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INTELSAT EARTH STATION STANDARDS (IESS)

Document IESS–207 (Rev. 4)

STANDARDS A, B, F and H

ANTENNA AND WIDEBAND RF PERFORMANCE CHARACTERISTICS OF C–BAND EARTH STATIONS ACCESSING THE INTELSAT SPACE SEGMENT

(6 and 4 GHz Frequency Bands)

Approval Date: 10 March 2005

INTELSAT C–BAND EARTH STATION STANDARDS (IESS)
STANDARDS A, B, F and H
(6 and 4 GHz Frequency Bands)

1. ANTENNA SYSTEM*

For the purposes of this IESS module the term RFP (request for proposal) is considered to include any document specifying contractual performance characteristics.

1.1 Gain–to–Noise Temperature Ratio

INTELSAT has developed this IESS module for earth stations that would meet one of eight minimum G/T values†. The selection of a Standard A, B, F–1, F–2, F–3, H–2, H–3, or H–4‡ earth station will depend upon User requirements with respect to site location, traffic volume, and the channel performance.

Approval of an earth station in an INTELSAT Standard category§ will only be obtained if one of the minimum conditions of Table 1 are met in the direction of the satellite and for the polarizations chosen for each satellite series (see Paragraph 1.3) under clear sky conditions, in light wind, and for any frequency in the frequency bands defined in Paragraph 2.2.

Such approval will be limited to angles of operation for which the above condition is satisfied. Therefore, the User should bear in mind that the earth station may need to be modified before permission is given to operate with satellites

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* Because of the difficulties associated with the testing of small aperture antennas, Standard H Users are strongly urged to consider the advantages of utilizing an INTELSAT type accepted antenna.

† Beginning with the adoption of IESS–207 (Rev. 3) INTELSAT discontinued classifying earth stations with the designation Standard D. Existing Standard D earth stations must meet the requirements contained in IESS–207 (Rev. 2).

‡ The designation Standard H–1 has been reserved for future use.

§ The designation of Standard A, B, F, or H is applicable to linear polarized earth stations operating with INTELSAT VIIIA. Earth stations are categorized as A, B, F, or H on the basis of G/T performance, as well as compliance with the other specifications contained in this module.

seen at different angles of elevation. Although antennas with elevation angles operating below 5° do not qualify as Standard earth stations, they will be considered on a case–by–case basis.

During adverse climatic conditions, such as rain, snow, strong winds, etc., the nominal performance may not necessarily be met. The percentage of time during which this occurs will depend, inter alia, upon the statistics of the local weather, upon antenna performance characteristics, and upon the relationship between the weather parameters and the channel performance.

If the local weather parameters are known in sufficient detail, then, for a particular station design, a reasonable estimate of channel performance statistics can be made. Where such estimates show that an earth station with the minimum G/T required might not permit the performance criteria given in the applicable ITU–R recommendations identified in the IESS–300 series modules to be met, Users should give serious consideration to a station of higher performance.

The preferred method of determining the G/T of an earth station is by radio star measurement whenever feasible, and, where possible, at a high elevation angle. Correction for the operating elevation angle can then be performed through the system noise temperature (T) profile. For G/T determination in the case of earth stations with limited antenna steering capability, or for small aperture antennas, separate measurements of the antenna gain (G), and the system noise temperature (T) can be employed. For radio star measurements, Cassiopeia A, Taurus A, and Cygnus A are recommended sources. For either method of G/T determination, appropriate correction factors should be applied. A discussion of G/T measurement methods, sources of measurement error, and measurement correction factors may be found in Rec. ITU–R S.733–1. Additional information on measurement methods, source characteristics, and correction factors is also available in the INTELSAT SSOG.

1.2 Antenna Radiation Patterns

1.2.1 General

In a continuing effort to promote the efficient utilization of the geostationary orbit while maintaining a reasonable interference budget, INTELSAT has established the long term objective of bringing all of its antennas within a specification consistent with the ITU–R recommendations. Users should take this factor into account when considering modifications such as alteration of their antenna feeds for polarization purity or increased bandwidth.

1.2.2 Minimum Transmit Antenna Main Beam Gain

The transmit main beam gain of the antenna measured at the antenna feed must be adequate to satisfy the off–axis emission EIRP density criteria of Rec. ITU–R S.524–5. Users should refer to the IESS–300 series for guidance in meeting this requirement.

In designing the transmit subsystem, trade–offs between various parameters such as antenna transmit gain, sidelobe patterns, HPA size and high power combining arrangements should be considered.

1.2.3 Antenna Sidelobes

Sidelobe levels are referred to the gain of an isotropic antenna and shall meet the criteria defined in the following subsections.

These requirements shall be met within any frequency defined in Paragraph 2.2 and for any direction which is within 3° of the geostationary arc.

The following definitions apply to these requirements:

G = gain of the sidelobe envelope relative to an isotropic antenna in the direction of the geostationary orbit, in dBi.

θ = angle in degrees between the main beam axis and the direction considered.

90 percent = the total number of peaks within the orbital boundaries defined by Rec. ITU–R S.580–5.

