Satellite communications

Education curriculum
Satellite communications
Education curriculum
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.
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<thead>
<tr>
<th>Acronym</th>
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<td>AIR</td>
<td>All India Radio</td>
</tr>
<tr>
<td>AOCS</td>
<td>attitude and orbit control system</td>
</tr>
<tr>
<td>APT</td>
<td>Asia Pacific Telecommunity</td>
</tr>
<tr>
<td>ATM</td>
<td>asynchronous transfer mode</td>
</tr>
<tr>
<td>BER</td>
<td>bit error rate</td>
</tr>
<tr>
<td>BSS</td>
<td>broadcast satellite service</td>
</tr>
<tr>
<td>CBT</td>
<td>computer-based teaching</td>
</tr>
<tr>
<td>CDMA</td>
<td>code division multiple access</td>
</tr>
<tr>
<td>CISC</td>
<td>complex instruction set computer</td>
</tr>
<tr>
<td>C/KT</td>
<td>carrier-to-receiver noise density</td>
</tr>
<tr>
<td>C/N</td>
<td>carrier-to-noise (ratio)</td>
</tr>
<tr>
<td>DAMA</td>
<td>demand assignment multiple access</td>
</tr>
<tr>
<td>DBS</td>
<td>direct broadcasting satellite</td>
</tr>
<tr>
<td>DCT</td>
<td>discrete cosine transform</td>
</tr>
<tr>
<td>DECU</td>
<td>Development and Educational Communication Unit</td>
</tr>
<tr>
<td>DFT</td>
<td>discrete Fourier transform</td>
</tr>
<tr>
<td>DMA</td>
<td>direct memory access</td>
</tr>
<tr>
<td>DOE</td>
<td>Department of Electronics</td>
</tr>
<tr>
<td>DOS</td>
<td>disk operating system</td>
</tr>
<tr>
<td>DOT</td>
<td>Department of Telecommunications</td>
</tr>
<tr>
<td>DSDB</td>
<td>digital sound and data broadcasting</td>
</tr>
<tr>
<td>DSP</td>
<td>digital signal processing</td>
</tr>
<tr>
<td>DTH</td>
<td>direct-to-home</td>
</tr>
<tr>
<td>DVB</td>
<td>digital video broadcasting</td>
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<tr>
<td>EIRP</td>
<td>effective isotropic radiated power</td>
</tr>
<tr>
<td>EMC</td>
<td>electromagnetic compatibility</td>
</tr>
<tr>
<td>EMI</td>
<td>electromagnetic interference</td>
</tr>
<tr>
<td>ETSI</td>
<td>European Telecommunications Standards Institute</td>
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<tr>
<td>FFT</td>
<td>fast Fourier transform</td>
</tr>
<tr>
<td>FIR</td>
<td>finite impulse response</td>
</tr>
<tr>
<td>FM</td>
<td>frequency modulation</td>
</tr>
<tr>
<td>FMTV</td>
<td>frequency modulation television</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
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<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>FSS</td>
<td>fixed satellite service</td>
</tr>
<tr>
<td>GEO</td>
<td>geosynchronous Earth orbit</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>G/T</td>
<td>antenna gain to system noise temperature ratio</td>
</tr>
<tr>
<td>HDTV</td>
<td>high-definition television</td>
</tr>
<tr>
<td>HPA</td>
<td>high-power amplifier</td>
</tr>
<tr>
<td>IIR</td>
<td>infinite impulse response</td>
</tr>
<tr>
<td>IMD</td>
<td>India Meteorological Department</td>
</tr>
<tr>
<td>IMT</td>
<td>International Mobile Telecommunication</td>
</tr>
<tr>
<td>INSAT</td>
<td>Indian National Satellite System</td>
</tr>
<tr>
<td>I/O</td>
<td>input/output</td>
</tr>
<tr>
<td>IP</td>
<td>Internet protocol</td>
</tr>
<tr>
<td>ISDN</td>
<td>integrated services digital network</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
</tr>
<tr>
<td>ITU</td>
<td>International Telecommunication Union</td>
