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# INTERNATIONAL COMMUNICATIONS SATELLITE SYSTEMS

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ABSTRACT

Ten satellite systems for international communication are briefly described. Modulation and coding schemes on some of these systems are highlighted.

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## 1.0 Introduction

After a quarter century of innovation, development, cooperation and services, satellite communications have had significant world wide impact and brings people closer than ever before. International satellite communications has increased by a factor of more than one hundred. Nearly two hundred countries and territories use satellite for television, radio, telephone and data services. As technology advances, service requirements and traffic patterns change, the interests of satellite communication communities also change. Among the changes is the creation of multiple international communication satellite systems.

In this paper an attempt is made to highlight these systems. Among the international systems considered are:

- INTELSAT
- INMARSAT
- MOLNIYA - STATSIONAR
- EUTELSAT
- ORION
- ARABSAT
- ASIASAT
- ASTRA
- PANAMSAT
- HISPASAT

Although some of these systems are regional, in this paper a system is referred to as international if its operation is beyond the boundary of a single nationality. Otherwise they are referred to as domestic or national systems. A glance at some of the synchronous orbit satellites is shown in Figure 1 [1].

## 2.0 INTELSAT

INTELSAT is the international telecommunication satellite cooperative established by the world wide treaty. With 15 satellites the INTELSAT system covers all three oceanic regions over the globe. Its membership contains 115 countries and link together more than 165 countries and territories. At present, there are more than one thousand ground stations utilizing INTELSAT's space segments. Technically, INTELSAT was the first to use channelized repeater in INTELSAT IV, the first to exploit spatial re-use of frequencies in IS-IVA, the first to combine spatial and polarization frequency re-use in INTELSAT V, the first to implement high speed TDMA and SS/TDMA in INTELSAT VI, the first to use a linearizer in INTELSAT VII. Most of all, all INTELSAT digital systems employed error correcting codecs. A number of these codecs have been introduced into other international communication satellite systems.

To meet traffic demand the following INTELSAT systems have been implemented:

- FDMA/FM
- SPADE, SCPC
- IBS
- INTELNET
- TDMA
- IDR
- VISTA

Some of these systems are well known, others can be found in references [2, 3, 4, 5]. The INTELSAT gateway stations are shown in Table 1. The six INTELSAT satellite series are summarized in Table 2. The main features of INTELSAT VII is shown in Table 3. No new modulation and coding schemes have been proposed through the TDMA system to be operated on INTELSAT VII.

All INTELSAT digital systems employ phase modulation. For SPADE and SCPC systems rate 3/4 self-orthogonal convolutional code with threshold decoding is used for 48 kbps data, the rate 7/8 convolutional code are used for 56 kbps data. The (128, 112) BCH code of 120 Mbps is implemented in the INTELSAT TDMA system. The (24, 12) Golay code is used for digital speech interpolation assignment messages. For INTELSAT's IBS both rate 1/2 and rate 3/4 punctured convolutional codes with soft decision Viterbi decoding are part of the system. Operated from 64 kbps to 45 Mbps the INTELSAT Intermediate Data Rate (IDR) system has a constraint length 7 convolutional punctured code of code rate 3/4 with Viterbi decoding [6].

## 3.0 INMARSAT

The system was established in 1979 and operational in 1982 for the purpose of international maritime communication. Today the INMARSAT system provides services to more than 70 countries. Among one of the most forward looking international organization INMARSAT not only provides services to ships in all three oceanic regions, but also is in the process of providing land mobile as well as aeronautical applications. In a recent paper on mobile satellite services Mr. Olof Lundberg, the Director General of INMARSAT set the tone for international co-ordination, co-operation and competition [7]. Coordination for networks operate within the allocated and limited L-band is essential, because such networks have been planned by Australia, Canada, France Japan, Mexico, Papua-New Guinea, U.S., U.S.S.R. as well as INMARSAT. Cooperation among the network providers, users and manufacturers can enhance the marketability and unify the compatibility. Competition can keep cost low and the quality of service high.

