INTERNATIONAL TWO-WAY SATELLITE TIME TRANSFERS USING INTELSAT SPACE SEGMENT AND SMALL EARTH STATIONS

L. B. Veenstra
International Telecommunications Satellite Organization
3400 International Drive, N.W.
Washington, D.C. 20008-3098

Abstract

The satellite system operated by the International Telecommunications Satellite Organization (INTELSAT) provides new and unique capabilities for the coordination of international time scales on a world wide basis using the two-way technique. A network of coordinated clocks using small satellite earth stations collocated with the time scales is possible. Antennas as small as 1.8 m at K-band and 3 m at C-band transmitting powers of less than 1 W will provide signals with timing jitters of less than 1 ns using existing spread spectrum modems.

One way time broadcasting is also possible, under the INTELSAT INTELNET system, possibly using existing international data distribution (press and financial) systems that are already operating spread spectrum systems.

The technical details of the satellite and requirements on satellite earth stations are given. The resources required for a regular operational international time transfer service is analyzed with respect to the existing international digital service offerings of the INTELSAT Business Service (IBS) and INTELNET. Coverage areas, typical link budgets, and a summary of previous domestic and international work using this technique are provided. Administrative procedures for gaining access to the space segment are outlined. Contact information for local INTELSAT signatories is listed.

The microwave time and ranging experiments (MITREX) modem is an efficient device for time transfer via satellite using spread spectrum techniques. International time transfer using satellite spread spectrum techniques regularly will probably require the use of an INTELSAT space segment. There are no substantial technical problems in such use. However, it is necessary to identify the operational issues of using this system in the INTELSAT environment. This paper describes the INTELSAT service compatible with spread spectrum time transfer and suggests how such a service could be implemented.

INTELSAT

INTELSAT, the International Telecommunications Satellite Organization, with headquarters in Washington, D.C., is an international cooperative of 119 member nations that owns and operates the global commercial communications satellite system used by over 178 countries around the world for international communications and by 35 countries for domestic communications. A fundamental characteristic of the system, from the point of view of time transfer is that access to the INTELSAT space segment is controlled by various national entities, usually the members of INTELSAT. These entities are responsible for the operation of earth stations accessing INTELSAT space segment. In many cases, these entities, the posts, telephones and telegraphs (PT&T), are part of their national government or are chartered by their governments to provide access to INTELSAT. The earth stations may be owned directly by the entities, by common carriers or by the end users, depending on national policy. INTELSAT operates only the space segment and has no direct role in the operation of the ground segment. Thus, time transfer users will need to arrange with their national entities for earth station operation and for the right to use INTELSAT space segment. Appendix 1 of this paper contains contact points for these entities in countries of interest to the PTTI community.

Services

Two specialized INTELSAT services, IBS and INTELNET, are intended for digital links to small earth stations. INTELNET in particular, has enough flexibility in its technical description to allow the operation of a spread spectrum time transfer link.

INTELNET

INTELNET was designed to facilitate the operation of very small earth stations in one–way data broadcasting and two–way low speed data transfers. Spread spectrum operation is allowed, along with conventional BPSK or QPSK modulation. Operation under the INTELNET service description is specifically authorized for very small antennas.

Space segment is leased in "bulk" under the INTELNET service. This offering is defined in terms of specific transponder bandwidths with a corresponding allocation of power. Any required bandwidth may be used, with the resources scaled from the defined allocation. For example, at K–band, a lease of 100 Khz capacity would provide 8.6 dBW of transponder power. A lease of 2.25 MHz would provide 22.1 dBW. In general, the ratio of power to bandwidth is higher (excess power) than is needed for a single spread spectrum time transfer link. Both full time and occasional use service, with a minimum of 30 minutes per period, is available. Listed below are the basic lease powers, referenced to a 100 Khz bandwidth, available on the INTELSAT V series spacecraft.

Global	C–Band	-6.5 dBW
Hemi	C–Band	-5.5 dBW
Zone	C–Band	-5.5 dBW
Spot	K–Band	+8.6 dBW

INTELNET DATA BROADCAST FOR ONE WAY TIME TRANSFER

There are a variety of commercial services operating spread spectrum one way data broadcasting systems on INTELSAT. Many of these are operated in C–band on Global transponders, typically with a chip rate (spreading code rate) of 2.4576 MHz. Most are press news services, operating multiple time division multiplexed channels or low data rates, having an aggregate rate of either 9.6 or 19.2 kbit/s.

These broadcasts could be used for one way time dissemination if the transmitting stations chip rate was synchronized to a standard, and a low speed data subchannel was used to carry ephemeris and other correction information.

INTELSAT Business Service

Space segment for digital communications links can also be obtained under the INTELSAT Business Service (IBS) tariff. In this service the power and bandwidth supplied for a channel are defined in terms of reference links between standard sized earth stations. The reference link assumes conventional QPSK data transmission with either rate 3/4 or rate 1/2 forward error correction (F.E.C.). Sufficient power is available to provide better than 10^{-8} bit error rate performance under clear sky conditions. It is available under a full-time, part-time (scheduled at least 1 hour per day, 7 days per week), or occasional-use tariff. While the spread spectrum nature of the MITREX modem is outside the IBS technical description, the IBS service should be considered when it is necessary to provide communication links between standards sites. On most transponders where IBS is used, INTELSAT has reserved occasional use capacity. This bandwidth could be used to accommodate the MITREX modem operating under the INTELNET service as described below.

