REGIONAL CENTRES FOR SPACE SCIENCE AND TECHNOLOGY EDUCATION

Satellite communications

Education curriculum

United Nations

REGIONAL CENTRES FOR SPACE SCIENCE AND TECHNOLOGY EDUCATION
(AFFILIATED TO THE UNITED NATIONS)

Satellite communications
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Preface

Satellite communications systems have been undergoing radical change in recent years, making a transition from a technology dominated by Governments and geostationary satellites to one that includes low-Earth orbit (LEO) and medium-Earth orbit (MEO) satellite systems operated by publicly held corporations. The new systems utilize multiple antenna beams forming cells on the Earth's surface similar to those used by terrestrial cellular telephony systems and are capable of carrying various types of traffic ranging from voice to Internet traffic.

Communications satellites are radio-relay stations in space. They serve much the same purpose as the microwave towers seen along highways. The satellites receive radio signals transmitted from the ground, amplify them, and retransmit them back to the ground. Since the satellites are at high altitude, they can "see" across much of the Earth. This gives them their principal communications advantage: the ability to cover large distances of the terrain.

Satellite communications systems consist of several different segments, including a space segment, a ground control segment and ground infrastructure equipment. The space segment contains the satellites, which act as nodes in space, routing the communication signal from an Earth terminal to either a final or an intermediate destination point on the Earth's surface. The ground control segment is responsible for monitoring the health and status of each satellite as well as for keeping the satellites in their appropriate locations in space. The infrastructure equipment controls the networking aspect of the entire communication system, keeping track of the duration of a communication session for billing purposes as well as assigning communication channels to the various users.

Contents

Explanatory notes

AIR	All India Radio
AOCS	attitude and orbit control system
APT	Asia Pacific Telecommunity
ATM	asynchronous transfer mode
BER	bit error rate
BSS	broadcast satellite service
CBT	computer-based teaching
CDMA	code division multiple access
CISC	complex instruction set computer
C/kT	carrier-to-receiver noise density
C/N	carrier-to-noise (ratio)
DAMA	demand assignment multiple access
DBS	direct broadcasting satellite
DCT	discrete cosine transform
DECU	Development and Educational Communication Unit
DFT	discrete Fourier transform
DMA	direct memory access
DOE	Department of Electronics
DOS	disk operating system
DOT	Department of Telecommunications
DSDB	digital sound and data broadcasting
DSP	digital signal processing
DTH	direct-to-home
DVB	digital video broadcasting
EIRP	effective isotropic radiated power
EMC	electromagnetic compatibility
EMI	electromagnetic interference
ETSI	European Telecommunications Standards Institute
FFT	fast Fourier transform
FIR	finite impulse response
FM	frequency modulation
FMTV	frequency modulation television

FSS	fixed satellite service
GEO	geosynchronous Earth orbit
GPS	Global Positioning System
G/T	antenna gain to system noise temperature ratio
HDTV	high-definition television
HPA	high-power amplifier
IIR	infinite impulse response
IMD	India Meteorological Department
IMT	International Mobile Telecommunication
INSAT	Indian National Satellite System
I/O	input/output
IP	Internet protocol
ISDN	integrated services digital network
ISO	International Organization for Standardization
ITU	International Telecommunication Union
JDCP	Jhabua Development Communications Project
KCP	Kheda Communications Project
LAN	local area network
LEO	low-Earth orbit
LNA	low-noise amplifier
MBS	multimedia broadcast service
MCPC	multiple channels per carrier
MEO	medium-Earth orbit
MIC	microwave integrated circuit
MPEG	Moving Picture Experts Group
MSS	mobile satellite service
NICNET	National Informatics Centre Network
NOAA	National Oceanic and Atmospheric Administration
OBP	on-board processing
PTI	Press Trust of India
RFI	radio frequency interference
RISC	reduced instruction set computer
SCPC	single channel per carrier

SITE	Satellite Instructional Television Experiment
S/N	signal-to-noise (ratio)
SNG	satellite news gathering
SSMA	spread spectrum multiple access
TCP/IP	transmission control protocol/Internet protocol
TDCC	Training and Development Communication Channel
TDM	time division multiplexing
TDMA	time division multiple access
TT and C	Telemetry, Tracking and Command
TVRO	television receive-only system
UGC	University Grant Commission
VHRR	very high resolution radiometer
VSAT	very small aperture terminal

Introduction

Space science and technology education can be pursued at the elementary, secondary and university levels. In spacefaring nations, elements of space science and technology have been introduced into science curricula at those levels. Such an innovation has not taken place in many developing countries, partly because the benefits of space science and technology have not been appreciated enough and partly because the facilities and resources for teaching science and technology at educational institutions are not yet well developed. Education in space science and technology in developed countries has become highly interactive; the World Wide Web and other information technologies have become useful tools in education programmes at all levels.