The INMARSAT system consists of the space segment, coast stations, and stations on ships. For the space segment INMARSAT currently leases capacity on various satellites, such as MARISAT of

COMSAT General, MARECS of ESA (European Space Agency), as well as INTELSAT satellites. At present there are 13 coastal earth stations coordinated by the Operations Control Center in London provide services to more than 4,000 ship stations. Most of these stations are 1.0 m in diameter, with 23 dB gain. The system supports data transmission up to 56 kbps [8].

Due to small antenna size on ships and severe fading environment error coding becomes essential. Comprehensive transmission channel modeling, analysis and simulation were provided by researchers at DFVLR. In addition, modulation and coding scheme for maritime satellite channel were evaluated. BPSK with differential coding were selected, and rate 1/2 constraint length 7 convolutional with interleaved Viterbi decoding as well as multiple burst error correcting Reed-Solomon code were recommended [9]. At present the INMARSAT system contains a (63, 57) BCH code for assignment and request messages, a (63, 39) BCH code for channel request messages. The ship-to-shore 56 kbps data transmission uses the convolutional code with soft decision. Rate 3/4 decoders are also implemented [6].

## 4.0 MOLNIYA-STATSIONAR

At least one hundred MOLNIYA satellites, over three series, were built and launched by the Soviet Union since 1965. Since 1970 MOLNIYA systems have provided international services mostly to neighboring U.S.S.R. countries. Since 1975 STATSIONAR satellites have been continuously launched into the 80's.

STATSIONAR satellites have associated a number of ground station networks including Orbita, Ekran and Moskva. Both MOLNIYA and STATSIONAR satellite systems operated on the Intersputnik network for international communication. The Intersputnik network includes most communist east European and Asian nations with close relation to the Soviet Union such as Cuba.

Among other technical details the MOLNIYA and STATSIONAR satellites differ in orbits. MOLNIYA systems operate on an elliptical inclined orbit and 62-65 degree inclination for power conservation and earth coverage. The STATSIONAR satellites are operated on the synchronous equatorial orbit. The STATSIONAR has three system variations: RADUGA, EKRAN, and GORIZONT. Each system variation has a number of series.

For example, Raduga 20, EKRAN 20 or GORIZONT 20. The STATSIONAR satellites operation 5.7/6.2 GHz and 3.4/3.9 GHz bands. Although it is difficult to get detail information on these satellites some data is available from the U.S. Congressional Research Reports on Soviet Space Programs and other references cited by Martin [10]. As far as modulation and coding are concern, it is most likely phase modulation with convolutional coding have been used for their digital systems. This is judged from other scientific journals published in the U.S.S.R.

## 5.0 EUTELSAT

With 26 signatories the system was formally established in 1985 by the European Conference of Post and Telecommunication Organization (CEPT) and operated from Paris. Just as NASA has the mandate to support U.S. industry, EUTELSAT was created to promote satellite technology in Europe. From technical viewpoint EUTELSAT has had close association with the European Space Agency (ESA). The EUTELSAT TDMA system is operational since 1987.

The EUTELSAT system has four satellites in orbit and each satellite has ten transponders. Each transponder has 80 MHz or 72 MHz usable bandwidth. The system is operated at Ku-band. Each EUTELSAT satellite has three spot beams with both vertical and horizontal polarization. The second version of the EUTELSAT system is scheduled to be operational in 1990. The revised system has five satellites totaling sixteen transponders, nine of them with 36 MHz bandwidth and system is capable of controlling 29 traffic stations and each station can monitor 7 transponders. The countries (stations) can communicate through this system are: Austria (Aflenz), Belgium-Netherland-Luxembourg (Lessive), Cyprus (Makarios), France (Bercenay-en-othe), Germany (Usingen), Italy (Fucino), Portugal (Sintra), Spain (Guadalajara), Sweden-Denmark-Finland- Norway (AEGSTA), Turkey (Ankara), and United Kingdom (Madley) [11, 12]. Seven of the transponders have 72 MHz usable bandwidth with a 50W TWTA, the EUTELSAT II has the unique switchable beam coverages. For narrow spot beam 50 dBW e.i.r.p. from the satellite is obtainable. For wide beam, coverage, 44 dBW is expected at edge of coverage. With EUTELSAT II satellites, the TDMA stations have diameters of 11m with G/T of 37 dB/K. The modulation for EUTELSAT digital systems is QPSK, and the error coding is the rate 7/8 (128, 112) BCH code as used in the INTELSAT TDMA system. Except the transmission rate of the EUTELSAT system is lower at 24.576 Mbps.