Operational Matters

Satellite Locations

INTELSAT operates 15 satellites, serving the three ocean regions, Atlantic, Indian, and Pacific. These locations in degrees East are:

AOR	IOR	POR
307.0	57.0	174.0
325.5	60.0	177.0
332.5	63.0	180.0
335.5	66.0	183.0
338.5		
341.5		
359.0		

Frequency Bands

At C–Band, INTELSAT satellites operate with both left and right circular polarization in the following frequency bands:

Ground Transmit: 5854 – 6423 MHz
Ground Receive: 3629 – 4198 MHz

At K–Band, INTELSAT satellites operate with horizontal and vertical polarization in the following frequency bands:

Ground Transmit:	14,004 – 14,494 MHz
Ground Receive:	10,954 – 11,694 MHz
Ground Receive:	11,709 – 11,946 MHz (307 Deg. West only)
Ground Receive:	12,501 – 12,746 MHz (307 Deg. East only)

Transponder Configurations

Most of the Europe–North American IBS traffic is carried on the INTELSAT VA(F–13) located at 307o East. The following configurations of transponders are currently available:

East K–band spot	to	West K–band spot
West K–band spot	to	East K–band spot
East K–band spot	to	West C–band hemi
West C–band hemi	to	East K–band spot
West K–band spot	to	East C–band hemi
East C–band hemi	to	West K–band spot
East K–band spot	to	West C–band hemi
West C–band hemi	to	East K–band spot
West C–band zone	to	East C–band zone
East C–band zone	to	West C–band zone
West C–band hemi	to	West C–band hemi
East C–band zone	to	East C–band zone

The full–connectivity transponder configuration provides the most flexible environment for time transfer links. This consists of a set of four transponders, interconnected at the satellite so that a signal received on any of the four uplink beams is retransmitted on all four downlink beams simultaneously. Two of the beams operate at C–band. These are the West Hemi and the East Hemi. The K–band West spot covers the United States and southern Canada, and the East K–band beam covers western European be seen Figure 1 and 2. Figures 3 through 7 show the global coverage areas for all the C and K satellite antennas from the 307, 341.5 (typical AOR), 359, 63 (typical IOR) and 174 (typical POR). In addition to showing the coverage areas for the Spot, Hemi, and Zone antennas, the usable area is delimited by plots of the locations having 10, 5 and zero degree elevation look angles toward the satellite.

Full–connectivity operation can be used with spread spectrum code division multiple access (CDMA) to allow several time transfer links to be established simultaneously on the same frequency, with all carriers visible to each user. This means that in a two-station, two-way transfer, it is possible for each site to monitor its own signal while receiving from the remote site.

Additional capacity in the form of East spot-West spot K-band capacity is available at the 325.5o East and 335.5o East locations. C-band capacity is assigned on the 325.5, 335.5 and 341.5o East locations serving the Atlantic Ocean region.

The Indian Ocean Region is served by satellites at 60 and 63o East with Global transponders and east/west zone capacity at C band. A cross strap connection WS/EZ provides a link a K-band in Europe to C-band to the Far East.

In the Pacific region at 174 and 180 degrees East, K-band capacity is available in the Pacific Ocean region between Korea or Japan and the West coast of the United States.

In all three ocean regions there are satellites with capacity reserved for occasional use. The reserved bandwidth is 3.173 MHz wide, sufficient for a 2.048 Mbits/s IBS carrier. These occasional use channels clearly would accommodate a spread spectrum link if the transmit spectrum were restricted by additional filtering. In the full-connectivity transponders, described above, the reserved capacity is in the form of two adjacent occasional-use channels, providing a bandwidth of 6.345 MHz. The operating frequencies for the occasional use channels are listed in Appendix 2.

Link Budgets for MITREX

The link budgets below show the required power for a time transfer link operating in the full-connectivity transponder. The transmitted power has been set to produce at least 54 dB-Hz to a small K-band (1.8 m) station. This same power will also be sufficient for use with a C-band 4.5 m antenna.

Uplink beam	WS	ES	EH	WH
Antenna size	1.8	1.8	4.5	4.5 meters
Hpa power	7.7	0.9	1.0	1.0 Watts
Hpa power	8.9	-0.4	0.0	-0.1 dBW
Antenna gain	46.0	46.0	47.7	47.7 dBi
E.I.R.P.	54.9	45.6	47.7	47.6 dBW
Downlink beam	WS	ES	EH	WH
Beam edge power	11.7	9.8	-4.1	-3.5 dBW
2.25 MHz lease	22.1	22.1	8.0	8.0 dBW

MITREX Modem Use

The simplest way to use the MITREX modem on INTELSAT would be to identify a tariffed INTELNET service that provides at least the necessary power and bandwidth. For regular PSK transmissions, the signal bandwidth at the -18 dB points is required to be within the allocated bandwidth. As can be seen in the attached spectrum analyzer plot. Figure 8 shows, the bandwidth of the MITREX modem is 3.5 MHz at the -18 dB point. The 6 dB bandwidth of the MITREX modem output is 2 MHz. It is possible to apply additional filtering to the spread spectrum transmitted signal reducing its -18 dB bandwidth, and thus the nominal tariff. However with the spread spectrum operation at such low levels, the -18 dB bandwidth may not be appropriate for tariffing.