The incorporation of elements of space science and technology into university- level science curricula can serve a dual purpose for developed and developing countries. It can enable all countries to take advantage of the benefits inherent in the new technologies, which, in many cases, are spin-offs from space science and technology. It can revitalize the educational system, introduce the concepts of high technology in a non-esoteric fashion and help create national capacities in science and technology in general. In that regard, Lewis Pyenson emphasized in his recent work entitled *Servants of Nature*[1] that:

> "Both geographical decentralization and interdisciplinary innovation have become watchwords in academic science. Electronic information processing to some extent obviates the necessity for a scientist or scholar to reside at an ancient college of learning. Universities everywhere have adapted to new socioeconomic conditions by expanding curricula. They have always responded in this way, although never as quickly as their critics would like. Measured and deliberate innovation is one of academia's heavy burdens. It is also a great strength. Emerging fields of knowledge become new scientific disciplines only after they have found a secure place in universities. We look to universities for an authoritative word about the latest innovations. New scientific ideas emerge in a variety of settings, but they become the common heritage of humanity only when processed by an institution for advanced instruction like the modern university."

There are many challenges in the teaching of science at university level, both in developing and developed countries, but the challenges are of a higher magnitude in developing countries. The general problem confronting science education is the inability of students to see or experience the phenomena being taught, which often leads to an inability to learn basic principles and to see the relationship between two or more concepts and their practical relevance to problems in real life. Added to those problems are a lack of skills in the relevant aspects of mathematics and in problem-solving strategies. There are also language problems in countries in which science is not taught in the national language(s). Over the years, developed countries have overcome most of the basic problems, except perhaps a psychological problem, namely that students may consider science to be a difficult subject. In developing countries, however, basic problems linger, exacerbated by the fact that there are not enough academically and professionally well-trained teachers.

Establishment of the regional centres for space science and technology education

The General Assembly, in its resolution 45/72 of 11 December 1990, endorsed the recommendation of the Working Group of the Whole of the Scientific and Technical Subcommittee, as endorsed by the Committee on the Peaceful Uses of Outer Space, that the United Nations should lead, with the active support of its specialized agencies and other international organizations, an international effort to establish regional centres for space science and technology education in existing national/regional educational institutions in the developing countries (A/AC.105/456, annex II, para. 4 (n)).

The General Assembly, in its resolution 50/27 of 6 December 1995, paragraph 30, also endorsed the recommendation of the Committee on the Peaceful Uses of Outer Space that those centres be established on the basis of affiliation to the United Nations as early as possible and that such affiliation would provide the centres with the necessary recognition and would strengthen the possibilities of attracting donors and of establishing academic relationships with national and international space-related institutions.

Regional centres have been established in India for Asia and the Pacific, in Morocco and Nigeria for Africa, in Brazil and Mexico for Latin America and the Caribbean and in Jordan for Western Asia, under the auspices of the Programme on Space Applications, implemented by the Office for Outer Space Affairs (A/AC.105/749). The objective of the centres is to enhance the capabilities of Member States, at the regional and international levels, in various disciplines of space science and technology that can advance their scientific, economic and social development. Each of the centres provides postgraduate education, research and application programmes with emphasis on remote sensing, satellite communications, satellite meteorology and space science for university educators and research and application scientists. All centres are implementing nine-month postgraduate courses (in remote sensing, satellite communications, meteorological satellite applications, and space and atmospheric sciences) based on model curricula that emanated from the United Nations/Spain Meeting of Experts on the Development of Education Curricula for the Regional Centres for Space Science and Technology Education, held in Granada, Spain, in 1995. Since 1995, these curricula (A/AC.105/649 and http://www.oosa.unvienna.org/SAP/centres/centres.htm) have been presented and discussed at regional and international educational meetings.

The Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III), held in Vienna in July 1999, recommended that collaboration should be established between the regional centres and other national, regional and international organizations to strengthen components of their education curricula.[2] In its resolution 54/68 of 6 December 1999, the General Assembly endorsed the resolution of UNISPACE III entitled “The Space Millennium: Vienna Declaration on Space and Human Development”, in which action was recommended to ensure sustainable funding mechanisms for the regional centres.[3]

United Nations Expert Meeting on the Regional Centres for Space Science and Technology Education: Status and Future Developments

The Office for Outer Space Affairs of the Secretariat organized, in cooperation with the European Space Agency (ESA), the United Nations Expert Meeting on the Regional Centres for Space Science and Technology Education: Status and Future Development in Frascati, Italy, from 3 to 7 September 2001. The Meeting was hosted by the ESA European Space Research Institute in Frascati.

