进一步深入探讨卫星通信有关内容的读者来说，无疑是有助的。

本书可以作为通信专业大学教材，也可以作为卫星通信领域工程技术人员的参考书。

曹志刚
清华大学电子工程系
2002 年 11 月

Preface

In keeping with the objectives of the previous editions, the third edition is intended to provide broad coverage of satellite communications systems, while maintaining sufficient depth to lay the foundations for more advanced studies. Mathematics is used as a tool to illustrate physical situations and obtain quantitative results, but lengthy mathematical derivations are avoided. Numerical problems and examples can be worked out using a good calculator or any of the excellent mathematical computer packages readily available. Mathcad™ is an excellent tool for this purpose and is used in many of the text examples. The basic Mathcad notation and operations are explained in Appendix H. In calculating satellite link performance, extensive use is made of decibels and related units. The reader who is not familiar with some of the more specialized of these units will find them explained in Appendix G.

The main additions to the third edition relate to digital satellite services. These have expanded rapidly, especially in the areas of Direct Broadcast Satellite Services (mainly television), and the Internet; new chapters have been introduced on these topics. Error detection and correction is an essential feature of digital transmission, and a separate chapter is given to this topic as well. The section on code-division multiple access, another digital transmission method, has been expanded.

As in the previous editions, the basic ideas of orbital mechanics are covered in Chap. 2. However, because of the unique position and requirements of the geostationary orbit, this subject has been presented in a chapter of its own. Use of non-geostationary satellites has increased significantly, and some of the newer systems utilizing *low earth orbits* (LEOs) and *medium earth orbits* (MEOs), as proposed for Internet use, are described. Iridium, a 66 LEO system that had been designed to provide mobile communications services on a global scale, declared bankruptcy in 2000 and the service was discontinued. For

Mathcad is a registered trademark of Mathsoft Inc.

this reason, the description of Iridium was not carried through into the new edition. In December 2000 a new company, Iridium Satellite LLC., was formed. Details of the company and the services offered or proposed will be found at http://www.iridium.com/. Considerable use has been made of the World Wide Web in updating the previous edition, and the web sites are referenced in the text. Listings of artificial satellites, previously appended in tabular form, can now be found at the web sites referenced in Appendix D; these listings have the advantage of being kept current.

Much of the information in a book of this nature has to be obtained from companies, professional organizations, and government departments. These sources are acknowledged in the text, and the author would like to thank the personnel who responded to his requests for information. Thanks go to the students at Lakehead University who suggested improvements and provided corrections to the drafts used in classroom teaching; to Dr. Henry Driver of Computer Sciences Corporation who sent in comprehensive corrections and references for the calculation of geodetic position. The author welcomes readers' comments and suggestions and he can be reached by email at dennis.roddy@lakeheadu.ca. Thanks also go to Carol Levine for the friendly way in which she kept the editorial process on schedule, and to Steve Chapman, the sponsoring editor, for providing the impetus to work on the third edition.

Dennis Roddy
Thunder Bay, Ontario
January 2001

Satellite Communications

(Third Edition)

Dennis Roddy

Tsinghua University Press

Contents

Chapter

1

Overview of Satellite Systems

1.1 Introduction

The use of satellites in communications systems is very much a fact of everyday life, as is evidenced by the many homes which are equipped with antennas, or "dishes," used for reception of satellite television. What may not be so well known is that satellites form an essential part of telecommunications systems worldwide, carrying large amounts of data and telephone traffic in addition to television signals.

Satellites offer a number of features not readily available with other means of communications. Because very large areas of the earth are visible from a satellite, the satellite can form the star point of a communications net linking together many users simultaneously, users who may be widely separated geographically. The same feature enables satellites to provide communications links to remote communities in sparsely populated areas which are difficult to access by other means. Of course, satellite signals ignore political boundaries as well as geographic ones, which may or may not be a desirable feature.