1.2.3.1 Transmit Sidelobe Design Objective (Standard B, F, and H Antennas with an RFP Issued Prior to 1996*)

It is recommended that the gain of 90 percent of the copolarized and crosspolarized sidelobe peaks not exceed an envelope described by (Rec. ITU–R S.465–5 and ITU–R S.580–5):

$$G = 29 - 25 \log_{10} \theta \text{ dBi}, \quad 1°* \le \theta \le 20°$$
$$G = -3.5 \text{ dBi}, \quad 20° < \theta \le 26.3°$$
$$G = 32 - 25 \log_{10} \theta \text{ dBi}, \quad 26.3° < \theta < 48°$$
$$G = -10 \text{ dBi}, \quad 48° \le \theta$$

1.2.3.2 Transmit Sidelobe Mandatory Requirements

a) Standard A

Antennas with a RFP Issued Prior to 12 March 1986

At angles greater than 1° away from the main beam axis, it is required that the gain of 90 percent of the copolarized and crosspolarized sidelobe peaks not exceed an envelope described by:

$$G = 32 - 25 \log_{10} \theta \text{ dBi}, \quad 1° \le \theta < 48°$$
$$G = -10 \text{ dBi}, \quad 48° \le \theta$$

Antennas with a RFP Issued After 11 March 1986

At angles greater than 1° away from the main beam axis, it is required that the gain of 90 percent of the copolarized and crosspolarized sidelobe peaks not exceed an envelope described by:

$$G = 29 - 25 \log_{10} \theta \text{ dBi}, \quad 1° \le \theta \le 20°$$

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* This design objective is identical to the mandatory sidelobe requirements for antennas with an RFP issued after 1995.

* For D/λ below 100, this angle becomes $100 \lambda / D$ Degrees.

G = –3.5 dBi,	20□	<	θ	□ 26.3□
G = $32 - 25 \log_{10} \theta$ dBi,	26.3□	<	θ	< 48□
G = –10 dBi,	48□	□	θ	

b) Standards B and F

<u>Antennas Having An RFP Issued Prior To 1996</u>

At angles greater than 1□ away from the main beam axis, it is required that the gain of 90 percent of the copolarized and crosspolarized sidelobe peaks not exceed an envelope described by:

G = $32 - 25 \log_{10} \theta$ dBi,	1□*	□	θ	< 48□
G = –10 dBi	48□	□	θ	

<u>Antennas Having an RFP Issued After 1995</u>

At angles greater than 1□ away from the main beam axis, it is required that the gain of 90 percent of the copolarized and crosspolarized sidelobe peaks not exceed an envelope described by:

G = $29 - 25 \log_{10} \theta$ dBi,	1□*	□	θ	□ 20□
G = –3.5 dBi,	20□	<	θ	□ 26.3□
G = $32 - 25 \log_{10} \theta$ dBi,	26.3□	<	θ	< 48□
G = –10 dBi,	48□	□	θ	

c) Standard H

<u>Antennas Having An RFP Issued Prior To 1996</u>

At angles greater than 100 □/D□ away from the main beam axis it is required that the gain of 90 percent of the copolarized and crosspolarized sidelobe peaks not exceed an envelope described by:

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* For D/λ below 100, this angle becomes 100 λ /D Degrees

G = 32 – 25 log θ dBi, 100 □/D□ □ θ < 48□
G = –10 dBi 48□ □ θ

Antennas Having an RFP Issued After 1995

At angles greater than 100 □/D□ away from the main beam axis it is required that the gain of 90 percent of the copolarized and crosspolarized sidelobe peaks not exceed an envelope described by:

D/□ < 50

G = 32 – 25 log θ dBi, 100 □/D□ □ θ < 48□
G = –10 dBi, 48□ □ θ

D/□ □ 50 (Rec. ITU–R S.580–5 and Rec. ITU–R S.465–5)

G = 29 – 25 log θ dBi, 100 □/D□ □ θ □ 20□
G = –3.5 dBi, 20□ < θ □ 26.3□
G = 32 – 25 log θ dBi, 26.3□ < θ < 48□
G = –10 dBi, 48□ □ θ

1.2.3.3 Receive Sidelobes

In order to protect receive signals from interference arising elsewhere, restrictions should also be placed on the receive sidelobe characteristics. Therefore, while not mandatory, it is recommended that the transmit sidelobe characteristics apply to the receive band as well.

Unless other agreements have been negotiated, interference protection will be afforded only to the following sidelobe envelopes:

(a) Standard A

Antennas with RFP Issued Prior to 12 March 1986

G = 32 – 25 $\log_{10}$ θ dBi, 1□ □ θ < 48□
G = –10 dBi, 48□ □ θ

Antennas with an RFP Issued After 11 March 1986

G = 29 – 25 $\log_{10} \theta$ dBi, 1□ □ θ □ 20□
G = –3.5 dBi, 20□ < θ □ 26.3□
G = 32 – 25 $\log_{10} \theta$ dBi, 26.3□ < θ < 48□
G = –10 dBi, 48□ □ θ