Earth Stations

The earth station requirements to operate a time transfer link are quite modest.

The presented link budgets assume the use of 1.8 m K–band stations as a minimum size. This certainly is not the absolute minimum, but it does represent a useful compromise of physical size, link power requirements, and sidelobe performance. Therefore a station equipped with a solid state amplifier would clearly be suitable. Links involving larger stations will need even less transmitting power. At C–Band earth stations in the range of 2.5 to 3 meter diameter are practical.

Any earth station classed as a standard INTELSAT antenna must satisfy the sidelobe gain limit described by the expression:

$$G = 32 - 25 \log i,$$

where G is the gain of the sidelobe envelope relative to an isotropic antenna in the direction of the geostationary orbit and is expressed in dBi, and i is the angle in degrees from the axis of the main lobe.

In addition antennas operating at C–band must use circular polarization with a voltage axial ratio that does not exceed 1.09. However C–band antennas with a diameter of 2.5 m or less are only required to have a voltage axial ratio of 1.3. To operate in the IBS service a K–band antenna must have a minimum G/T ratio of 25 dB/K, qualifying as a standard E1. At C–Band the G/T requirement is 22.7 dB/K and a minimum transmitting gain of 47.7 dBi to qualify as an F1 (nominal 4.5m diameter) standard antenna. To operate under the INTELNET service, there is no minimum G/T requirement.

Implementation

INTELSAT has always been willing to support innovative uses of satellite technology by granting free use of space segment for tests and demonstrations. A request for free use must be submitted through the national signatory for each station involved. The technical approval process for a test or demonstration has two parts:

1. Initially, the earth stations involved must be approved. Small stations not having the minimum G/T values (25 dB/K at K–band, 22.7 dB/K at C– Band) for IBS stations, would have to qualify under the standard G specification.
2. A transmission plan for the proposed experiment will have to be examined to see whether what is proposed will work with the resources requested and, finally, whether the proposed transmissions may cause harm to other users of the space segment.

After approval, the carrier powers are set up in accordance with a test plan issued by INTELSAT and the experiment will then proceed. At the conclusion of the experiment, the participating Signatories are obligated to submit to INTELSAT a test report on the results. This report will be made available to any interested INTELSAT members.

One objective of such an experiment should be an evaluation of the compatibility of such a service with normal INTELSAT operations, with the view to proposing a tariffed technical description of spread spectrum time transfer. This could then be submitted to the INTELSAT Board of Governors for formal approval as a regular international service with the resources allocated and the consequent tariffs appropriate to the unique demands of spread spectrum time transfer.

Alternatively, commercial service could start immediately under the INTELNET service definition and tariffs. The occasional-use option would probably satisfy the requirements for periodic coordination links between various national standard labs.

Appendix 1.

INTELSAT Correspondent Representatives

Australia	Mr. Alan Ward Intelsat Access Center GPO Box 7000 Sydney NSW 2001, Australia Tel. 2–287–5612 Tlx. 10162 OTCNA
Austria	Dipl. Ing. Wolfgang Schladofsky Generaldirektion fur die Post- und Telegraphenverwaltung Abt. 21 Postgasse 8 A–1011 Vienna, Austria Tel. 1–5125234 Tlx. 112300 GENT A
Canada	Mr. M. Stephens Teleglobe Canada 680 Sherbrooke St West Montreal, Quebec, H3A 2S4 CANADA Tel. 514–289–7584 Tlx. 9224 Ms. G. Pazos 514–289–7771
China	Mr. Yang Xueming Directorate General of Telecom Ministry of the P&T 13 West Changan Ave. 100804 Beijing Peoples Republic of China Tel. 661390 Tlx. 222185 DGTEL
France	Mr. J. Meunier France Telecom – D.T.R.E. 246 rue de Bercy 75584 Paris, FRANCE Tel. 1–43426275 Tlx. 670372

Germany	Mr. A. Binzer Referat S15 FTZ Darmstadt, GERMANY Tel. 6151–833459 Tlx. 419201 Mr. G. Rudolf 6151–83–3383
Greece	Mr. S. Kontoleon Hellenic Telecom. Org. (OTE) International Comm. Dept 15 Stadiou Street Athens 124. GREECE Tel. 322–0899 Tlx. 219797
India	Mr. M.K.G. Nayar Videsh Sanchar Nigam, Ltd. Videsh Sanchar Bhavan Matatma Gandi Road, Fort Bombay – 400 001 India Tel. 22–271819x307 Tlx. 11 2429 VSHN IN HQ BY
Italy	Dr. Luigi Ruspantini Telespazio Via Alberto Bergamini 50 00159 Rome, ITALY Tel. 498–2355 Tlx. 610654
Japan	Mr. Naohiko Hattori, Director Network Engineering Department KDD Tokyo Network Headquarters 3–2 Nishi Shinjuku 2–Chome Shinjuku–ku Tokyo 163, Japan Tel. 3–347–6600 Tlx. 22500 KDD TOKYO