</tr>
<tr>
<td>JDCP</td>
<td>Jhabua Development Communications Project</td>
</tr>
<tr>
<td>KCP</td>
<td>Kheda Communications Project</td>
</tr>
<tr>
<td>LAN</td>
<td>local area network</td>
</tr>
<tr>
<td>LEO</td>
<td>low-Earth orbit</td>
</tr>
<tr>
<td>LNA</td>
<td>low-noise amplifier</td>
</tr>
<tr>
<td>MBS</td>
<td>multimedia broadcast service</td>
</tr>
<tr>
<td>MCPC</td>
<td>multiple channels per carrier</td>
</tr>
<tr>
<td>MEO</td>
<td>medium-Earth orbit</td>
</tr>
<tr>
<td>MIC</td>
<td>microwave integrated circuit</td>
</tr>
<tr>
<td>MPEG</td>
<td>Moving Picture Experts Group</td>
</tr>
<tr>
<td>MSS</td>
<td>mobile satellite service</td>
</tr>
<tr>
<td>NICNET</td>
<td>National Informatics Centre Network</td>
</tr>
<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
</tr>
<tr>
<td>OBP</td>
<td>on-board processing</td>
</tr>
<tr>
<td>PTI</td>
<td>Press Trust of India</td>
</tr>
<tr>
<td>RFI</td>
<td>radio frequency interference</td>
</tr>
<tr>
<td>RISC</td>
<td>reduced instruction set computer</td>
</tr>
<tr>
<td>SCPC</td>
<td>single channel per carrier</td>
</tr>
<tr>
<td>Acronym</td>
<td>Full Form</td>
</tr>
<tr>
<td>---------</td>
<td>-----------</td>
</tr>
<tr>
<td>SITE</td>
<td>Satellite Instructional Television Experiment</td>
</tr>
<tr>
<td>S/N</td>
<td>signal-to-noise (ratio)</td>
</tr>
<tr>
<td>SNG</td>
<td>satellite news gathering</td>
</tr>
<tr>
<td>SSMA</td>
<td>spread spectrum multiple access</td>
</tr>
<tr>
<td>TCP/IP</td>
<td>transmission control protocol/Internet protocol</td>
</tr>
<tr>
<td>TDCC</td>
<td>Training and Development Communication Channel</td>
</tr>
<tr>
<td>TDM</td>
<td>time division multiplexing</td>
</tr>
<tr>
<td>TDMA</td>
<td>time division multiple access</td>
</tr>
<tr>
<td>TT and C</td>
<td>Telemetry, Tracking and Command</td>
</tr>
<tr>
<td>TVRO</td>
<td>television receive-only system</td>
</tr>
<tr>
<td>UGC</td>
<td>University Grant Commission</td>
</tr>
<tr>
<td>VHRR</td>
<td>very high resolution radiometer</td>
</tr>
<tr>
<td>VSAT</td>
<td>very small aperture terminal</td>
</tr>
</tbody>
</table>
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 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. 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.
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>
<thead>
<tr>
<th>Module</th>
<th>Topics</th>
<th>Duration in weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Orientation course</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>Communication systems and digital signal processing</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>Satellite communication systems</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>Earth station technology</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Broadcasting using communication satellites</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Applications and trends in satellite communications</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>Operational communication satellite systems</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Network planning, management and operational issues of satellite communication systems</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Satellite communications for development, education and training</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>Pilot projects</td>
<td>10</td>
</tr>
</tbody>
</table>