(b) Standards B and F

Antennas with an RFP Issued Prior To 1996

G = 32 – 25 $\log_{10} \theta$ dBi, 1□ □ θ < 48□
G = –10 dBi, 48□ □ θ

Antennas with an RFP Issued After 1995

G = 29 – 25 $\log_{10} \theta$ dBi, 1□ □ θ □ 20□
G = –3.5 dBi, 20□ < θ □ 26.3□
G = 32 – 25 $\log_{10} \theta$ dBi, 26.3□ < θ < 48□
G = –10 dBi, 48□ □ θ

c) Standard H

Antennas with an RFP Issued Prior To 1996

G = 32 – 25 log θ dBi, 100 □/D□ □ θ < 48□
G = –10.0 dBi, 48□ □ θ

Antennas with an RFP Issued After 1995

D/□ < 50

G = 32 – 25 log θ dBi, 100 □/D□ □ θ < 48□
G = –10 dBi, 48□ □ θ

D/□ □ 50

$$G = 29 - 25 \log \theta \text{ dBi}, \quad 100\,\lambda/D^\circ \le \theta \le 20^\circ$$
$$G = -3.5 \text{ dBi}, \quad 20^\circ < \theta \le 26.3^\circ$$
$$G = 32 - 25 \log \theta \text{ dBi}, \quad 26.3^\circ < \theta < 48^\circ$$
$$G = -10 \text{ dBi}, \quad 48^\circ \le \theta$$

For $\theta < 100\,\lambda/D^\circ$ off–axis gain will be computed based on the antenna model contained in Annex III to Appendix 29 of the Radio Regulations.

1.2.3.4 Wide Angle Sidelobe Data

It is requested that the User submit wide angle sidelobe data to INTELSAT in advance of earth station verification tests via the satellite. These data might include, for instance, measurements on the antenna obtained on site using a boresight, or measurements made on an antenna of the same design on a test range at another location. Such data will be used to substantiate antenna performance beyond the off–beam angles which can be measured using INTELSAT facilities.

1.3 Polarization

1.3.1 Earth Station Transmit and Receive Polarization Sense

Earth station polarization requirements for operation in the 6/4 GHz frequency bands are shown in Tables 2(a) and 2(b). Earth stations are required to operate with the appropriate polarization sense for each beam*. In addition, earth stations shall be capable of meeting the following requirements:

(a) Standards A and B

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* Senses of polarization (i.e. left hand circular, right hand circular) are defined for circularly polarized signals in ITU Radio Regulation Article 1 Nos. 148 and 149. Users are referred to the IESS 400 series modules for a discussion on the definition of senses of polarization of linearly polarized signals and the dependence of the orientation of such signals on the earth station geographic position.

For both the uplink and downlink frequency bands, Standard A and B earth stations shall be capable of operating in both senses of polarization simultaneously*. Standard A and B earth stations will be required to certify the performance of the antenna in both polarizations senses. This will require the antenna to be equipped with a four port feed. The need to equip for operation (e.g., HPA, LNA, etc.) in both polarizations, however, will be governed by operational requirements.

(b) Standards F and H

For both the uplink and downlink frequency bands, Standard F and H earth stations shall be capable of operating in any designated transponder in any polarization sense. However, simultaneous operation in both senses of polarization will not be required, neither for the uplink nor for the downlink.

1.3.2 Earth Station Transmit and Receive Axial Ratio

Earth stations shall meet the following axial ratio requirements across the full minimum bandwidth described in Paragraph 2.2.

For test purposes, the tracking beamwidth of a Standard A antenna is defined as a box formed by ± 0.02 degree elevation and azimuth offsets from beam center.

1.3.2.1 Circularly Polarized Antennas

(a) Standards A and B

<u>Antennas Operating On INTELSAT VA, VI, VII, VIIA, VIII and IX</u>

For operation on INTELSAT VA, VI, VII, VIIA, VIII and IX satellites,

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* Both polarization senses simultaneously is defined as RHCP and LHCP simultaneously <u>or</u> linear horizontal and linear vertical simultaneously. Antennas accessing INTELSAT VIIIA are required to have linear polarization capability only.

all antennas shall meet the axial ratio requirements described below, as appropriate, since these satellites are dual–polarized.

<u>Retrofitted Antennas, Frequency Reuse</u>*

The voltage axial ratio for transmission shall not exceed 1.09 (27.3 dB polarization isolation) within a cone defined by the antenna tracking and/or pointing errors; however, the design goal is 1.06 (30.7 dB polarization isolation). It is recommended that this axial ratio not be exceeded for reception.

<u>New Antennas, Frequency Reuse</u>

The voltage axial ratio for transmission shall not exceed 1.06 (30.7 dB polarization isolation) within a cone defined by the antenna tracking and/or pointing errors. It is recommended that this axial ratio not be exceeded for reception.

New antennas for the purpose of the above paragraph are considered to be those which have a RFP (or similar document specifying contractual performance characteristics) issued after August 1977.

(b) Standard F

The voltage axial ratio of transmission in the direction of the satellite shall not exceed 1.09 (27.3 dB polarization isolation) within a cone defined by the antenna tracking and/or pointing errors; however, the design objective is 1.06 (30.7 dB polarization isolation). It is recommended that this axial ratio not be exceeded for reception.