The Meeting reviewed the status of establishment and operation of the regional centres with a view to enhancing cooperation between the centres. The main objective of the Meeting was to review and update curricula at the university level and across cultures in four areas: remote sensing, satellite meteorology, satellite communications and space science. The Meeting considered that education varied significantly between countries and even between institutions within the same country which led to differences in space science and technology education curricula in terms of course content and modes of presentation. The Meeting noted that the model curricula (A/AC.105/649) had contributed to resolving such problems.

The Meeting established five working groups to focus on the following specific topics and respective education curriculum: (a) management issues of the centres; (b) remote sensing; (c) satellite meteorology; (d) satellite communications; and (e) space science. The working groups drew on the knowledge and expertise of participants, thereby taking into account the results of previous nine-month postgraduate courses, particularly those organized since 1996 at the Centre for Space Science and Technology Education in Asia and the Pacific and since 1998 at the African Centre for Space Science and Technology—in French Language and the African Regional Centre for Space Science and Technology Education—in English Language.

The Meeting, through its working groups, updated the four education curricula and drew up course syllabuses that differ from most of those available in literature and on the World Wide Web. They are based on physics, mathematics and engineering as taught in many universities around the world. They are not tailored to any specific space-related project or mission that may have been or will be executed by any specific institution.

Curriculum on satellite communications

The present chapter contains the deliberations of the working group on satellite communications that was established during the United Nations Expert Meeting on the Regional Centres for Space Science and Technology Education: Status and Future Development. The working group reviewed the curriculum of courses that had been held at the Centre for Space Science and Technology Education in Asia and the Pacific (annex I) and developed a broad outline of topics that should be part of the satellite communications curriculum.

The group felt that the details of the respective topics and their coverage needed to be specified by each regional centre. Through specialized education and research, each regional centre should assist its participating member States to acquire a higher capability in the development and transmission of knowledge related to satellite

communications. That should be done with a view to enhancing the indigenous national and regional capabilities in the utilization of satellite-based communications technology for sustainable development.

Review of the existing curriculum

The working group reviewed the curriculum that was used for the first, second and third postgraduate courses in satellite communications, held at the Centre for Space Science and Technology Education in Asia and the Pacific from 1 January 1997 to 30 September 1998, from 1 July 1999 to 31 March 2000, and from 1 August 2001 to 30 April 2002, respectively. The duration of the courses was 39 weeks consisting of 35 weeks of course work, including 10 weeks for pilot-project preparation, and 4 weeks of visits to various satellite communications facilities. Following the course, participants carried out one-year pilot projects in their home countries.

The modules for the three courses are shown in table 1.

Table 1
Modules for the curriculum on satellite communications

Module	*Topics*	*Duration in weeks*
0	Orientation course	1
1	Communication systems and digital signal processing	5
2	Satellite communication systems	6
3	Earth station technology	3
4	Broadcasting using communication satellites	3
5	Applications and trends in satellite communications	3
6	Operational communication satellite systems	1
7	Network planning, management and operational issues of satellite communication systems	1
8	Satellite communications for development, education and training	2
9	Pilot projects	10
	Total duration	**35**

The courses met five days a week, with eight 45-minute sessions per day. The breakdown by module and type of training is shown in table 2.

Table 2
Breakdown of the curriculum by module and type of training

	Module								
Type of training	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Lectures	40	138	120	46	42	62	30	20	32
Practical exercises		54	48	28	48	28			20
Visits			24	24	12	16			24
Library			24	12	8	4	10	20	4
Class tests and exams		8	24	10	10	10			
Total	**40**	**200**	**240**	**120**	**120**	**120**	**40**	**40**	**80**

Note: The numbers indicate 45-minute sessions.

Revised curriculum for the course on satellite communications

Objectives

The specific objectives of the courses are:

(a) To develop the skills of university educators, researchers, telecommunications professionals, government personnel and others in the field of satellite communications and its applications to broadcasting, telecommunications, health care, education, disaster management etc.;

(b) To provide assistance in preparing satellite-based communications projects, defining policy and establishing communications systems;

(c) To develop expertise in the use of operational systems and integrate advances in communications technology in day-to-day activities;

(d) To provide assistance in promoting intra- and interregional cooperation in utilizing and expanding the scope of communications technology;

(e) To promote the development and enhancement of public awareness of the benefits of satellite-based communication technologies in improving the quality of life.

Structure of the curriculum

Satellite-based communication is the most effective medium for reaching out to the world and in bringing nations closer together into what is described as a "global village". It is against this background that the course must provide participants from developing countries with skills to appreciate the fullest potential of the technology.

The course will consist of eleven modules (including an orientation module), each covering specific areas of satellite communications (theory, technology and applications). The duration of the course is nine months, consisting of 35 weeks of courses and 4 weeks of visits to satellite communications establishments, followed by one year of pilot-project work in the participant's home country. The topics covered in the modules and duration are shown in table 3.