The Netherlands	Mr. Peter Essers PTT Telecommunicatie Directorate for Infrastructure (DIS) Prinses Beatrixlaan 9 P.O. Box 30000 2500 GA The Hague The Netherlands Tel. 70434725 Tlx. 32482 DIS NL
New Zealand	Mr. L. A. Watt International Relations Telecom Networks and Int'l. Ltd. Telecom Corp. of New Zealand Ltd. P.O. Box 1092 Wellington, New Zealand Tel. 4-738-444x8061 Tlx. 31688 TELINT NZ
Norway	Mr. Claus Svendsen Norwegian Telecommunications Admin PO Box 6701, St. Olavs Plass N-0130 Oslo 1, NORWAY Tel. 70434725 Tlx. 71203 Gentel N
Spain	Mr. J. Lorente TELEFONICA Plaza de Espana 4, Pta. 3 - 7th Floor Madrid 28008, Spain Tel. 1 241 9380 Tlx. 47793 Mr. A. Martin 1-522-2936
Sweden	Barbro Svensson Televerket S-123 86 Farsta SWEDEN Tel. 8-713-1568 Tlx. 14970 GENTEL S

Switzerland

Mr. P. Breu
General Directorate PTT
Radio and Television Main Division
Satellite Communications Branch
Speichergasse 6
CH-3030 Berne, Switzerland
Tel. 31-623756
Tlx. 911025
Mr. P. Chablais 31-622533

USSR

Mr. G. Korolev, Director
U.S.S.R. Satellite Communications Company
Ministry Of Posts and Telecommunications
7 Gorky Street
103375 Moscow, U.S.S.R.
Tel. 95-9255108
Tlx. 411120

United Kingdom

Mr. M. Seymour
British Telecom, PLC
Landsec House Room 407
23 New Fetter Lane
London EC4A 1AE, England
Tel. 1-492-3166
Tlx. 883739
Mr. Mike Perry 1-492-2263

United States

Mr. Calvin Harriott
Communications Satellite Corp.
950 L. Enfant Plaza S.W.
Washington D.C. 20024
Tel. 202-863-6427
Tlx. 892688

INTELSAT

Mr. Lester Veenstra
INTELSAT
3400 International Drive, N.W.
Washington, D.C. 20008
Tel. 202-944-7090
Tlx. 64290

Appendix 2.

Typical Occasional–Use Frequencies

Transponder Configuration		Uplink	Downlink	Satellite
11/71	WH/ES	5938.7425	10963.7425	(335)
71/11	ES/WH	14044.9975	3744.9975	(335)
11/11	WH/WH	5933.7700	3708.7700	(307)
41/41	WZ/WZ	5930.5975	3705.5975	(307)
41/41	WZ/WZ	5933.7700	3708.7700	(307)
41/51	WZ/EZ	5939.9625	3714.9625	(332)
51/41	EZ/WZ	5939.9625	3714.9625	(332)
62/72	WS/ES	4123.4025	11073.4025	(335)
72/62	ES/WS	4123.4025	11073.4025	(335)
43/53	WZ/EZ	6095.5975	3870.5975	(307)
53/43	EZ/WZ	6095.5975	3870.5975	(307)
13/373	WH/ES	6106.9825	12686.9825	(307)
73/13	ES/WH	14176.0425	3876.0425	(307)
23/163	EH/WS	6095.5975	11875.5975	(307)
63/23	WS/EH	14170.0000	3870.0000	(307)
14/24	WH/EH	6216.4225	3991.4225	(174)
24/14	EH/WH	6216.4225	3991.4225	(174)
64/54	WS/EZ	14296.2150	3996.2150	(174)
54/64	EZ/WS	6221.1925	11496.1925	(174)
64/54	WS/EZ	14264.2200	3964.2200	(63)
54/64	EZ/WS	6189.1975	11464.1975	(63)
61/171	WS/ES	14058.0000	12563.0000	(307)
71/161	ES/WS	14058.0000	11763.0000	(307)
69/79	WS/ES	14459.4075	11659.4075	(325)
69/79	ES/WS	14459.4075	11659.4075	(325)
38/38	GA/GA	6388.5925	4163.5925	(332)
86/86	GB/GB	6303.5975	4078.5975	(60)
12/22/62/72/162/172		Full Connectivity		
		6017.1600	3792.1600	(307)(Hemi)
		14092.1600	11797.1600	(307) (WS)
		12597.1600		(307) (ES)

