Satellite Technology
An Introduction

Andrew F. Inglis

Electronic Media Guides

Satellite Technology

An Introduction

Andrew F. Inglis

Focal Press
Boston London

Focal Press is an imprint of Butterworth–Heinemann.

Library of Congress Cataloging-in-Publication Data
Inglis, Andrew F.
Satellite technology: an introduction / Andrew F. Inglis
p. cm.—(Electronic media guide)
Includes bibliographical references and index.
ISBN 0-240-80078-8
1. Artificial satellites in telecommunication. 2. Earth stations (Satellite telecommunication) I. Title. II. Series.
TK5104.I53 1991
621.382'54—dc20 90-45629
CIP

British Library Cataloguing in Publication Data
Inglis, Andrew
Satellite technology: an introduction.–(Electronic media guide).
1. Broadcasting. Use of communications satellites.
I. Title II. Series
621.3897

ISBN 0-240-80078-8

Butterworth–Heinemann
80 Montvale Avenue
Stoneham, MA 02180

10 9 8 7 6 5 4 3 2 1

Printed in the United States of America

Satellite Technology

ELECTRONIC MEDIA GUIDES

Elizabeth Czech-Beckerman *Managing Electronic Media*

Ken Dancyger *Broadcast Writing: Dramas, Comedies, and Documentaries*

Donna L. Halper *Full-Service Radio: Programming for the Community*

Donna L. Halper *Radio Music Directing*

William Hawes *Television Performing: News and Information*

Robert L. Hilliard *The Federal Communications Commission: A Primer*

John R. Hitchcock *Sportscasting*

Andrew F. Inglis *Satellite Technology : An Introduction*

Carla B. Johnston *Election Coverage: Blueprint for Broadcasters*

Marilyn J. Matelski *TV News Ethics*

Marilyn J. Matelski *Daytime Television Programming*

Robert B. Musburger *Electronic News Gathering: A Guide to ENG*

Preface

During the past 15 years there has been a phenomenal growth in the use of communication satellites for the transmission and distribution of radio and television programs. Satellites have evolved from a novelty in high technology with an uncertain future, to an indispensable component of these industries. They were initially perceived to be useful mainly for the transmission of voice and data traffic, but as their capabilities became better understood they began to play an equal, if not more important role, in the transmission and distribution of television programs. Later, they became widely used for the distribution of radio programs.

There is now a synergistic relationship between satellites and the radio and television industries. These industries provide a major market for satellite communication services but also are highly dependent on them. Neither cable television (CATV) nor electronic news gathering (ENG) could have reached its present state of development without the use of satellites.

The introduction of satellites into the radio and television industries created a new set of challenges and opportunities for the members of their technical communities. The new concepts, new vocabulary, and new technologies of satellites must be learned by the engineers responsible for the design and operation of broadcasting and cable TV systems. It is equally a requirement for students who are pursuing a course of study leading to employment in the engineering departments of broadcasting and cable TV companies.

This volume contributes to the learning process by providing an introduction to satellite technology in language that is accessible to those who are not specialists. The scope of its subject matter is broad, ranging from the theory of satellite operation to practical instructions for the initial setup of mobile earth stations. For those who wish to pursue the study of the technical aspects of satellites further, a comprehensive list of references are included.

The author is indebted to the many members of the broadcasting and satellite industries who supplied reference materials and invaluable advice and suggestions. He is grateful to Wayne Rawlings and his staff from Station KCRA-TV in Sacramento who provided information on the practical operation of satellite news gathering (SNG) earth stations. Most of all he wishes to thank Walter Braun, John Christopher, and Marvin Freeling of GE American Communications. They were an indispensable resource, and they carefully reviewed the manuscript for technical accuracy. Any remaining errors, however, are the author's!

Contents

1

SATELLITE COMMUNICATION SYSTEMS

OVERVIEW

This chapter is an introduction to the technology of the satellite communication systems used for the transmission and distribution of radio and television programs. Succeeding chapters describe the applications and technical characteristics of satellites and earth stations, earth station equipment and design procedures, Federal Communications Commission (FCC) rules and regulations, earth station installation and operational procedures, and sources of satellite services and equipment.

Satellite Communication System Elements

The elements of a satellite communication system are shown in Figure 1.