**Total duration**: 35 weeks

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>
<thead>
<tr>
<th>Type of training</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lectures</td>
<td>40</td>
<td>138</td>
<td>120</td>
<td>46</td>
<td>42</td>
<td>62</td>
<td>30</td>
<td>20</td>
<td>32</td>
</tr>
<tr>
<td>Practical exercises</td>
<td>54</td>
<td>48</td>
<td>28</td>
<td>48</td>
<td>28</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visits</td>
<td>24</td>
<td>24</td>
<td>12</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>24</td>
</tr>
<tr>
<td>Library</td>
<td>24</td>
<td>12</td>
<td>8</td>
<td>4</td>
<td>10</td>
<td>20</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class tests and exams</td>
<td>8</td>
<td>24</td>
<td>10</td>
<td>10</td>
<td></td>
<td></td>
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</tbody>
</table>

**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

<table>
<thead>
<tr>
<th>Course modules</th>
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<tbody>
<tr>
<td><strong>Module No.</strong></td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>1</td>
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<tr>
<td>2</td>
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<td>3</td>
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<td>8</td>
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<td>9</td>
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<tr>
<td>10</td>
</tr>
</tbody>
</table>

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

Module 10: 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


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

<table>
<thead>
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<th>Module/submodule</th>
<th>Topic</th>
<th>Number of 45-minute sessions</th>
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<td>Introduction to activities of the local host institution</td>
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<td>Communication skills (oral, written, presentation, group discussion etc.)</td>
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<td>Linear convolution using discrete Fourier transform</td>
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Module/submodule | Topic | Number of 45-minute sessions
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Optimum approximation of FIR filters | 1.4 Laboratory exercises/tutorial | 2
FIR equi-ripple approximation | MATLAB-based exercises | 10
Wavelet transform | Design of FIR and IIR filters | 4
Examples of DSP-based subsystems for satellite communications | Implementation of DFT/FFT | 4
Subtotal | Examples of DSP-based communication subsystems | 58
Familiarization with and implementation of evaluation board | Familiarization with and implementation of evaluation board | 12
FIR and IIR filters | Subtotal | 22
Demodulator algorithm | Total* | 192
Viterbi coding | Satellite communication systems (6 weeks) | 2
FFT and discrete cosine transform (DCT) | 2.1 Classroom lectures | 4
Satellite communication techniques
Introduction to satellite communications | 28
Evolution of satellite communications | Multiplexing techniques | 4
Elements of satellite communications | Modulation techniques | 6
Types of satellite orbits | Multiple access techniques | 6
Geosynchronous satellite communications | Code division multiple access (CDMA) | 2
Satellite communications services | Coding theory and error correction techniques | 4
Satellite orbits | IP over satellite | 4
Launch vehicles and launching of satellites | Satellite configurations | 2
Satellite communications links | Space environment | 2
Frequency bands for satellite communications | Satellite bus subsystems | 12
Propagation effects on satellite communication links | Mechanical structure | 2
Satellite communication techniques
Multiplexing techniques | 2
Modulation techniques | Attitude and orbit control system (AOCS) | 2
Multiple access techniques | Propulsion subsystem | 2
Code division multiple access (CDMA) | Electrical power subsystem | 2
Coding theory and error correction techniques
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<td>Life of a satellite</td>
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<td>Satellite communications (video computer-based teaching (CBT) and tutorials)</td>
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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 |
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<td>Environmental test facility</td>
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<td>Communication system laboratories</td>
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<td>Remote sensing laboratories</td>
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<td>Technology of Earth station subsystems</td>
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<td>Antenna reflector and mount for large, medium and small Earth stations</td>
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<td>Feed system for large, medium and small Earth stations</td>
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<td>Antenna size and gain</td>
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<td></td>
<td>Radiation pattern and antenna coverage</td>
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<td></td>
<td>Redundancy and reliability</td>
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<tr>
<td></td>
<td>Environmental specifications</td>
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<td></td>
<td>VSAT/mobile/briefcase/hand-held terminals</td>
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<td></td>
<td><strong>Check out of Earth stations</strong></td>
<td><strong>8</strong></td>
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<tr>
<td></td>
<td>Antenna measurements (farfield, nearfield, anechoic chamber)</td>
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<td></td>
<td>LNA and G/T</td>
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<td></td>
<td>HPA and EIRP</td>
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</tr>
<tr>
<td></td>
<td>Frequency converter</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Test-loop translator</td>
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<td><strong>Reliability of Earth stations</strong></td>
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<td>Operations and maintenance of fixed and transportable Earth stations</td>
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<td></td>
<td>Fabrication techniques</td>
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<tr>
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<td>Mechanical fabrication techniques</td>
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<td></td>
<td>Electronics fabrication techniques</td>
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<td>Microwave integrated circuits (MIC)</td>
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<td>Number of 45-minute sessions</td>
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<td>3.2 Local visits</td>
<td>Department of Telecommunications (DOT) Earth station</td>
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<td>Department of Electronics (DOE) Software Technology Park</td>
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<td></td>
<td>Antenna test facility (host institution)</td>
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<td>MIC facility (host institution)</td>
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<td>Electronics fabrication facility (host institution)</td>
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<td>Mechanical fabrication facility (host institution)</td>
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<td>3.3 Experiments/demonstrations</td>
<td>Familiarization with Earth station subsystems</td>
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<td>Testing of Earth station subsystems</td>
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<td>Testing of feed system</td>
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<td></td>
<td>Testing of HPA</td>
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<td>Testing of LNA</td>
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<td>Testing of frequency converter</td>
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<td>Testing of antenna tracking system (manual and auto mode)</td>
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<td>4 Broadcasting using communication satellites (3 weeks)</td>
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<td>4.1 Classroom lectures</td>
<td>Broadcasting system standards</td>
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<td>Frequency modulation television (FMTV)</td>
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<td>High-definition television (HDTV)</td>
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<td>Digital video broadcasting (DVB)</td>
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<td>Moving Picture Experts Group (MPEG)</td>
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<td>Digital television (video presentation)</td>
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<td></td>
<td>Satellite links for TV broadcasting (analog and digital)</td>
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<td>Frequency bands for satellite broadcasting and national/international regulations</td>
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<td>Satellite TV and access systems</td>
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<tr>
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<td>Cable TV</td>
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<td>Direct broadcasting satellite/direct-to-home (DBS/DTH)</td>
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<td>Conditional access</td>
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<td></td>
<td>Network management</td>
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</tr>
<tr>
<td></td>
<td>Satellite news gathering (SNG) for radio and TV</td>
<td>2</td>
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<tr>
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<td>Radio networking</td>
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<tr>
<td></td>
<td>Digital audio broadcasting</td>
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</tr>
<tr>
<td></td>
<td>Outdoor broadcasting van</td>
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<tr>
<td></td>
<td>TV studio and its operations</td>
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<td></td>
<td>TV coverage of sports</td>
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<td>Multicasting</td>
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## Module/submodule