Table 3
Course modules

Module No.	*Topics*	*Number of weeks*
0	Orientation course	1
1	Communication systems and digital signal processing	5
2	Satellite communication systems	5
3	Earth station technology	3
4	Transmission, multiplexing and multiple access	2
5	Broadcasting using communication satellites	2
6	Applications and trends in satellite communications	3
7	Operational communication satellite systems	1
8	Network planning, management and operational issues of satellite communication systems	1
9	Satellite communications for development, education and training	2
10	Pilot projects	10
	Total duration	**35**

Lectures will constitute 40 per cent of the classes and practical exercises 60 per cent.

Equipment and facilities

The minimum requirements for equipment and facilities are as follows:

High-performance multimedia personal computers

MATLAB software program

Spectrum analyser

Signal generator

Network analyser

Power meter

Frequency counter

Microwave transmission line system

Optical bench

Transponder or satellite simulator

Earth station with both transmit and receive functions (e.g. the minimum requirement would be a very small aperture terminal (VSAT))

Test loop translator

Bit error rate (BER) test set

Television receive-only system (TVRO)

Revised curriculum

Module 0: Orientation course

0.1 Introduction to the course

0.2 Introduction to activities and specifics of the regional centre

0.3 Communications skills (oral, written, presentation, group discussion)

0.4 Introduction to the local environment (language, geographic perspective, social system etc.)

Module 1: Communication systems

1.1 Principles of communications and networking

1.1.1 Lectures

Telecommunications overview
Principles of information theory
Principles of modulation and coding
Microwave theory and techniques
Optical communications
Principles of networking and protocols

1.1.2 Laboratory sessions

MATLAB simulations and hardware experiments

1.2 Digital signal processing

1.2.1 Lectures

Discrete time signals and systems
Sampling of continuous time signals
Z-transform
Discrete Fourier transform
Computation of discrete Fourier transform
Structure for discrete time systems
Filter design techniques
Examples of digital signal processing (DSP)-based subsystems for satellite communications

1.2.2 Laboratory exercises/tutorial

MATLAB-based exercises

Module 2: Satellite communication systems

2.1 Lectures

Introduction to satellite communications
Satellite orbits
Satellite configurations
Launch vehicles and launching of satellites
Space environment
Reliability
Satellite bus subsystems
Communication payload (transparent and on-board processing (OBP))
Satellite communications links
Frequency bands for satellite communications
Electromagnetic interference (EMI), electromagnetic compatibility (EMC), radio frequency interference (RFI)
Propagation effects on satellite communication links

2.2 Experiments and demonstrations

Link parameter calculations, including real propagation models
Demonstration with satellite simulator
Orbit and footprint simulations

Module 3: Earth station technology

3.1 Lectures

Satellite communications Earth station—an overview
Technology of Earth station subsystems
Earth station design and fabrication considerations
Earth station standards
Check out of Earth stations
Reliability of Earth stations
Operations and maintenance

3.2 Experiments and demonstrations

Using transmit/receive (TX/RX) satellite terminals

Module 4: Transmission, multiplexing and multiple access

4.1 Lectures

Analog and digital modulation techniques
Forward-error correction coding
Multiplexing/de-multiplexing
Spread-spectrum techniques
Multiple access techniques

4.2 Laboratory experiments

MATLAB simulations
Hardware experiments

Module 5: Broadcasting using communication satellites

5.1 Lectures

Analog and digital broadcasting system standards
Digital television
Satellite TV and access systems
Internet protocol (IP) broadcasting

Selected applications, for example:

Satellite News Gathering (SNG) for radio and TV
Radio networking
Digital audio broadcasting
Outdoor broadcasting van
TV studio and its operations
TV coverage of sports
Multicasting
Videoconferencing via satellite
Multimedia (video presentation)
Video on demand

5.2 Laboratory experiments and demonstrations

Practical experiments with TV and IP terminals

Module 6: Applications and trends in satellite communications

6.1 Lectures

Satellite communications services

Selection from satellite communications applications, for example:

VSAT networks
Meteorological data reception system
News and meteorological data dissemination system
Data collection system
Disaster management using satellite communications

Search and rescue system:

International
Regional

Warning dissemination system
Telemedicine
Time and frequency transmission system

Mobile and personal communication services
Strategic satellite communication systems
Satellite navigation system
Satellite-based Internet system
Multimedia broadband satellite system

6.2 Laboratory experiments and demonstrations

Selected hardware experiments using existing facilities and end-user equipment and system demonstrations

Module 7: Operational communication satellite systems

7.1 Lectures

Overview of operational communications satellite systems

Fixed satellite service (FSS)
Mobile satellite service (MSS)
Broadcast satellite service (BSS)
Multimedia broadcast service (MBS)

Selection from operational communications satellite systems
International Telecommunication Union (ITU) and other standardization organizations (International Organization for Standardization (ISO), Asia Pacific Telecommunity (APT), European Telecommunications Standards Institute (ETSI))
International regulations