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* With regard to frequency planning and system operation of retrofitted Standard A and B antennas, INTELSAT will assume that a voltage axial ratio of 1.06 is met in the transmit and receive bands.

(c) Standard H

The voltage axial ratio of transmission in the direction of the satellite shall not exceed 1.09 (27.3 dB polarization discrimination) for Standard H–4 and 1.3 (17.7 dB polarization discrimination) for Standards H–3 and H–2 within a cone defined by the antenna tracking and/or pointing errors. The design goal is 1.09 for Standards H–3 and H–2. It is recommended that these axial ratios not be exceeded for reception.

1.3.2.2 Linearly Polarized Antennas (INTELSAT VIIIA)

(a) Standards A, B and F–3

The voltage axial ratio of transmission in the direction of the satellite shall not be less than 31.6 (30.0 dB polarization discrimination) within a cone defined by the antenna tracking and/or pointing errors. It is recommended that this axial ratio be exceeded for reception.

(b) Standards F–2, F–1, H–4, H–3 and H–2

The voltage axial ratio of transmission in the direction of the satellite shall not be less than 22.4 (27.0 dB polarization discrimination) within a cone defined by the antenna tracking and/or pointing errors, however, the design objective is 31.6 (30 dB polarization isolation). It is recommended that this axial ratio be exceeded for reception.

1.3.3 Polarization Orientation Of Linearly Polarized Antennas (INTELSAT VIIIA)

1.3.3.1 Faraday Rotational Effects

Faraday rotation affects linearly polarized waves passing through the ionosphere. The effect of Faraday rotation is a decrease in the cross polarization discrimination. Because the magnitude of Faraday rotation varies as $1/f^2$, the effect is not as significant a consideration at Ku–band. At C–band, however, the $1/f^2$ dependence makes Faraday rotation an important consideration, particularly on the downlink.

The magnitude of the Faraday rotation depends on frequency, latitude, elevation angle, direction of propagation, the position of the sun relative to the earth station and solar flare activity. Faraday rotation has a distinct diurnal variation pattern which can lead to a diurnal variation in crosspolarization isolation. The diurnal variations become larger in years of high sun spot activity and during the equinox periods of all years.

Automated techniques to compensate for, or to minimize, the effect of Faraday rotation do exist and are similar to those used to compensate for rain depolarization. Faraday rotation effects can, also, be minimized by applying a fixed feed rotation equal to one half the expected diurnal variation. It is not possible, however, to select a fixed, pre–set rotational compensation that is adequate for all sun spot activity periods. Rather the rotational compensation must be set on a yearly or seasonal basis.

Users using linear polarization in C–band are urged to consider feed designs which would permit, if necessary, feed rotational compensation. Users of large earth stations should also consider feed designs which can accommodate an automated compensation network. As the direction of Faraday rotation is opposite on the uplink and downlink, feed designs which permit independent adjustment of the uplink and downlink are highly desirable.

1.3.3.2 Required Linear Polarization Orientation Accuracy

It is required that the earth station feed be able to match the spacecraft polarization
angle within 1 degree under clear–weather conditions. This requirement does not
apply to earth stations employing Faraday rotation compensation.

Because of the diurnal variation of Faraday rotation, it is recommended that the antenna feed be aligned during the time period immediately preceding local sunrise. If possible, feeds should be aligned during the time period within one month of a solstice. Alignment of feeds during the period within one month of a equinox should be avoided when possible. It is recommended that the orientation of feeds aligned during periods other than the solstice be realigned during the next solstice period.

1.3.4 Rain Depolarization Compensation for Standard A and B Antennas (Linearly or Circularly Polarized Antennas)

Although the frequency plans established for INTELSAT satellites provide margin for rain depolarization, there may be a few geographical areas where propagation statistics indicate additional measures are necessary in order to compensate for rain depolarization on both the up and down link and for both polarizations. If rain depolarization statistics indicate that the isolation between polarizations is expected to be worse than 12 dB for 0.01% of the year in the uplink, the earth station should consider the use of a compensating network, particularly on the uplink and on links having low elevation angles. Compensation on the uplink is more critical than on the downlink in view of the potential for co–channel interference to other Users.

Earth stations in this category should, as a minimum, be constructed in a manner which allows the addition of a compensating network, should it become required in the future. Experimental observations indicate that an adequate degree of compensation for the depolarization effects can be achieved by means of a single parameter technique, in this case differential phase. The recommended threshold at which depolarization compensation is initiated during a rain event is at 5 dB below the clear sky isolation. A settling time in the order of 1 second is considered adequate for the majority of the depolarization events caused by rain. Occasionally, lighting discharges can cause abrupt changes in depolarization due to ice crystals which tend to align with the electric field prior to discharge. Approximately 1 second is, typically, required for such abrupt changes to be tracked accurately by a compensation network. Operation of a compensating network should not disturb the antenna tracking.

In developing frequency plans, INTELSAT will attempt to avoid the need for an adaptive network whenever possible.