FIGURE 1
INTELSAT V-A(F-13) at 307 Degrees East West Spot

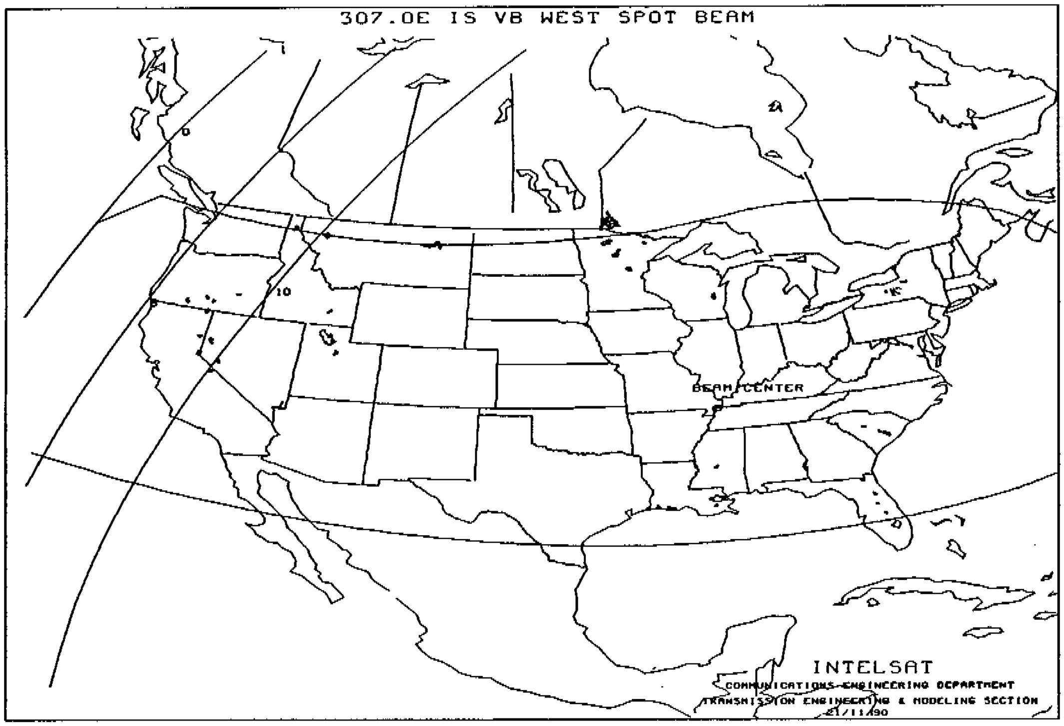


FIGURE 2
INTELSAT V-A(F-13) at 307 Degrees East East Spot

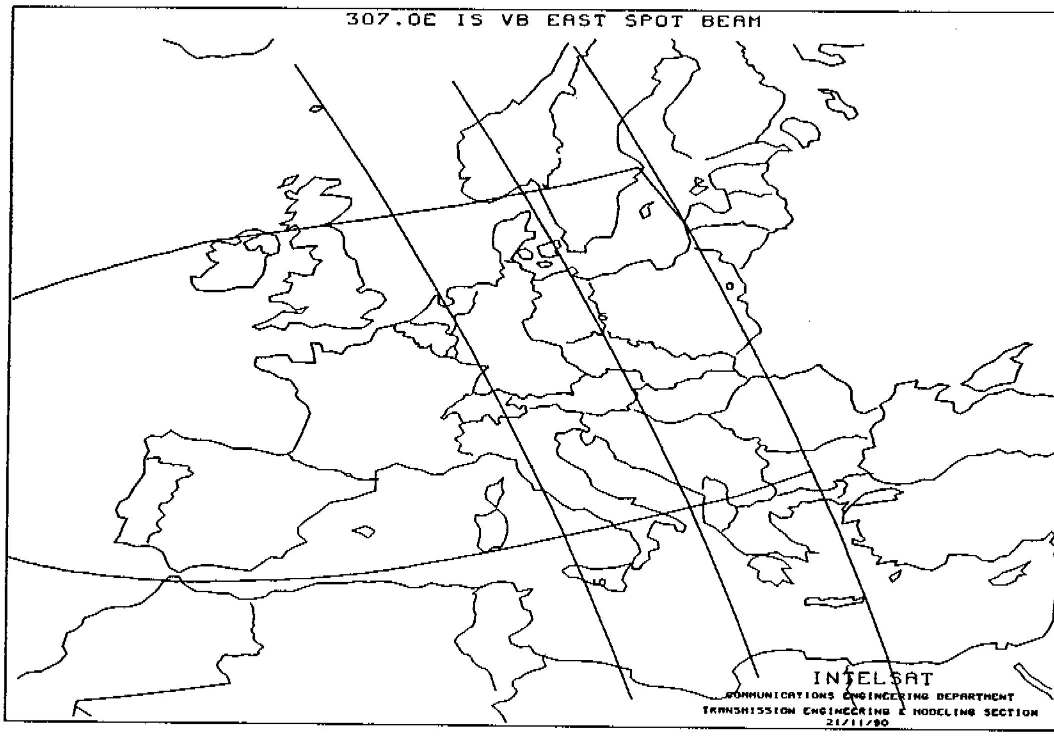
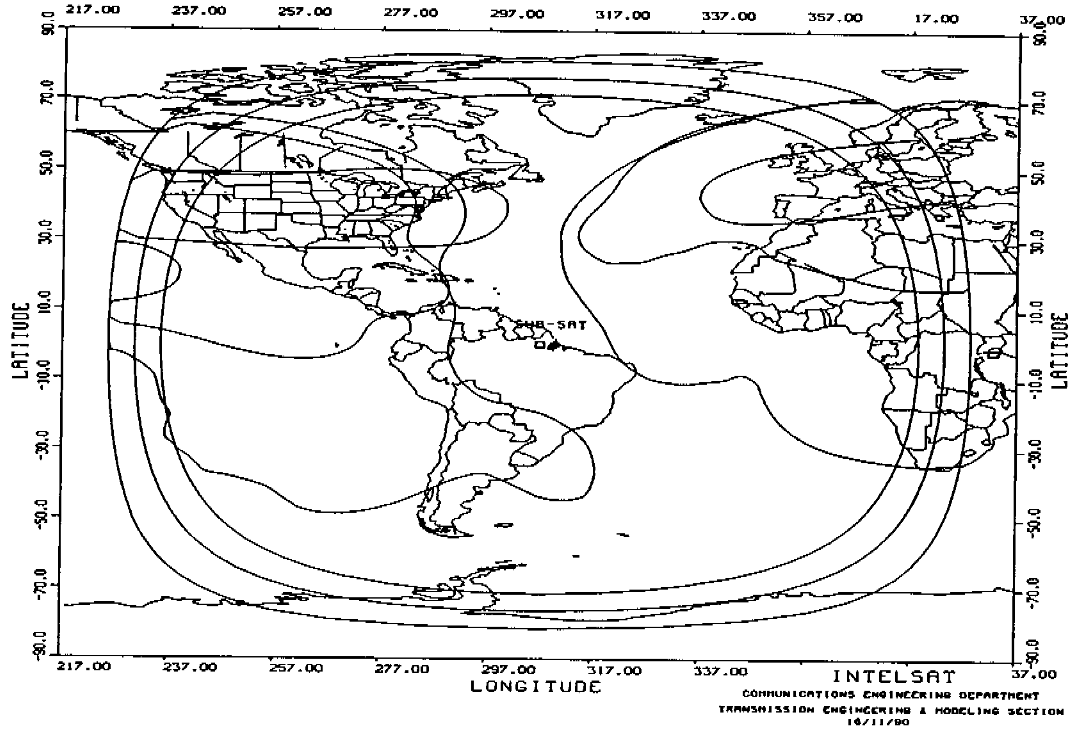