Module 8: Network planning/management/operational issues of satellite communications systems

8.1 Lectures

Technical considerations for network planning
Planning for space segment
Planning for ground segment
Network operations and control
Management of communication satellite operations
Intra-system/inter-system interference coordination
Space law
Financial aspects of satellite communication

Module 9: Satellite communications for development, education and training

9.1 Lectures

Satellite communications for development, education and training—an overview

Regional experience with:

Hardware
Software
Social research

Local broadcasting (TV, radio, cable network)
Planning for satellite communications for development
Satellite technology for development, education and training
Operational, technological and legal issues in trans-border channels for development
Teleconferencing experiences of users for rural development
Disaster management

9.2 Demonstrations with existing systems

Module10: Pilot project

Project definition

Needs of the participant's country
Topic of interest to the participant
The work leading towards the one-year project

Suggested topics for the project

Earth station subsystems
Systems analysis for communications satellites
Spacecraft design
Antenna footprint design
Communication systems design
Network planning and relevant software development
Applications of TV and radio for development communications
Economics of satellite communications
Domestic system definition
Policy research

Notes

[1] L. Pyenson and S. Sheets-Pyenson, *Servants of Nature: a History of Scientific Institution, Enterprises, and Sensibilities* (New York, W. W. Norton and Company, 1999).

[2] *Report of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space, Vienna, 9-30 July 1999* (United Nations publication, Sales No. E.00.I.3), chap. II, sect. G, para. 220.

[3] Ibid., chap. I, resolution 1, para. 1 (e) (ii). The Declaration is also available on the home page of the Office for Outer Space Affairs (http://www.oosa.unvienna.org).

Annex I

Curriculum for the first three courses

Table
Curriculum of the course in satellite communications

Module/ submodule	*Topic*	*Number of 45-minute sessions*
0	Orientation course (1 week)	
0.1	Introduction to the regional centre	2
0.2	Introduction to activities of the local host institution	2
0.3	Communication skills (oral, written, presentation, group discussion etc.)	24
0.4	Introduction to the host country	6
	Geographic perspectives of the host country	
	Social systems and customs	
	Festivals of the host country	
0.5	Local language—common phrases in the local language	6
	Total	40
1	Communication systems and digital signal processing	
1.1	Classroom lectures—communication systems (3 weeks)	
	Telecommunications overview	
	Distribution, traffic, signalling, switching	6
	Analog and digital communications systems	2
	Long-distance communications	1
	Fibre optics technology and applications	4
	Data networking	10
	Signalling and modulation	
	Local area network (LAN)	
	Wiring plans	
	Data services in public networks	
	Introduction to transmission control protocol/Internet protocol (TCP/IP)	
	Internet	
	Asynchronous transfer mode (ATM)	
	Personal communication services	4
	Integrated services digital network (ISDN)	3
	Packet switching fundamentals	3
	Broadband—an overview	3
	Protocols	3
	Microwave theory and techniques	6
	Transmission line parameters (Z, Y, ABCD, S)	
	Waveguide and coaxial components	
	Applications of microwave technology	

Module/ submodule	*Topic*	*Number of 45-minute sessions*
	Introduction to computers	6
	Computer architecture	
	Complex instruction set computer (CISC)	
	Reduced instruction set computer (RISC)	
	Parallel processor	
	Input/output (I/O) devices	
	I/O programming	
	I/O controlling	
	Interrupt	
	Direct memory access (DMA)	
	Operating systems	
	Standard operating systems	
	Disc operating system (DOS)	
	UNIX and Linux	
	Windows 95 NT	
	Communication theory and mathematical tools	
	Probability theory and basic statistics	10
	Information theory	6
	Spherical geometry	1
	Linear algebra	4
	MATLAB mathematical tools	8
	Subtotal	80
1.2	Laboratory sessions	
	Computer	4
	MATLAB	8
	Microwave measurements	8
	Analog and digital modems	4
	Fibre optics	8
	Subtotal	32
1.3	Classroom lectures—digital signal processing (2 weeks)	
	Discrete time signals and systems	4
	Discrete time signals: sequences	
	Discrete time systems	
	Linear time-in variant systems	
	Frequency domain representation of sampling	
	Discrete time signals and systems	
	Representation of sequences by Fourier transform	
	Fourier transform theorems	
	Discrete time random signals	
	Sampling of continuous time signals	6
	Periodic sampling	
	Frequency domain representation of sampling	
	Reconstruction of a band limited signal from its samples	
	Discrete time processing of continuous time signals	