1.4 Antenna Steering or Beam Positioning

1.4.1 Antenna or Beam Steerability

Automatic or manual steering shall be capable of changing the antenna pointing to be compatible with geostationary satellites at orbital locations within the intended ocean region of operation and for which the earth station elevation angle is not less than 5°. Operation below 5° will be reviewed on a case–by–case basis.

INTELSAT satellites are planned for locations within the nominal orbital arcs indicated below:

AOR	=	304.5°	to	359°	E
IOR	=	33°	to	66°	E
APR	=	83°	to	157°	E
POR	=	174°	to	180°	E

Users should consider in their designs the possibility that the above limits of each operating region may change if additional orbital locations are utilized by INTELSAT. Users are strongly encouraged to consider antenna designs which permit the easy reconfiguration of their antenna to operate in all visible regions in order to ensure compatibility with future operational plans.

Operational considerations indicate the desirability of full steering capability. Such capability would permit on–site demonstrations of compliance with mandatory sidelobe levels, and would, in addition, allow future operation with satellites at other locations.

If a natural obstruction prevents full compliance with the above paragraphs, INTELSAT should be contacted by the User during the earth station design stage.

1.4.2 Antenna Steering Data

Beginning in 1992, INTELSAT discontinued routinely providing the pointing angles appropriate to a given satellite for each station. Instead, INTELSAT now provides the parameters necessary for an earth station to compute its own pointing angles. INTELSAT will, on an exceptional basis, continue to provide pointing data when difficulties would be experienced by current stations with the revised approach pending resolution of the difficulty. The User is referred to IESS–412 for details of the computational method.

1.4.3 Tracking Requirements

Standard A, B, F and H earth stations shall meet the minimum tracking requirements
contained in Table 3.

Receive–only stations should be designed with a tracking capability consistent with the overall objectives of the User's network, bearing in mind the stationkeeping tolerances INTELSAT intends to employ.

Users need to consider the EIRP stability requirements contained in the IESS–300 series when selecting an antenna tracking system. Tropospheric scintillation can occur in C–band under both adverse weather and clear–weather conditions. The effects of scintillation may be significant on links having elevation angles less than 20°. On links having elevation angles near 5° scintillation effects can be severe. As a consequence of scintillation, antennas employing active tracking on low elevation paths may experience antenna mispointing or may transmit excessive EIRP levels when uplink power control is employed. The use of program track is, therefore, highly recommended on links operating with elevation angles less than 20° for those periods when tropospheric scintillation is severe and is recommended as the primary tracking method for antennas with elevation angles below 10°.

1.4.4 Satellite Stationkeeping Limits

Under nominal conditions, INTELSAT intends to maintain the orbital movements of its satellites to the limits indicated below:

Nominal Stationkeeping

Satellite	North– (degrees)	East–West (degrees)
VA	± 0.1	± 0.1
VI, VII, VIIA, VIII, VIIIA and IX	± 0.05	± 0.05

1.4.5 Satellite Beacon Characteristics

Beacon transmit frequencies for the INTELSAT satellites are shown below:

Satellite	Beacon Frequencies (MHz)
VA and VI	3,947.5 or 3,948.0 and 3,952.0 or 3,952.5
VII, VIIA, VIII, VIIIA and IX	3,947.5 or 3,948.0, 3,950.0, and 3,952.0 or 3,952.5

Only two of the four beacons on each INTELSAT VA and VI satellite can be operated simultaneously; one at the low frequency (3947.5 or 3948.0 MHz) and the other at the high frequency (3952.0 or 3952.5 MHz).

For autotracking of the INTELSAT VA, and VI series of satellites by means of the
beacon signals transmitted by these satellites, it is necessary to be able to receive and
adequately differentiate between each of the four beacon frequencies. It should be noted that two beacon frequencies will normally be used on each satellite at any given time, the choice of which will be determined by INTELSAT. Alternate means for tracking of these satellites may be utilized.

The preferred method of tracking the INTELSAT VII, VIIA, VIII, VIIIA and IX series of satellites is by means of the unmodulated tracking beacon (3,950.0 MHz) since the carrier component of the modulated telemetry beacons will vary in power level as a function of the nature of the information on the beacon. In the event the 3,950.0 MHz beacon should fail, the tracking arrangement of the previous paragraph would be employed. It is, therefore, necessary to be able to receive and adequately differentiate between each of the INTELSAT VII, VIIA, VIII, VIIIA and IX beacon frequencies.

Additional information on the satellite beacons which may be required in the design of tracking/beacon receivers is provided in the IESS–400 series modules.

2. GENERAL RADIO FREQUENCY REQUIREMENTS

2.1 Satellite RF Bandwidth and Beam Switching Capabilities

Information on the INTELSAT satellites' RF bandwidth and beam switching capabilities is provided in the IESS–400 series which describes each satellite series.

2.2 Transmit and Receive Bandwidth

2.2.1 Feed System and Low Noise Receiving Equipment Bandwidth

INTELSAT carriers can be assigned to any of the available transponders and to any satellite series (as may be necessary for contingency operation or resource management). For this reason, earth stations are required to be capable of operating over the full extent of the applicable frequency bands as shown in Table 4. To permit operational flexibility the instantaneous bandwidth of the LNA and antenna feed elements shall cover the full bandwidth listed in Table 4. The RF electronics (i.e., frequency translators, local oscillators, HPAs, etc.) need only be capable of operation, with tuning if necessary, across the applicable bandwidth.