The signal to be transmitted, that is, the *baseband signal,* is received at an *earth station,* where it modulates a high-power radio frequency transmitter. The earth station antenna radiates the transmitter signal to a *geosynchronous* satellite, which appears to remain in a fixed position in space. The satellite receives the radiated signal, shifts its frequency, and amplifies it by means of a *transponder*, then reradiates it to back to earth where it can be received by earth stations in the coverage area of the satellite.

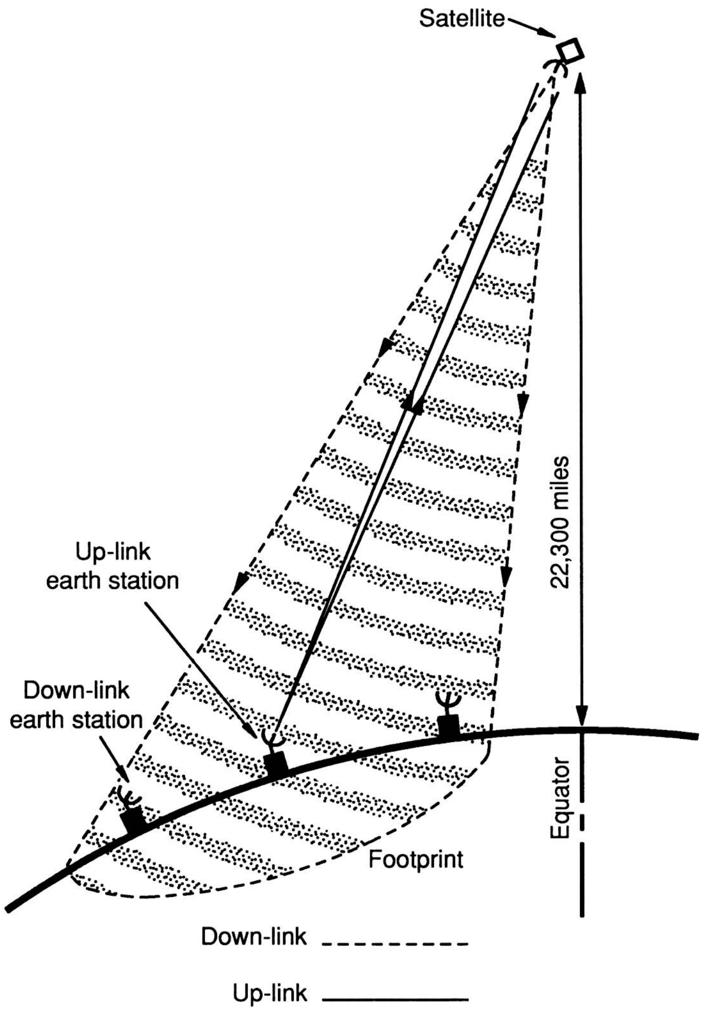
Earth stations form the *ground segment* of a satellite communication system,while the satellite constitutes the *space segment*. The transmission system from earth station to satellite is called an *uplink,* and the system from satellite to earth is called a *downlink.*

Satellite Service Areas, or *Footprints*

Earth station antennas have very narrow beams, both to increase their gain and to avoid interference with adjacent satellites. By contrast, the antennas on communication satellites usually have rather broad beams so that they can provide service to and from a large area—typically an entire region, country, or even an entire hemisphere. In an exception to this practice, some satellites have narrow *spot beams* for specialized service to limited areas. The area which receives a signal of useful strength from the satellite is known as its *footprint.*

Satellite Frequency Bands

Three frequency bands, C-band, Ku-band, and DBS (direct broadcast by satellite) are used for satellite transmission of radio and television programs. C-band downlink transmissions are in the 4 GHz region of the spectrum, which is shared



▶ ***Figure 1** Satellite communication system.*

with terrestrial microwave services. Ku-band downlinks operate in the 12 GHz region and have exclusive use of these frequencies. Direct Broadcast Satellite (DBS) downlinks operate in the 12.5 GHz region and are intended for direct pickup by small home antennas. The technical characteristics of these frequency bands are described in Chapter 3.