## 6.0 ORION

The ORION satellite system is planned to be implemented for international public telecommunication services between U.S., the U.K. and other possible countries in North America and Europe. To be expected operational in 1992 the ORION satellites are to be located at 322.5°E/37.5°W and 313°E/47.0°W in orbit. These satellites use 14 GHz for uplink and 11.45 - 12.2 GHz and 12.5-12.75 GHz for downlink. Each ORION satellite has 34 transponders in eight fixed beams. The bandwidth of each satellite is 2 GHz. Every satellite is to be operated at Ku-band. The satellites are designed to operate in both horizontal and vertical polarizations. The system is designed to provide digital services primary to VSAT stations with size from 1.2m to 1.8m. TVRO stations are of 0.85m. The maximum e.i.r.p. of a ORION satellite is 54.7 dBW.

Modulation for the ORION depends on the carrier type and information rate. For television services there are 17.5, 30, and 36 MHz analog FM bandwidths with frequency deviations of 7.5, 19 and 25 MHz respectively. Digital video is transmitted at 44.7 Mbps with QPSK. For information rates of less than 8 Mbps both BPSK and QPSK can be used. For data rate at 8 Mbps 8 OPSK will be used, For data rates between 40 Mbps to 60 Mbps, 16 QAM is proposed. For 140 Mbps, 64 QAM modulation will be implemented. Depending on the modulation scheme both rate 1/2 and rate 3/4 convolutional codes are used for error corrections.

## 7.0 Concluding Remarks

Based on Westar VI series satellites the first ASISAT system is due to launch in the Spring of 1990 by the Chinese Long March III. The northern beam of ASIASAT intends to cover most China, India, Japan and the Northern part of Southeast Asia. The southern beam covers Thailand, Pakistan and may be Iran. Half of the ASIASAT system capacity may be expected to be used for television distribution.

ASIASAT has twenty four 36 MHz bandwidth transponders with dual polarization frequency reuse. Transmitters are operated at 3702 to 4198 MHz and the receivers are operated at 5927 to 6423 MHz. At edge of coverage the e.i.r.p per transponder is 34.5 dBW.

ARABSAT came into existence at the end of 1976 through the twenty two countries of the League of Arab States. Two satellites were launched in 1984. The technology of ARABSAT satellite centered around INTELSAT V and Telecom I. The communication subsystem uses C-band with one additional downlink at 2.5 GHz. Modulation is FM without channel coding.

ASTRA is operational since February 1989. The system is a Luxembourg based broadcasting network for the European continent. There are scrambling devices used in ASTRA system to black out the unintended receivers. 50,000 TVRO with such decoder are expected in 1989.

PanAmSat has been operational since June 1988 with a 24 - hour-per-day English language news service through Cable News Network(CNN). PanAmSat is in the process to expand the coverages to Peru, the Dominican Republic and Costa Rica, The digital carriers of PanAmSat system can also be operated from 64 kbps to 2.0 48 Mbps with QPSK modulation throughout. Error correcting. Code used are rate 1/2 constraint length 7 convolutional codes either with Viterbi decoding or sequential decoding. The choices of modulation and coding in the PanAmSat system are actually left to the users.

HISPASAT is recently proposed for 1992 by Spain to provide television services covering not only the country of Spain, but also Europe, North and South America. Thus it is classified here as an international system. HISPASAT intends to use 1.2m to 4.5m earth stations at Ku band, and 2.0m to 2.5m antennas for television receive only. At C-band the system intends to have 2.6m to 7.0 earth stations. Technical details such as modulation and coding are not yet available.