The assignment of Standard F earth stations built prior to 1996* to either Band No. 1 or 2 will be mutually agreed to between the earth station owner, the owner's correspondents, and INTELSAT. Due to the Ku–band connectivity that is available in Band Segment No. 1, preference is normally given to this band. In view of the limited global beam resources, utilization of Band Segment No. 2 will be dealt with on a case–by–case basis (for the global beam transponders in this segment).

Standard F earth stations built prior to 1996 which envision large traffic requirements are encouraged to have the RF equipment designed to operate over the full extent of both band segments.

2.2.2 Requirement for Simultaneous Transmission of Multiple Carriers

Users should anticipate having to transmit multiple carriers, when operating with multiple beam satellites. It may be required that at least one carrier be transmitted to each downlink beam to which access is desired. Additionally, it may be necessary to "dual feed" the same carrier at two different frequencies simultaneously during frequency plan transitioning. Accordingly, to avoid a prolonged service disruption, Users are strongly urged to consider a means of simultaneous transmission of the same carrier at two different frequencies anywhere with the required frequency band listed in Table 4. Global beam capacity will normally be made available only to those earth stations not covered by the other satellite beams in order to maximize the satellite capacity.

2.2.3 Frequency Conversion Equipment

It is recommended that earth stations be equipped with frequency conversion equipment capable of operating anywhere within the bandwidth segments indicated in Table 4, in order to allow operational flexibility during frequency plan transitions and contingency circumstances.

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* Standard F earth stations built after 1995 are required to be capable of operating across the 5,925 – 6,425 MHz and 3,700 – 4,200 MHz bands.

Although two 70 MHz frequency converters can be used for multicarrier operation with 72 MHz transponders, Users should consider the use of 140 MHz IF conversion equipment.

2.3 Common Wideband Receiving Amplifier Linearity Requirements

2.3.1 General

It is expected that adequate intermodulation performance will be obtained if the common wideband receiving amplifier meets a two carrier intermodulation specification as follows:

(a) Input power of each carrier equals 3 dB below expected total receive power level.

(b) Level of each third–order intermodulation product equals 51 dB below the level of each carrier.

2.3.2 Total Receive Power Flux Density at the Earth's Surface

The maximum expected total receive power flux densities for earth stations are shown in Table 5.

2.4 Amplitude, Group Delay, and Electrical Path Length Equalization

In designing the RF subsystem, consideration should be given to specific amplitude, group delay and electric path length equalization requirements addressed in the applicable modulation/access modules which are intended to be used with the earth station.

3.0 TESTING AND CONTROL REQUIREMENTS

3.1 Test Equipment

The quantity and type of test and measuring equipment provided at an earth station will depend largely upon the wishes of the User and upon the quantities and types of equipment used. All apparatus should be tested and maintained in such a way that the performance requirements described in this document can be measured and assured.

Certain tests and measurements between cooperating pairs of earth stations require compatibility of test equipment.

Specific test equipment requirements which may apply to the various modulation/access techniques are described in the appropriate modules of the IESS.

3.2 Earth Station Control and Monitoring

In view of the numerous earth stations accessing the space segment on a multiple access (simultaneous) basis, any variation in transmit RF frequency, transmit EIRP, and antenna tracking could cause interference with other services or cause hazardous conditions in the space segment. Accordingly, it is mandatory that earth stations be controlled at all times to avoid such interference.

In addition, bearing in mind the fact that earth stations may be operated on a part time, or reservation basis, the station control facility should be compatible with such operation.

This requirement is considered to be satisfied when earth stations are attended 24–hours per day by operating personnel capable of adjusting frequency, EIRP and tracking. In the event stations are not manned on a 24–hour per day–basis, this requirement is considered to be satisfied when a positive means is available* (remotely or otherwise) for immediately turning off RF carriers which are interfering with services or creating hazardous conditions in the space segment.

For those earth stations being controlled remotely, the full functionality of the Engineering Service Circuits (ESC) must be extended to the control point.

Earth stations should be equipped with means whereby the power of their own transmitted carriers can be measured at some point after the HPA. In

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* Available is defined as meaning that a point of contact is available to the IOC, whenever the earth station is operational. Users are strongly encouraged to consider the advantages of 24–hour per day staffing in their operational planning.

addition, a means should be provided to observe the spectrum of carriers transmitted and received by the earth station, e.g., by means of a spectrum analyzer. In this way, Users will be able to detect malfunctions in their transmitting and receiving equipment.

Users should consider the use of station fault indicators and automatic status reporting. Remote diagnostics should also be considered such that unmanned stations can be remotely controlled and test routines exercised. In addition, it is desirable that unattended earth stations use automatic fail–safe features to cease transmission in the event that the power at the feed input exceeds the nominal value by more than 1.5 dB.

3.3 Engineering Service Circuits (ESC)

The engineering service circuits requirements related to Standard earth stations are provided in the IESS–403 module.