Satellite Transmission Modes

Frequency modulation is ideally suited for the transmission of television signals, and it has been almost universally used to date. It has three important advantages over amplitude modulation for this purpose:

1. It does not require highly linear power amplifiers, either in the satellite or the uplink.
2. It has a substantial *noise improvement factor* (see Chapters 4 and 5), so that the signal-to-noise-ratio of the output video signal is higher than that of the radio frequency carrier.
3. The transmitted energy can be more uniformly distributed across the channel bandwidth by *sideband energy dispersal*. This process is important for C-band systems because it increases the legally permissible downlink power (see Chapter 4).

The other transmission mode alternative, digital transmission, is not presently used for television signals because of its bandwidth requirements. It is, however, excellently adapted for high-fidelity audio signals, and it is widely used by radio networks for program distribution (see Chapters 2 and 5).

Somewhat paradoxically, the digital mode also has the potential for *reducing* the bandwidth required for a video signal transmission system. This results from the repetitiveness and large amount of redundancy in the video signal and requires advanced digital processing techniques. As of this writing (1990), none of them has had the benefit of extensive tests. Signal processing for bandwidth reduction invariably results in at least a small reduction in picture quality, such as, reduced sharpness in the images of moving objects.

Competitive Transmission Mediums

Satellites compete with other communication mediums—microwave, coaxial cable, and fiber optic cable—for the transmission of television signals. Each of these mediums has characteristics which make it especially suited for certain types of service. None of them excels in all respects, and all will continue to be used extensively in the foreseeable future.

To date, the competition to satellites for television service has come primarily from coaxial cable and microwave. Fiber optics is now coming into use and will significantly change the competitive situation in the future.

Satellites and Fiber Optics

The most striking feature of fiber optic systems is their enormous bandwidth—a typical system has a bandwidth of 3 GHz (3,000 MHz) as compared with 36 MHz for a satellite transponder or 864 MHz for the 24 transponders in a C-band satellite.

This bandwidth makes it possible for fiber optic systems to transmit video signals in a digital rather than an analogue format. The digital format has many advantages, but its huge bandwidth requirements have made the medium and long-haul digital transmission of video signals difficult or impractical with coaxial cable, microwave, or satellites (but note the earlier discussion of possible future bandwidth reduction by the use of digital transmission).

Fiber optic cable systems are now being installed for intercity, point-to-point transmission circuits by all major communication carriers for voice, data, and video. These facilities will doubtless provide very serious competition to satellites for fixed, point-to-point video transmission services.

In addition, long-range planners in the communications industry have envisioned a future for fiber systems that goes beyond fixed, point-to-point services. Their proposal is to provide every home and business with a fiber optic cable connection to a nationwide communication system that would use a technology known as ISDN (integrated services digital network), or its equivalent. Two-way digital bit streams on the cable would provide radio and television programs, telephone service, facsimile service, and access to remotely located computers and a variety of data banks to every home and business.

This is an extremely attractive concept, and if it proves to be technically feasible, economically competitive, and politically possible, it could make satellites obsolete for most television communication services, except mobile applications. (It could also make television broadcasting and present-day cable TV obsolete.) The installation and operation of such a nationwide system, however, involves massive technical, financial, and political problems, not all of which have clear solutions. At best, it will be more than a decade before such a system can be designed, approved by the government, financed, constructed, and put into operation. In the meantime, satellites will continue to play a vital role in the television industry.

THE GEOSYNCHRONOUS ORBIT

Location

Geosynchronous satellites are located in the *geosynchronous orbit,* which forms a circle in the plane of the equator, 22,300 miles above the earth (see Figure 2). They revolve once each day in synchronism with the earth's rotation; and at this elevation the gravitational force pulling them toward the earth is exactly balanced by the centrifugal force pulling them outward. Since they revolve at the same rotational speed as the earth, they appear stationary from the earth's surface; and radio signals can be transmitted to and from them with highly directional antennas pointed in a fixed direction. It is this property that makes satellite communications practical.