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<th>Number of 45-minute sessions</th>
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<tr>
<td>Videoconferencing via satellite</td>
<td>2</td>
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<tr>
<td>Multimedia (video presentation)</td>
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<td>Video on demand</td>
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### 4.2 Laboratory experiments/demonstrations

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<thead>
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</thead>
<tbody>
<tr>
<td>Familiarization with video baseband systems</td>
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<tr>
<td>Measurement of video signal-to-noise (S/N) ratio versus carrier-to-noise (C/N) radio and video threshold</td>
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<tr>
<td>Measurement of TV audio S/N</td>
<td></td>
</tr>
<tr>
<td>Measurement of S/N versus FM deviation</td>
<td></td>
</tr>
<tr>
<td>Measurement of TV signal parameters using waveform monitor, vectorscope and automated test equipment</td>
<td></td>
</tr>
<tr>
<td>SCPC/multiple channels per carrier (MCPC) digital TV</td>
<td></td>
</tr>
<tr>
<td>Determination of transponder operating points for:</td>
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</tr>
<tr>
<td>Single carrier per transponder</td>
<td></td>
</tr>
<tr>
<td>Multicarrier per transponder</td>
<td></td>
</tr>
<tr>
<td>Familiarization with radio networking terminals</td>
<td></td>
</tr>
<tr>
<td>Demonstration of operations of SNG terminals</td>
<td></td>
</tr>
<tr>
<td>Setting up a TV direct reception system</td>
<td></td>
</tr>
<tr>
<td>Digital sound and data broadcasting (DSDB) system</td>
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</tr>
<tr>
<td>Multimedia broadcasting/multicasting</td>
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</tr>
<tr>
<td>subtotal</td>
<td>48</td>
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</table>

### 4.3 Local visits

| 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                                                                 | 102                         |