TABLE 1
G/T REQUIREMENTS
(C–band Standard Earth Stations)

Earth Station Standard	Minimum G/T Requirement (1)(2) (dB/K)
A	35.0 + 20 log f/4
B	31.7 + 20 log f/4
F–3	29.0 + 20 log f/4
F–2	27.0 + 20 log f/4
F–1	22.7 + 20 log f/4
H–4	22.1 + 20 log f/4
H–3	18.3 + 20 log f/4
H–2	15.1 + 20 log f/4

NOTES:

(1) G = antenna gain measured at the input of a low noise amplifier relative to an isotropic radiator,

T = receiving system temperature referred to the input of the low noise amplifier, relative to 1 kelvin, and

f = frequency in GHz.

(2) These requirements also apply to linearly polarized antennas operating with INTELSAT VIIIA.

TABLE 2(a)
EARTH STATION POLARIZATION REQUIREMENTS TO OPERATE WITH
INTELSAT VA, VI, VII and VIIA SATELLITES (6/4 GHz)

Coverage	INTELSAT VA		INTELSAT VI		INTELSAT VII/VIIA	
	Earth Station Transmit	Earth Station Receive	Earth Station Transmit	Earth Station Receive	Earth Station Transmit	Earth Station Receive
1. Global A	LHCP	RHCP	LHCP	RHCP	LHCP	RHCP
2. Global B	RHCP	LHCP	RHCP	LHCP	RHCP	LHCP
3. West Hemisphere (Hemi 1)* †	LHCP	RHCP	LHCP	RHCP	LHCP	RHCP
4. East Hemisphere (Hemi 2)* †	LHCP	RHCP	LHCP	RHCP	LHCP	RHCP
5. NW Zone (Z1)** ZA†	RHCP	LHCP	RHCP	LHCP	RHCP	LHCP
6. NE Zone (Z3)** ZB†	RHCP	LHCP	RHCP	LHCP	RHCP	LHCP
7. SW Zone (Z2)** ZC†	N/A	N/A	RHCP	LHCP	RHCP	LHCP
8. SE Zone (Z4)** ZD†	N/A	N/A	RHCP	LHCP	RHCP	LHCP
9. C–Spot A	N/A	RHCP	N/A	N/A	LHCP	RHCP
10. C–Spot B	N/A	LHCP	N/A	N/A	RHCP	LHCP

* Hemi 1, Hemi 2, ZA, ZB, ZC, ZD nomenclature applies to INTELSAT VII and VIIA only.

** Z1, Z2, Z3, Z4 nomenclature applies to INTELSAT VI only.

† This indicates the normal mode of operation for INTELSAT VII and VIIA; the inverted mode implies different beams in the East and West, as illustrated in IESS–409.

Notes: LHCP = Left–Hand Circularly Polarized. N/A = Not Applicable on this Spacecraft.
RHCP = Right–Hand Circularly Polarized.

TABLE 2(b)

EARTH STATION POLARIZATION REQUIREMENTS TO OPERATE WITH INTELSAT VIII, VIIIA and IX SATELLITES (6/4 GHz) (1)

COVERAGE	INTELSAT VIII and IX (1)		INTELSAT VIIIA (1)	
	Earth Station Transmit	Earth Station Receive	Earth Station Transmit	Earth Station Receive
1. Global A	LHCP	RHCP	N/A	N/A
2. Global B	RHCP	LHCP	N/A	N/A
3. Hemi 1(2)	LHCP	RHCP	N/A	N/A
4. Hemi 2(2)	LHCP	RHCP	N/A	N/A
5. Zone 1 Zone 2 Zone 3 Zone 4 Zone 5 (4)	RHCP RHCP RHCP RHCP RHCP	LHCP LHCP LHCP LHCP LHCP	N/A N/A N/A N/A N/A	N/A N/A N/A N/A N/A
6. Hemi A(3)	N/A	N/A	HPOL	VPOL
7. Hemi B(3)	N/A	N/A	VPOL	HPOL

NOTES:

(1) N/A = Not Applicable
RHCP = Right Hand Circularly Polarized   LHCP = Left Hand Circularly Polarized
VPOL = Vertically Linearly Polarized   HPOL = Horizontal Linearly Polarized

(2) The INTELSAT VIII may be operated in the normal or inverted attitude. In the AOR and IOR Hemi 1 corresponds to the West Hemi and Hemi 2 to the East Hemi. In the POR the INTELSAT VIII will be operated in the inverted mode and, therefore, Hemi 1 corresponds to the East Hemi and Hemi 2 to the West Hemi.

(3) The INTELSAT VIIIA Hemi A and Hemi B coverages are coincident.

(4) Applicable to INTELSAT IX with 5 Zone mode only.