Orbital Slots

International regulatory bodies and national governmental organizations, such as the Federal Communications Commission (FCC) (see Chapter 6), designate the locations on the geosynchronous orbit where communication satellites can be located. These locations are specified in degrees of longitude and are known as *orbital slots.*

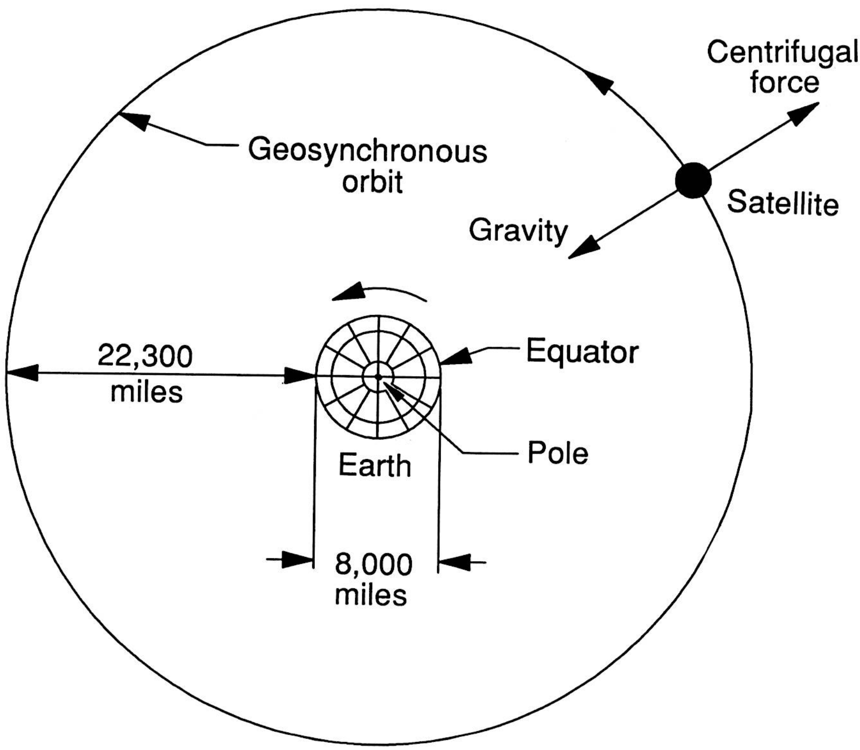
Since all communication satellites operate in the same frequency bands, the spacing between orbital slots must be great enough to reduce to an acceptable level the interference between transmissions to and from adjacent satellites. The minimum spacing required to achieve this objective depends on the width of the earth station antenna beams, that is, the directivity of their antennas.

In response to the huge demand for orbital slots, the FCC has progressively reduced the required spacing and has established a future standard of only 2° for C- and Ku-band satellites—a spacing which requires the use of very narrow antenna beams. DBS satellites are designed to be received by smaller and less directional receiving antennas in individual homes (see Chapter 4 for the relation between antenna size and beam width). Accordingly, DBS orbital slot assignments are located at intervals of 9°.

Western Hemisphere Orbital Slot Allocations and Assignments

By international agreement negotiated through the International Telecommunications Union (ITU), each country is allocated an arc of the geosynchronous orbit, within which it can assign orbital slots. A national regulatory body—the FCC in the case of the United States—makes the slot assignments within this arc. The current (1990) orbital slot allocations and assignments for the western hemisphere are tabulated on the following pages (see Chapter 3 for the definitions of fixed service satellites (FSS), direct broadcast satellites, C band and Ku band). The slot assignments change frequently, and the tables must be updated periodically.

United States The United States is allocated the orbital arcs 62°-103° and 120°-146° west longitude for C-band satellites and 62°-105° and 120°-136° west longitude for Ku-band satellites. Within each band, a single satellite is assigned to each slot. The assignments as of January 1990 within these arcs are shown in Table 1 and Figure 3.