Module/ submodule	*Topic*	*Number of 45-minute sessions*
	Continuous time processing of discrete time signals	
	Changing the sampling rate using discrete time processing	
	Practical considerations	
	Z-transform	10
	Properties of region of convergence for Z-transform	
	Inverse Z-transform	
	Z-transform properties	
	Inverse Z-transform using contour integration	
	Complex convolution theorem	
	Parseval's relation	
	Unilateral Z-transform	
	Discrete Fourier transform (DFT)	6
	Representation of periodic sequences	
	Discrete Fourier series	
	Properties of discrete Fourier series	
	Fourier transform of periodic signals	
	Sampling of Fourier transform	
	Fourier representation of finite duration sequences	
	Discrete Fourier transform	
	Linear convolution using discrete Fourier transform	
	Computation of discrete Fourier transform	8
	Efficient computation of discrete Fourier transforms	
	Goertzel algorithm	
	Decimation-in-time fast Fourier transform (FFT) algorithms	
	Decimation-in-frequency FFT algorithms	
	Implementation of FFT algorithms	
	FFT algorithms for composite N	
	Implementation of DFT using convolution	
	Effects of finite register length in DFT computations	
	Structure for discrete time systems	6
	Block diagram representation of linear constant coefficient differential equation	
	Basic structure for infinite impulses response (IIR) systems	
	Basic network structures for finite impulse response (FIR) systems	
	Overview of finite precision numerical effects	
	Effects of coefficient quantization	
	Effects of round-off noise in digital filters	
	Zero input cycles in fixed-point realizations of IIR digital filters	
	Filter design techniques	12
	Basic issues in digital filter design	
	IIR filter design	
	Frequency transformation of low-pass IIR filters	
	Design of filters by windowing	

Module/ submodule	*Topic*	*Number of 45-minute sessions*
	Optimum approximation of FIR filters	
	FIR equi-ripple approximation	
	Wavelet transform	2
	Examples of DSP-based subsystems for satellite communications	4
	Subtotal	58
1.4	Laboratory exercises/tutorial	
	MATLAB-based exercises	10
	Design of FIR and IIR filters	
	Implementation of DFT/FFT	
	Examples of DSP-based communication subsystems	
	Familiarization with and implementation of evaluation board	12
	FIR and IIR filters	
	Demodulator algorithm	
	Viterbi coding	
	FFT and discrete cosine transform (DCT)	
	Subtotal	22
	Total[a]	192
2	Satellite communication systems (6 weeks)	
2.1	Classroom lectures	
	Introduction to satellite communications	4
	Evolution of satellite communications	
	Elements of satellite communications	
	Types of satellite orbits	
	Geosynchronous satellite communications	
	Satellite communications services	
	Satellite orbits	4
	Launch vehicles and launching of satellites	4
	Satellite communications links	4
	Frequency bands for satellite communications	2
	Propagation effects on satellite communication links	2
	Satellite communication techniques	28
	Multiplexing techniques	4
	Modulation techniques	6
	Multiple access techniques	6
	Code division multiple access (CDMA)	2
	Coding theory and error correction techniques	4
	IP over satellite	4
	Satellite configurations	2
	Space environment	2
	Satellite bus subsystems	12
	Mechanical structure	2
	Attitude and orbit control system (AOCS)	2
	Propulsion subsystem	2
	Electrical power subsystem	2

Module/ submodule	*Topic*	*Number of 45-minute sessions*
	Telemetry, tracking and command (TT and C)	2
	Thermal subsystem	2
	Communication transponder	2
	Communication transponder subsystems	6
	Antenna and feed	2
	Receiver and transmitter	2
	I/O multiplexer	2
	Advanced communication transponder on-board processing	4
	Integration and testing of communication transponders	2
	Integration and testing of satellites	2
	In-orbit check out of communication payloads	2
	Reliability and space qualifications	2
	Reliability of satellite communication payloads	2
	EMI, EMC and RFI	2
	Electrostatic discharge hazards in satellite communications electronics	2
	Life of a satellite	2
	Satellite communications (video computer-based teaching (CBT) and tutorials)	28
	Subtotal	120
2.2	Experiments/demonstrations	
	Familiarization with measuring instruments	4
	Determination of satellite look angles and optimization of Earth station antennas	4
	Azimuth and elevation angles	
	X-Y angles	
	Optimization of sense of polarization	
	Measurement of satellite link parameters	8
	Total C/kT and down-link C/kT	
	Antenna gain to system noise temperature ratio (G/T) and effective isotropic radiated power (EIRP)	
	Bit error rate (BER) versus C/kT	
	Familiarization with and measurement of satellite transponder characteristics (communication simulator)	4
	Familiarization with and operation of single channel per carrier (SCPC), spread spectrum multiple access (SSMA) and time division multiple access (TDMA) equipment	12
	Testing of communication transponder subsystems	16
	Multiplexer	
	Receiver	
	Power amplifier	
	Antenna and feed	
	Subtotal	48
2.3	Visits to laboratories and other facilities of the host institution	24
	Communication payload research and development laboratories	
	Communications techniques laboratories	