From a brief review on international satellite communication systems in this paper, it is not very exciting to report the fact that with all the variation and technological advancement in modulation and error coding, very little has been actually introduced into these practical systems. It is time for modulation and coding experts to educate system decision makers to look beyond what has been done and to show what can be done. The NASA Conference on Advanced Modulation and Coding Technology is an important forum not only for sponsored industry briefing, but also a focal point of new modulation and coding techniques to be recommended for future satellite applications world wide.

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**SATELLITE LOCATIONS**

(Geostationary orbit, equatorial plane)

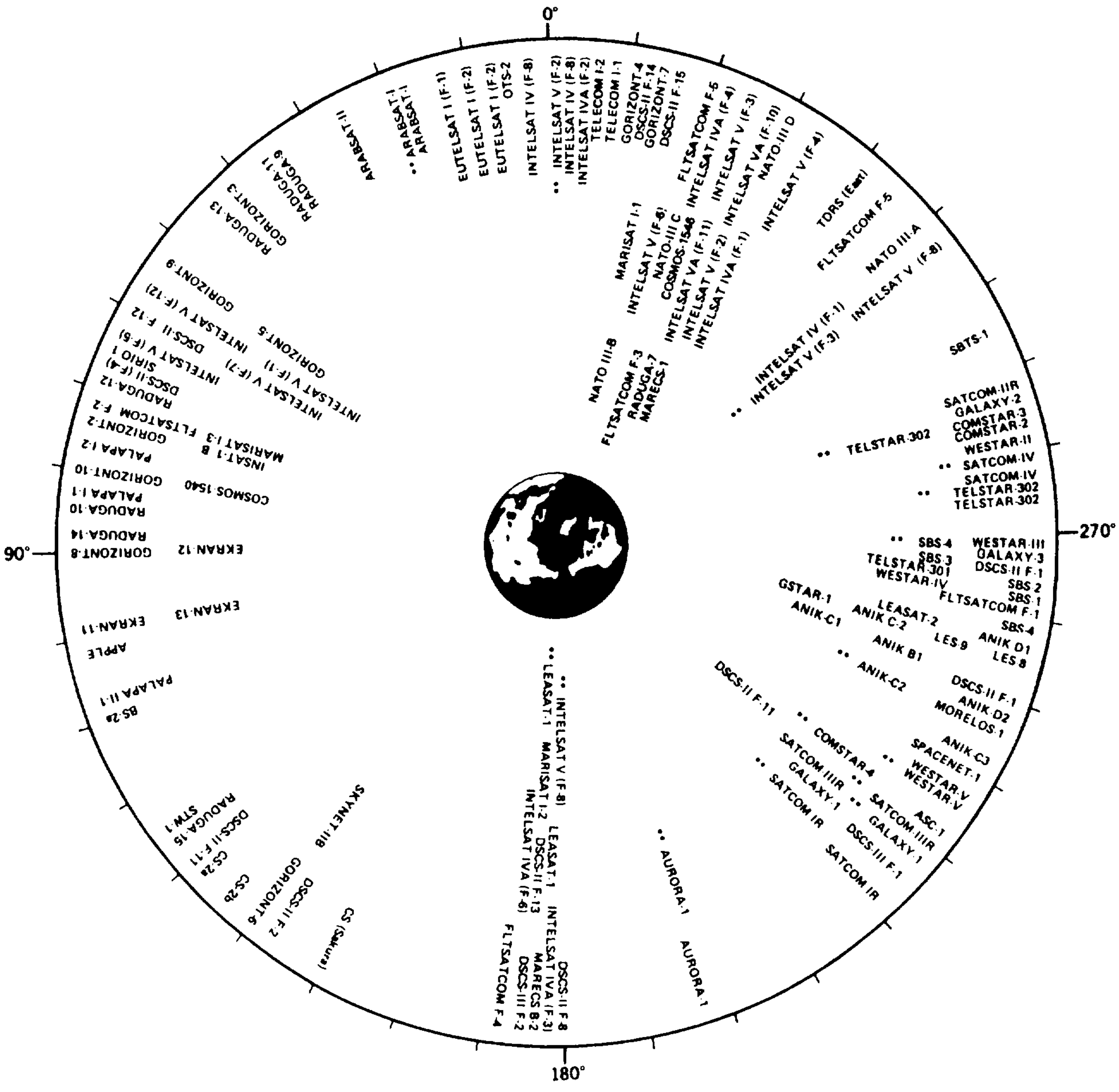


FIGURE 1:

# TABLE 1: INTELSAT GATEWAYS

| Type | Earth Station Standard | Antenna Size (m) | Minimum G/T (dB/°K) | Services | Frequency Bands (GHz) |
|---|---|---|---|---|---|
| LARGE (Country) | A | 15-32 | 35.0 | Telephony, data TV, IBS | 6/4 |
| | C | 11-30 | 37.0 | Telephony, data TV, IBS | 14/11&12 |
| | B | 11-13 | 31.7 | Telephony, data TV, IBS | 6/4 |
| INTER-MEDIATE (Teleport) | F-3 | 9-10 | 29.0 | Telephony, data IBS, TV | 6/4 |
| | E-3 | 8-10 | 34.0 | Telephony, data IBS, TV | 14/11&12 |
| | F-2 | 7-8 | 27.0 | Telephony, data IBS, TV | 6/4 |
| | E-2 | 5.0-7.0 | 29.0 | Telephony, data IBS, TV | 14/11&12 |
| SMALL (Business) | F-1 | 4.5-5 | 22.7 | IBS, TV | 6/4 |
| | E-1 | 3.5 | 25.0 | IBS, TV | 14/11&12 |
| | D-1 | 4.5-5.5 | 22.7 | VISTA | 6/4 |
| VSAT | G | 0.6-2.4 | 5.5 | INTELNET | 6/4;14/11&12 |
| TVRO | | 1.2-11 | 16 | TV | 6/4;14/11&12 |
| DOMESTIC | Z | 0.6-32 | 5.5-16 | Domestic | 6/4;14/11&12 |

# TABLE 2: INTELSAT SERIES

| INTELSAT DESIGNATION | I | II | III | IV | IV-A | V | V-A | VI |
|---|---|---|---|---|---|---|---|---|
| Year of First Launch | 1965 | 1967 | 1968 | 1971 | 1975 | 1980 | 1985 | 1989 |
| Prime Contractor | Hughes | Hughes | TRW | Hughes | Hughes | Ford Aerospace | Ford Aerospace | Hughes |
| Width Dimension, m (Undeployed) | 0 7 | 1 4 | 1 4 | 2 4 | 2 4 | 2 0 | 2 0 | 3 6 |
| Height Dimensions, m (Undeployed) | 0 6 | 0 7 | 1 0 | 5 3 | 6 8 | 6 4 | 6 4 | 6 4 |
| Launch Vehicles | Thor Delta | Thor Delta | Thor Delta | Atlas Centaur | Atlas Centaur | Atlas Centaur or Ariane 1, 2 | Atlas Centaur or Ariane 1, 2 | Ariane 4 or Commercial Titan |
| Design Lifetime, Years | 1 5 | 3 | 5 | 7 | 7 | 7 | 7 | 14 |
| Bandwidth, MHz | 50 | 130 | 300 | 500 | 800 | 2 144 | 2,250 | 3 300 |
| **Capacity** | | | | | | | | |
| Voice Circuits | 240 | 240 | 1,500 | 4 000 | 6,000 | 12 000 | 15,000 | 120 000 |
| Television Channels | — | — | — | 2 | 2 | 2 | 2 | 3 |

# TABLE 3: INTELSAT VII MAIN FEATURES

- 3 dB more E.I.R.P. than IS-VA

| | | | |
|---|---|---|---|
| Hemi | 29.0 | ⟶ | 33 dBW |
| Global | 26.5 | ⟶ | 29 dBW |
| Zone | 29.0 | ⟶ | 33 dBW |
| C-Spot | NEW | | (36.3 dBW) |
| Ku-Band Spot | 41.0 | ⟶ | 45 dBW |

- C-Band all SSPA
  Better linearity
- Ku-Band TWTA/Linearizer
  Better linearity ⟶ more capacity
  3 Spot Beams
- More flexible for domestic connectivity
- TDMA