▶ ***Figure 2*** *Geosynchronous satellites.*

▶ **Table 1** United States orbital slot assignments, January 1990

W. Long.	*Name*	*Operator*
	C-band Fixed Service Satellites (FSS)	
69°	Spacenet-2 (hybrid) H[1]	GTE Spacenet
72°	Satcom-2R V	GE Americom
74°	Galaxy-2 H	Hughes
76°	Comstar-4 V	Comsat
79°	Satcom H-1 (Hybrid) H	GE Americom
81°	Satcom-4/Galaxy-5E V	GE/Hughes
83°	ASC-2 H	Contel ASC
85°	Telestar-302 V	AT&T
87°	Spacenet-3 (hybrid) H	GTE Spacenet
91°	Galaxy-6 H	Hughes
93°	Spotnet-1 (hybrid) V	Spotnet
95°	Galaxy-3/3R H	Hughes
97°	Telstar-301/401(hybrid) V	AT&T
99°	Westar-4/Galaxy-4R H	Hughes
101°	Contelsat-1 (hybrid) V	Contel ASC
103°	Spacenet-1R (hybrid) H	GTE Spacenet
123°	Telstar-303 V	AT&T
125°	Galaxy-5W H	Hughes
127°	Spotnet-2 (hybrid)	Spotnet
129°	ASC-1 (hybrid) H	Contel ASC
131°	Satcom-3R V	GE Americom
133°	Galaxy-1/1R H	Hughes
135°	Satcom-C4 V	GE Americom
137°	Satcom-1R/C1 H	GE Americom
139°	Aurora-2 V	Alascom
143°	Aurora-1	Alascom
	Ku-band Fixed Service Satellites (FSS)	
62°	AMSC	AMSC
69°	Spacenet-2 (hybrid)	GTE Spacenet
72°	SBS-6	Hughes
74°	SBS-1/2	Hughes
79°	Satcom-H1 (hybrid)	GE Americom
81°	Satcom-K2	GE Americom
85°	Satcom-K1	GE Americom
87°	Spacenet-3 (hybrid)	GTE Spacenet
91°	SBS-4	IBM
93°	Spotnet-1 (hybrid)	Spotnet

▶ **Table 1** *(continued)*

W. Long.	*Name*	*Operator*
95°	SBS-3	MCI
97°	Telstar-301/401 (hybrid)	AT&T
99°	Galaxy A-R	Hughes
101°	Contelsat-1 (hybrid)	Contel-ASC
103°	Spacenet-1R (hybrid)	GTE Spacenet
105°	GStar-2	GTE Spacenet
121°	GStar-1/1R	GTE Spacenet
123°	SBS-5	IBM
125°	GStar-4	GTE Spacenet
127°	Spotnet-2 (hybrid)	Spotnet
129°	ASC-1 (hybrid)	Contel-ASC
131°	Galaxy-BR	Hughes
139°	AMSC	AMSC
	Ku-band Direct Broadcast Satellites (DBS)	
61.5°		
101.0°		
110.0°	See Chapter 2 for channel	
119.0°	assignments within these	
148.0°	slots.	
157.0°		
166.0°		
175.0°		

[1] V(ertical) and H(orizontal) following the satellite's name denotes the polarity on the downlink of the odd-numbered C-band transponders (see Chapter 3).

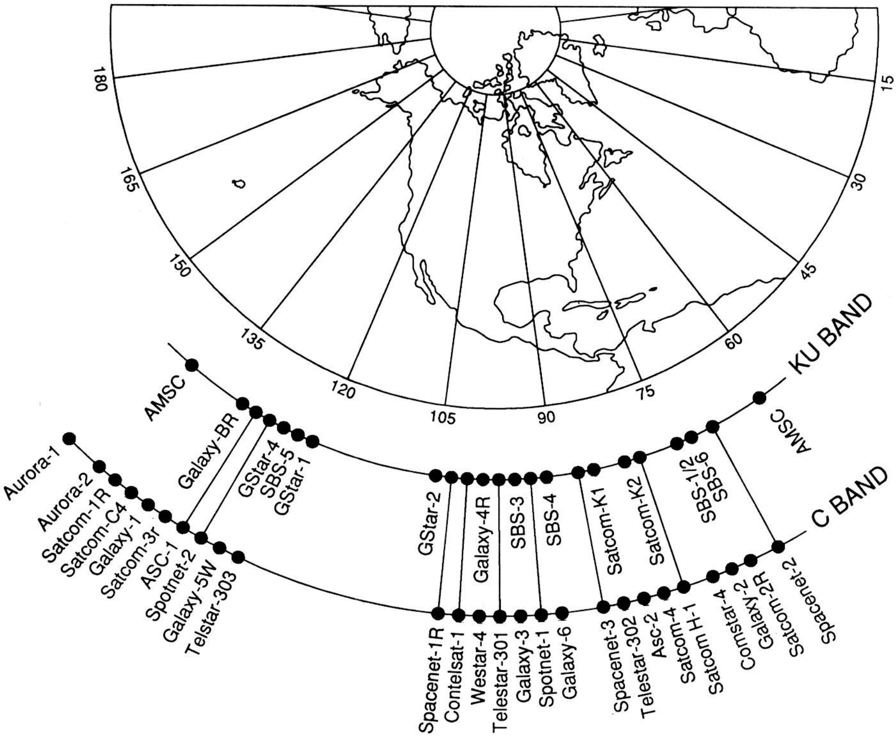
Source: *Broadcasting/Cable Yearbook.* Washington, D.C.: Broadcast Publications, Inc., 1990.