To give some idea of cost, the construction and launch costs of the Canadian Anik-E1 satellite (in 1994 Canadian dollars) were $281.2 million, and the Anik-E2, $290.5 million. The combined launch insurance for both satellites was $95.5 million. A feature of any satellite system is that the cost is *distance insensitive,* meaning that it costs about the same to provide a satellite communications link over a short distance as it does over a large distance. Thus a satellite communications system is economical only where the system is in continuous use and the costs can be reasonably spread over a large number of users.

Satellites are also used for remote sensing, examples being the detection of water pollution and the monitoring and reporting of weather conditions. Some of these remote sensing satellites also form a vital link in search and rescue operations for downed aircraft and the like.

A good overview of the role of satellites is given by Pritchard (1984) and Brown (1981). To provide a general overview of satellite systems here, three different types of applications are briefly described in this chapter: (1) the largest international system, Intelsat, (2) the domestic satellite system in the United States, Domsat, and (3) U.S. National Oceanographic and Atmospheric Administration (NOAA) series of polar orbiting satellites used for environmental monitoring and search and rescue.

1.2 Frequency Allocations for Satellite Services

Allocating frequencies to satellite services is a complicated process which requires international coordination and planning. This is carried out under the auspices of the International Telecommunication Union. To facilitate frequency planning, the world is divided into three regions:

Region 1: Europe, Africa, what was formerly the Soviet Union, and Mongolia

Region 2: North and South America and Greenland

Region 3: Asia (excluding region 1 areas), Australia, and the southwest Pacific

Within these regions, frequency bands are allocated to various satellite services, although a given service may be allocated different frequency bands in different regions. Some of the services provided by satellites are

Fixed satellite service (FSS)

Broadcasting satellite service (BSS)

Mobile satellite services

Navigational satellite services

Meteorological satellite services

There are many subdivisions within these broad classifications; for example, the fixed satellite service provides links for existing telephone networks as well as for transmitting television signals to cable companies for distribution over cable systems. Broadcasting satellite services are intended mainly for direct broadcast to the home, sometimes referred to as *direct broadcast satellite* (DBS) service [in Europe it may be known as *direct-to-home* (DTH) service]. Mobile satellite services would include land mobile, maritime mobile, and aeronautical mobile. Navigational satellite services include global positioning systems, and satellites intended for the meterorological services often provide a search and rescue service.

Table 1.1 lists the frequency band designations in common use for satellite services. The Ku band signifies the band *u*nder the K band, and the Ka band is the band *a*bove the K band. The Ku band is the one used at present for direct broadcast satellites, and it is also used for certain fixed satellite services. The C band is used for fixed satellite services, and no direct broadcast services are allowed in this band. The VHF band is used for certain mobile and navigational services and for data transfer from weather satellites. The L band is used for mobile satellite services and navigation systems. For the fixed satellite service in the C band, the most widely used subrange is approximately 4 to 6 GHz. The higher frequency is nearly always used for the uplink to the satellite, for reasons which will be explained later, and common practice is to denote the C band by 6/4 GHz, giving the uplink frequency first. For the direct broadcast service in the Ku band, the most widely used range is approximately 12 to 14 GHz, which is denoted by 14/12 GHz. Although frequency assignments are made much more precisely, and they may lie somewhat outside the values quoted here (an example of assigned frequencies in the Ku band is 14,030 and 11, 730 MHz), the approximate values stated above are quite satisfactory for use in calculations involving frequency, as will be shown later in the text.

Care must be exercised when using published references to frequency bands because the designations have developed somewhat differently for radar and communications applications; in addition, not all countries use the same designations. The official ITU frequency

TABLE 1.1 Frequency Band Designations

Frequency range, GHz	Band designation
0.1–0.3	VHF
0.3–1.0	UHF
1.0–2.0	L
2.0–4.0	S
4.0–8.0	C
8.0–12.0	X
12.0–18.0	Ku
18.0–27.0	K
27.0–40.0	Ka
40.0–75	V
75–110	W
110–300	mm
300–3000	μm