## 5 Applications and trends in satellite communications (3 weeks)

### 5.1 Classroom lectures

<table>
<thead>
<tr>
<th>Topic</th>
<th>Number of 45-minute sessions</th>
</tr>
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<tbody>
<tr>
<td>Satellite communications services</td>
<td>26</td>
</tr>
<tr>
<td>Rural/remote area communications</td>
<td>2</td>
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<tr>
<td>VSAT network</td>
<td>8</td>
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<tr>
<td>Time division multiplexing (TDM)-TDMA</td>
<td></td>
</tr>
<tr>
<td>SCPC-demand assignment multiple access (DAMA)</td>
<td></td>
</tr>
<tr>
<td>Remote terminals</td>
<td></td>
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<tr>
<td>Hub</td>
<td></td>
</tr>
<tr>
<td>Network management</td>
<td></td>
</tr>
<tr>
<td>Meteorological data reception systems (National Oceanic and Atmospheric Administration (NOAA), Indian National Satellite System (INSAT))</td>
<td>2</td>
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<tr>
<td>News and meteorological data dissemination system</td>
<td>2</td>
</tr>
<tr>
<td>Data collection system</td>
<td>2</td>
</tr>
<tr>
<td>Disaster management using satellite communications</td>
<td>2</td>
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<tr>
<td>Module/ submodule</td>
<td>Topic</td>
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<tr>
<td>------------------</td>
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<tr>
<td></td>
<td>Search and rescue system</td>
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<tr>
<td></td>
<td>International</td>
</tr>
<tr>
<td></td>
<td>Regional (INSAT)</td>
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<tr>
<td></td>
<td>Cyclone warning dissemination system</td>
</tr>
<tr>
<td></td>
<td>Telemedicine</td>
</tr>
<tr>
<td></td>
<td>Time and frequency transmission system</td>
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<tr>
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<td>Mobile and personal communication services (IMT-2000, 4G etc.)</td>
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<td>Strategic satellite communication systems</td>
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<td></td>
<td>Satellite navigation system</td>
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<tr>
<td></td>
<td>Satellite-based Internet system</td>
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<tr>
<td></td>
<td>Multimedia broadband satellite system</td>
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<td>Video CBT and tutorials</td>
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<td>5.2</td>
<td>Laboratory experiments/demonstrations</td>
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<tr>
<td></td>
<td>NOAA very high resolution radiometer (VHRR) data reception</td>
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<td>News and meteorological data dissemination system</td>
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<td></td>
<td>Search-and-rescue beacon</td>
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<tr>
<td></td>
<td>Operations of Global Positioning System (GPS) receiver and INSAT</td>
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<tr>
<td></td>
<td>reporting system</td>
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<td></td>
<td>VSAT terminal and network</td>
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<td></td>
<td>Data and sound broadcasting system</td>
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<td>Subtotal</td>
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<td>5.3</td>
<td>Local visit</td>
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<tr>
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<td>Press Trust of India (PTI)</td>
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<td></td>
<td>India Mobile Department (IMD)</td>
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<td>Airport</td>
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<td></td>
<td>National Informatics Centre Network (NICNET)</td>
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<td>Subtotal</td>
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<td>Total</td>
</tr>
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<td>6</td>
<td>Operational communications satellite systems (1 week)</td>
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<td>Overview of operational communications satellite systems</td>
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<td>FSS</td>
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<td>MSS</td>
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<tr>
<td></td>
<td>BSS</td>
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<tr>
<td></td>
<td>Broadband multimedia system</td>
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<tr>
<td></td>
<td>Operational communications satellite systems</td>
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<tr>
<td></td>
<td>International Telecommunication Union and other standardization</td>
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<td></td>
<td>organizations (ISO, APT, ETSI)</td>
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<td>International regulations</td>
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<td>Module/ submodule</td>
<td>Topic</td>
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<tr>
<td>7</td>
<td>Network planning/management/operational issues of satellite communications systems (1 week)</td>
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<tr>
<td></td>
<td>Technical considerations for network planning</td>
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<tr>
<td></td>
<td>Planning for space segment</td>
</tr>
<tr>
<td></td>
<td>Traffic requirements</td>
</tr>
<tr>
<td></td>
<td>Options for satellite transponder (coverage, power, bandwidth, bent-pipe/regenerative)</td>
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<tr>
<td></td>
<td>Cross-pol isolation and collocated satellites</td>
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<tr>
<td></td>
<td>Choice of orbits (geosynchronous Earth orbit (GEO), MEO, LEO)</td>
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<tr>
<td></td>
<td>Planning for ground segment</td>
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<tr>
<td></td>
<td>Trade-off between space segment and ground segment</td>
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<td></td>
<td>HPA power and transmit antenna size</td>
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<td>Off-axis radiation pattern</td>
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<td>LNA noise temperature and receive</td>
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<td></td>
<td>Antenna size</td>
</tr>
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<td>Cost</td>
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<td>Network operations and control</td>
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<td>Management of communication satellite operations</td>
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<td>Normal operations</td>
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<td>Operations of satellite control Earth station (tele-command, telemetry, tracking and ranging)</td>
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<td>Orbit determinations, station keeping and fuel management</td>
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<td>Sun outage and eclipse operations</td>
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<td>Loss of lock</td>
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<td>Intra-system/inter-system interference coordination</td>
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<td>Space law</td>
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<td>Financial aspects of satellite communications</td>
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<td>8</td>
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<td>Satellite communications for development education and training—an overview</td>
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<td>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)</td>
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<td>Hardware</td>
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<td>Software</td>
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<td>Social research</td>
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<td>Local broadcasting (TV, radio, cable network)</td>
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<td></td>
<td>Planning for satellite communications for development</td>
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<td>Research and evaluation</td>
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<td>Program production for development communications</td>
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</table>
## Module/ submodule | Topic | Number of 45-minute sessions
--- | --- | ---

Hardware
Cost
Satellite technology for development, education and training
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
Teleconferencing experiences of users for rural development
Disaster management
Subtotal

### 8.2 Demonstrations

Demonstration of talk-back systems (JDCP and TDCC)
Direct reception system (analog and digital)
Two-way video conference (Spacenet)

### 8.3 Field visits

Total

### 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

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

Recommended teaching material