FIGURE 3

INTELSAT V-A(F-13) at 307 Degrees East



INTELSAT V(F-6) at 341.5 Degrees East

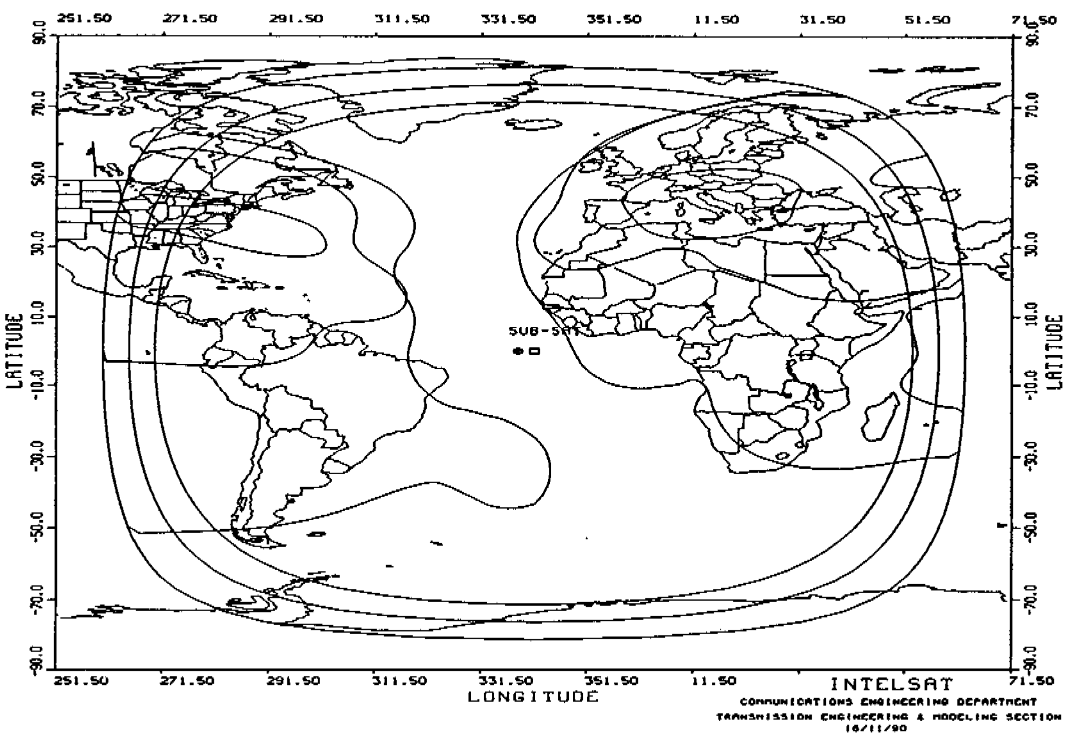


FIGURE 5
INTELSAT V-A(F-12) at 359.0 Degrees East

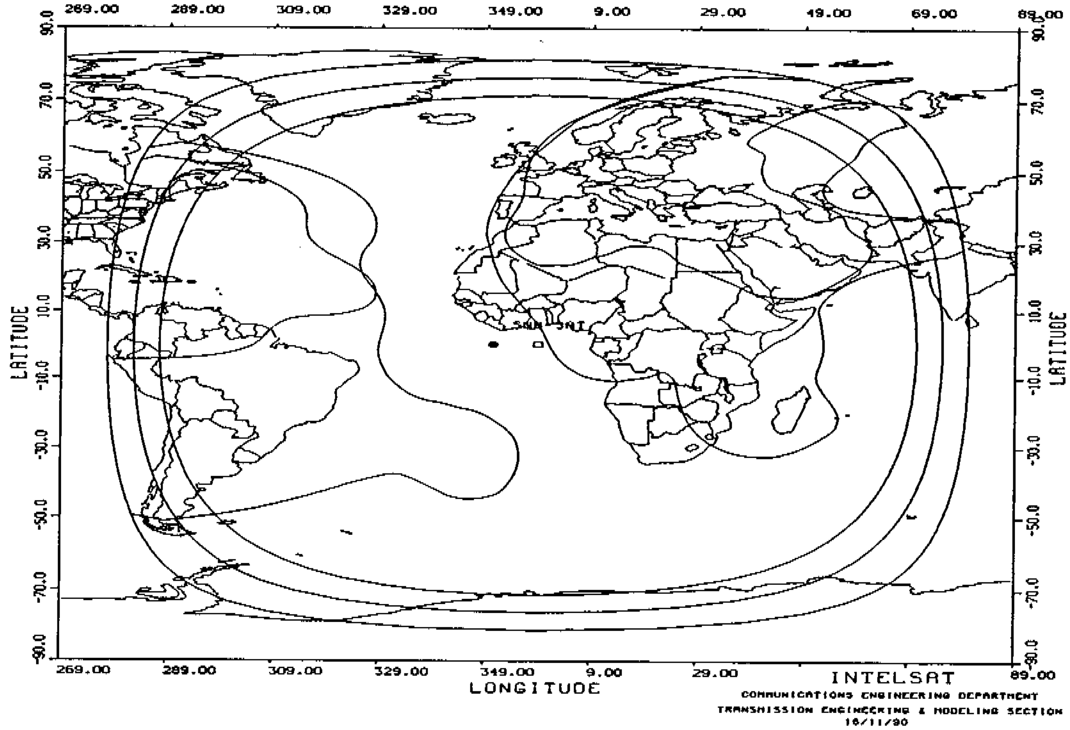


FIGURE 6
INTELSAT V(F-5) at 63 Degrees East

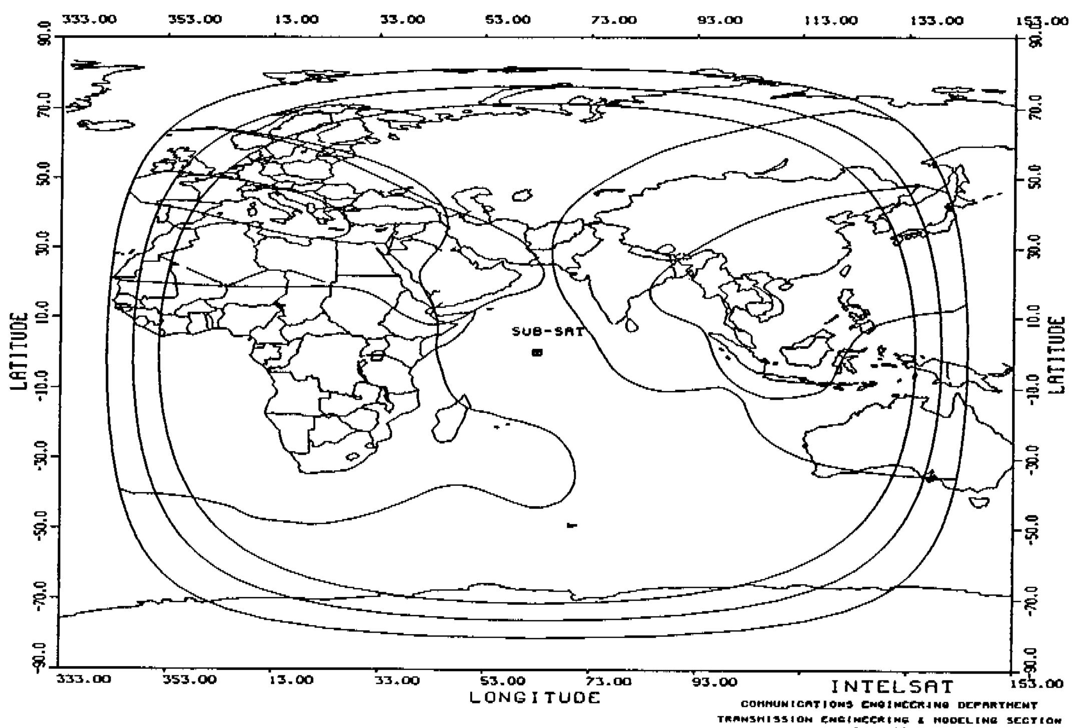
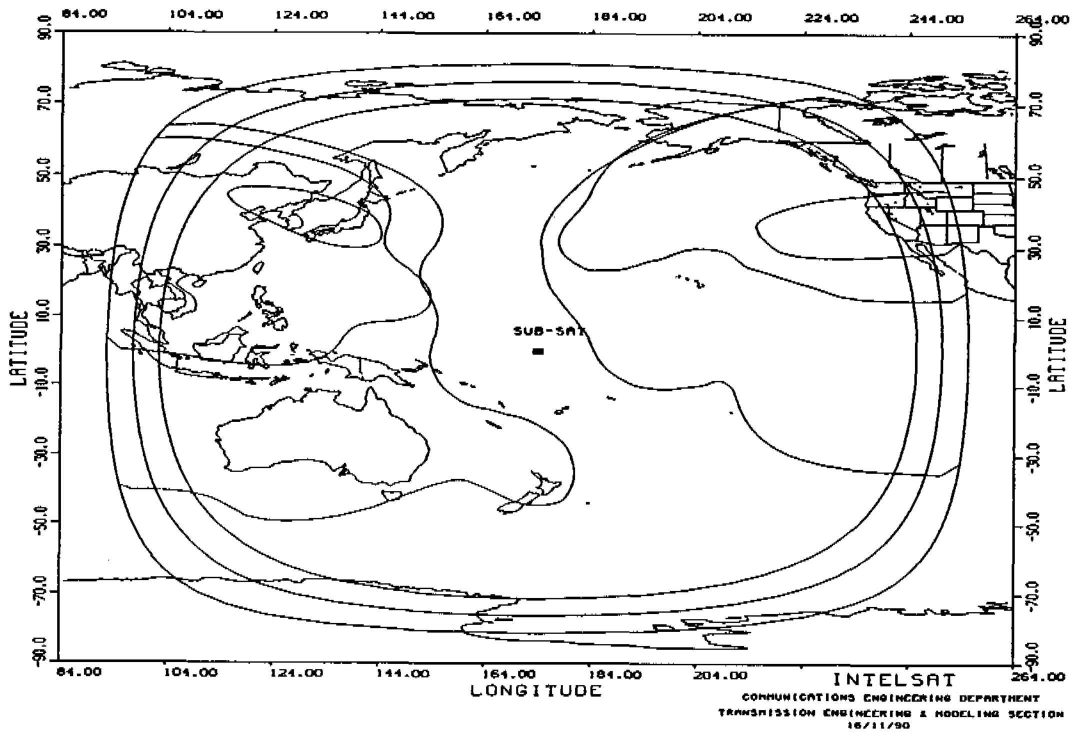
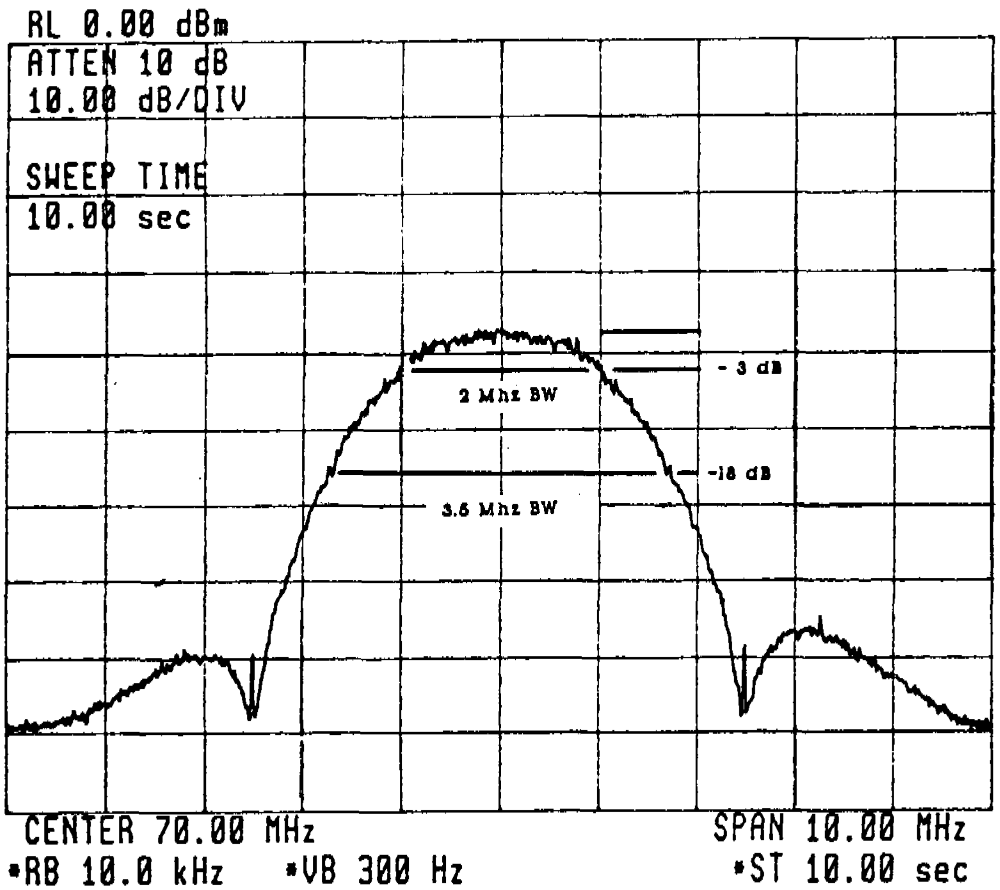


FIGURE 7
INTELSAT VA-(F-10) at 174 Degrees East





QUESTIONS AND ANSWERS

Dr. Gernot Winkler, U. S. Naval Observatory: If you used one of these occasional offerings of, say, a half an hour per week, and a bandwidth of 3.5 MHz, is there any restriction regarding the information other than just the time code. In other words, would there be a problem sending teletype messages also?

Mr. Veenstra: If we approach this as a time transfer sevice, it would be wise to say that the data channel which is being proposed on the newer spread spectrum modems is an order wire. Intelsat never charges for order wires. We know that earth stations need to talk to each other for coordination purposes. Unofficially and off the record to this minor group, I would suggest that you do not emphasize the fact that this is a data channel. I would suggest that you mention the fact that it is an order wire, a low data rate channel, that is used to coordinate at either end. That makes it easier for us to say that we will give this is a free channel because there is really no information being sent, they are transferring phase information. That is zero information so the bureaucrats do not think that you are transferring information for free. Call it an order wire and not a communications link.