Module/ submodule	*Topic*	*Number of 45-minute sessions*
	Payload fabrication facility	
	Environmental test facility	
	Communication system laboratories	
	Remote sensing laboratories	
	Subtotal	24
	Total[a]	192
3	Earth station technology (3 weeks)	
3.1	Classroom lectures	
	Satellite communications Earth station—an overview	2
	Technology of Earth station subsystems	22
	Antenna reflector and mount for large, medium and small Earth stations	
	Feed system for large, medium and small Earth stations	
	Antenna tracking system	
	Low-noise amplifier (LNA)	
	Solid-state power amplifier	
	High-power amplifier (HPA)	
	Frequency converter	
	Modulator and demodulator	
	Encoder and decoder	
	Test-loop translator	
	Electrical power supply system	
	Foresight and rearward link	
	Earth station design considerations	5
	Earth station standards	
	EIRP and G/T	
	Antenna size and gain	
	Radiation pattern and antenna coverage	
	Redundancy and reliability	
	Environmental specifications	
	VSAT/mobile/briefcase/hand-held terminals	
	Check out of Earth stations	8
	Antenna measurements (farfield, nearfield, anechoic chamber)	
	LNA and G/T	
	HPA and EIRP	
	Frequency converter	
	Test-loop translator	
	Reliability of Earth stations	1
	Operations and maintenance of fixed and transportable Earth stations	2
	Fabrication techniques	6
	Mechanical fabrication techniques	
	Electronics fabrication techniques	
	Microwave integrated circuits (MIC)	
	Subtotal	46

Module/ submodule	*Topic*	*Number of 45-minute sessions*
3.2	Local visits	24
	Department of Telecommunications (DOT) Earth station	
	Department of Electronics (DOE) Software Technology Park	
	Antenna test facility (host institution)	
	MIC facility (host institution)	
	Electronics fabrication facility (host institution)	
	Mechanical fabrication facility (host institution)	
	Subtotal	24
3.3	Experiments/demonstrations	
	Familiarization with Earth station subsystems	4
	Testing of Earth station subsystems	24
	Testing of feed system	
	Testing of HPA	
	Testing of LNA	
	Testing of frequency converter	
	Testing of antenna tracking system (manual and auto mode)	
	Subtotal	28
	Total[a]	98
4	Broadcasting using communication satellites (3 weeks)	
4.1	Classroom lectures	
	Broadcasting system standards	6
	Frequency modulation television (FMTV)	
	High-definition television (HDTV)	
	Digital video broadcasting (DVB)	
	Moving Picture Experts Group (MPEG)	
	Digital television (video presentation)	6
	Satellite links for TV broadcasting (analog and digital)	2
	Frequency bands for satellite broadcasting and national/international regulations	2
	Satellite TV and access systems	6
	Cable TV	
	Direct broadcasting satellite/direct-to-home (DBS/DTH)	
	Conditional access	
	Network management	
	Satellite news gathering (SNG) for radio and TV	2
	Radio networking	2
	Digital audio broadcasting	2
	Outdoor broadcasting van	2
	TV studio and its operations	2
	TV coverage of sports	2
	Multicasting	2

Module/ submodule	*Topic*	*Number of 45-minute sessions*
	Videoconferencing via satellite	2
	Multimedia (video presentation)	2
	Video on demand	2
	Subtotal	42
4.2	Laboratory experiments/demonstrations	48
	Familiarization with video baseband systems	
	Measurement of video signal-to-noise (S/N) ratio versus carrier-to-noise (C/N) radio and video threshold	
	Measurement of TV audio S/N	
	Measurement of S/N versus FM deviation	
	Measurement of TV signal parameters using waveform monitor, vectorscope and automated test equipment	
	SCPC/multiple channels per carrier (MCPC) digital TV	
	Determination of transponder operating points for:	
	Single carrier per transponder	
	Multicarrier per transponder	
	Familiarization with radio networking terminals	
	Demonstration of operations of SNG terminals	
	Setting up a TV direct reception system	
	Digital sound and data broadcasting (DSDB) system	
	Multimedia broadcasting/multicasting	
	Subtotal	48
4.3	Local visits	12
	TV broadcasting station of Doordarshan	
	Radio networking system of All India Radio (AIR)	
	TV studio of the Development and Educational Communication Unit (DECU)	
	Subtotal	12
	Total[a]	102
5	Applications and trends in satellite communications (3 weeks)	
5.1	Classroom lectures	
	Satellite communications services	26
	Rural/remote area communications	2
	VSAT network	8
	Time division multiplexing (TDM)-TDMA	
	SCPC-demand assignment multiple access (DAMA)	
	Remote terminals	
	Hub	
	Network management	
	Meteorological data reception systems (National Oceanic and Atmospheric Administration (NOAA), Indian National Satellite System (INSAT))	2
	News and meteorological data dissemination system	2
	Data collection system	2
	Disaster management using satellite communications	2