The United States is also allocated the eight DBS slots in the arc 62°-175°, listed in Table 1. The power requirements of DBS satellites are so great that it is not practical to provide power in a single satellite for all the channels in a single slot. Accordingly, more than one satellite is assigned to each slot; and channels rather than satellites are assigned to individual applicants. Up to 32 channels per slot may be assigned. Current DBS channel assignments are listed in Chapter 2.

Canada Canadian satellites are located in the arc 104.5°-117.5° west longitude. Canadian satellites in orbit as of January 1990 are shown in Table 2.

Mexico and South America Mexico shares orbital slots with Canada. Because of their geographic separation, satellites can operate in the same frequency band and from the same slot without excessive interference.

South America shares orbital slots with the United States. The South American continent lies somewhat to the east of North America; and South American countries utilize an arc that partially overlaps the U.S., arc but extends to the east of it. Orbital slots assigned to Mexico and South America as of January 1990 are shown in Table 3.



▶ ***Figure 3*** *United States orbital slot assignments.*

▶ **Table 2** Canadian orbital slot assignments, January 1990

	C-band Fixed Service Satellites (FSS)	
W. Long.	*Name*	*Operator*
104.5°	Anik-D1	Telsat
110.5°	Anik-D2	Telsat
	Ku-band, Fixed Satellite Service (FSS)	
W. Long.	*Name*	*Operator*
107.5°	Anik C-1	Telsat
110°	Anik C-2	Telsat
117.5°	Anik C-3	Telsat

Source: *Broadcasting/Cable Yearbook.* Washington, D.C.: Broadcast Publications, Inc., 1990.

▶ **Table 3** Mexican and South American orbital slot assignments, January 1990

MEXICO

Hybrid C- and Ku-band Fixed Service Satellites (FSS)

W. Long.	*Name*
113.5°	Morelos-1
116.5°	Morelos-2
141.0°	Morelos-3
145.0°	Morelos-4

SOUTH AMERICA

Country or administration	*Orbital slot*	*Satellite*	*Frequency*
Argentina	80.0°	Nahuel-1	C/Ku-band
	85.0°	Nahuel-2	C/Ku-band
Brazil	61.0°	SBTS-B3	C-band
	61.0°	SBTS-C3	Ku-band
	65.0°	SATS-2	C-band
	65.0°	SBTS-A2	C-band
	65.0°	SBTS-B2	C-band
	65.0°	SBTS-C2	Ku-band
	70.0°	SATS-1	C-band
	70.0°	SBTS-A1	C-band
Colombia	75.0°	Colombia-2	C-band
	75.0°	Satcol-2	C-band
	75.4°	Colombia-1A	C-band
	75.4°	Satcol-1A	C-band
	75.4°	Satcol-2B	C-band
Cuba	83.0°	STSC-1	C-band
	97.0°	STSC-2	C-band
ASETA	72.0°	Simon Bolivar-C	C-band
(Bolivia, Ecuador	77.5°	Simon Bolivar-A	C-band
Peru, Venezuela)	89.0°	Simon Bolivar-B	C-band
	106.0°	Simon Bolivar-1	C-band

Source: *Broadcasting/Cable Yearbook.* Washington, D.C.: Broadcast Publications, Inc., 1990.

Satellite Look, or Elevation Angle

The *look* angle, the elevation of the path to the satellite above the horizontal, is critical to the performance of its transmission link. Three problems are encountered with low elevation angles that are just above the horizon:

The first is the difficulty in clearing buildings, trees, and other terrestrial objects. Failure of the path to do so may result in attenuation of the signal by absorption or in distortions from multipath reflections.

The second is atmospheric attenuation. The length of a low elevation path through the atmosphere before it emerges into space is much longer; and this increases rain attenuation, particularly when operating in the Ku band.