Module/ submodule	*Topic*	*Number of 45-minute sessions*
	Search and rescue system	2
	International	
	Regional (INSAT)	
	Cyclone warning dissemination system	2
	Telemedicine	2
	Time and frequency transmission system	2
	Mobile and personal communication services (IMT-2000, 4G etc.)	8
	Strategic satellite communication systems	4
	Satellite navigation system	6
	Satellite-based Internet system	2
	Multimedia broadband satellite system	2
	Video CBT and tutorials	14
	Subtotal	62
5.2	Laboratory experiments/demonstrations	
	NOAA very high resolution radiometer (VHRR) data reception	
	News and meteorological data dissemination system	
	Search-and-rescue beacon	
	Operations of Global Positioning System (GPS) receiver and INSAT reporting system	
	VSAT terminal and network	
	Data and sound broadcasting system	
	Subtotal	28
5.3	Local visit	
	Press Trust of India (PTI)	
	India Mobile Department (IMD)	
	Airport	
	National Informatics Centre Network (NICNET)	
	Subtotal	16
	Total[a]	106
6	Operational communications satellite systems (1 week)	
6.1	Classroom lectures	
	Overview of operational communications satellite systems	8
	FSS	
	MSS	
	BSS	
	Broadband multimedia system	
	Operational communications satellite systems	18
	International Telecommunication Union and other standardization organizations (ISO, APT, ETSI)	2
	International regulations	2
	Total[a]	30

Module/ submodule	*Topic*	*Number of 45-minute sessions*
7	Network planning/management/operational issues of satellite communications systems (1 week)	
7.1	Classroom lectures	
	Technical considerations for network planning	2
	Planning for space segment	2
	Traffic requirements	
	Options for satellite transponder (coverage, power, bandwidth, bent-pipe/regenerative)	
	Cross-pol isolation and collocated satellites	
	Choice of orbits (geosynchronous Earth orbit (GEO), MEO, LEO)	
	Planning for ground segment	2
	Trade-off between space segment and ground segment	
	HPA power and transmit antenna size	
	Off-axis radiation pattern	
	LNA noise temperature and receive	
	Antenna size	
	Cost	
	Network operations and control	2
	Management of communication satellite operations	4
	Normal operations	
	Operations of satellite control Earth station (tele-command, telemetry, tracking and ranging)	
	Orbit determinations, station keeping and fuel management	
	Sun outage and eclipse operations	
	Loss of lock	
	Intra-system/inter-system interference coordination	4
	Space law	2
	Financial aspects of satellite communications	2
	Total[a]	20
8	Satellite communications for development, education and training (2 weeks)	
8.1	Classroom lectures	
	Satellite communications for development education and training—an overview	4
	Indian experience with the Satellite Instructional Television Experiment (SITE), Kneda Communications Project (KCP), Training and Development Communications Channel (TDCC), Jhabua Development Communications Project (JDCP) and University Grant Commission (UGC)	6
	Hardware	
	Software	
	Social research	
	Local broadcasting (TV, radio, cable network)	2
	Planning for satellite communications for development	4
	Research and evaluation	
	Program production for development communications	

Module/ submodule	*Topic*	*Number of 45-minute sessions*
	Hardware	
	Cost	
	Satellite technology for development, education and training	8
	Receive system	
	Transmit system	
	Talk-back system	
	DAMA control	
	Value-added services	
	Return video	
	Data broadcasting	
	Internet broadcasting	
	Multimedia broadcasting	
	Two-way videoconferencing	
	Operational, technological and legal issues in transborder channels for development	2
	Teleconferencing experiences of users for rural development	4
	Disaster management	2
	Subtotal	32
8.2	Demonstrations	20
	Demonstration of talk-back systems (JDCP and TDCC)	
	Direct reception system (analog and digital)	
	Two-way video conference (Spacenet)	
8.3	Field visits	24
	Total[a]	76
9	Pilot project (10 weeks)	
	Project definition	
	Needs of the participant's country	
	Topic of interest of the participant	
	The work leading towards the one-year project	
	Suggested topics for the project	
	Earth station subsystems	
	Systems analysis for communications satellites	
	Spacecraft design	
	Antenna footprint design	
	Communication systems design	
	Network planning and relevant software development	
	Applications of TV and radio for development communications	
	Economics of satellite communications	
	Domestic system definition	
	Policy research	

[a]Totals do not include tests and examinations or library work (see also chap. II.A, table 2).

Annex II

Recommended teaching material

Elbert, B. Introduction to satellite communications, 2. ed. Boston, Artech House Publishers, 1999.

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