TABLE 3

MINIMUM TRACKING REQUIREMENTS
(C–Band Standard Earth Stations)

Earth Station Standard (1)	VA	VI, VII, VII, VIIA, VIII, VIIIA and IX
A (2)	Manual and Autotrack	Manual and Autotrack
B (2)	Manual and Autotrack	Manual and Autotrack
F–3 (5)	Autotrack	"Fixed" Antenna (3)(6)(7)
F–2 (5)	Manual E/W only (5) (Weekly Peaking)	"Fixed" Antenna (3)
F–1 (3)(5)	"Fixed" Antenna (4)	"Fixed" Antenna
H–4	"Fixed" Antenna (4)	"Fixed" Antenna
H–3	"Fixed" Antenna (4)	"Fixed" Antenna
H–2	"Fixed" Antenna (4)	"Fixed" Antenna

NOTES: See next page.

NOTES TO TABLE 3

(1) The minimum tracking requirements are subject to the earth station meeting the axial ratio requirements of paragraph 1.3.2.

(2) Users are urged to include in their designs a provision to add program steering.

(3) "Fixed" antenna mounts will still require the capability to be steered from one satellite position to another, as dictated by operational requirements (typically once or twice every 2 to 3 years). These antennas should also be capable of being steered at least over a range of ± 5 degrees from beam center for the purpose of verifying that the antenna pointing is correctly set toward the satellite, and for providing a means of verifying the sidelobe characteristics in the range.

(4) Standard F–2, F–1, H–4, H–3, and H–2 Users should consider the possible need to upgrade the earth station with manual or autotrack systems in the event it becomes necessary to operate with satellites having higher than nominal inclination.

(5) These minimum requirements apply to Standard F earth stations which either transmit or
transmit and receive.

(6) Standard F–3 users are encouraged to consider autotrack designs. Earth stations using
fixed antennas must meet all specifications of this document irrespective of the satellite position within the box defined by nominal stationkeeping limits.

(7) Standard F–3 users should take into consideration their tracking requirements under contingency operation with another satellite series.

TABLE 4
MINIMUM BANDWIDTH REQUIREMENTS FOR STANDARD A, B, F, and H EARTH STATIONS

Earth Station Standard	Satellite	Earth Station Type (1)	Earth Station Transmit Band (MHz)		Earth Station Receive Band (MHz)	Tx & Rcv Bandwidth (MHz)	Notes
A, B	All	Existing	5,925 – 6,425		3,700 – 4,200	500	
	VA, VII, VIIA	New	5,925 – 6,425		3,700 – 4,200	500	
	VI, VIII, IX	New	5,850 – 6,425		3,625 – 4,200	575	(2)(3)
	VIIIA	New	5,850 – 6,650		3,400 – 4,200	800	(2)(3)
F–1, F–2, F–3	All	Existing	5,925 – 6,256 (Band Segment 1)	or	3,700 – 4,031 (Band Segment 1)	331	(4)
			6,094 – 6,425 (Band Segment 2)		3,869 – 4,200 (Band Segment 2)	331	(4)
	All	New	5,925 – 6,425		3,700 – 4,200	500	
H–4, H–3, H–2	VA,VI,VII,VIIA,VIII, IX	All	5,925 – 6,425		3,700 – 4,200	500	(2)
	VIIIA	All	5,925 – 6,425 (Band 1)	or	3,700 – 4,200 (Band 1)	500	(2)
			5,850 – 6,650 (Band 2)		3,400 – 4,200 (Band 2)	800	(2)

Notes: See following page.

NOTES TO TABLE 4

(1) Existing earth stations are defined to be those with an RFP, or similar contractual document, dated prior to 1996. New earth stations are those with an RFP dated after 1995.

(2) Users are encouraged to utilize the extended transmit and receive bandwidth available in the INTELSAT VI, VIII and VIIIA hemispheric beams. Users intending to buy new earth stations or antennas should consult with INTELSAT in the event they have any difficulty in utilizing these additional bandwidth segments. The extended bandwidths are as follows:

INTELSAT VI,VIII and IX Receive: 3,625 – 4,200 MHz
Transmit: 5,850 – 6,425 MHz
INTELSAT VIIIA Receive: 3,400 – 4,200 MHz
Transmit: 5,850 – 6,650 MHz

(3) Administrations not permitting operation across the full extent of the (5,850 – 6,650)/(3,400 – 4,200) MHz bands are only required to equip for operation in the (5,925 – 6,425)/(3,700 – 4,200) MHz bands.

(4) Existing Standard F earth stations are required to be capable to operate over the full extent of one of the 331 MHz bandwidth segments listed.

TABLE 5

MAXIMUM POWER FLUX DENSITY (PFD) AT THE EARTH's SURFACE
(C–Band Downlinks, dBW/m^2)

Satellite	Typical PFD Per Transponder			Maximum Total PFD*
	(Global)	(Hemi/Zone)	(C–Spot)	(A–Pol) or (B–Pol)**
VA	– 139.6	– 134.1	– 129.1	– 122.4
VI	– 137.1	– 132.1	N/A	– 123.5
VII	– 134.6	– 131.1	– 125.1	– 117.9
VIIA	– 134.1	– 131.1	– 124.5	– 117.4
VIII	– 133.1	– 130.1	N/A	– 118.8
VIIIA	N/A	– 128.6	N/A	– 113.4
IX	–130.6	–124.4	N/A	–116.0

NOTES:

* Maximum total PFD is the PFD resulting from all transponders in a given beam.

** Circularly Polarized Spacecraft

A–pol = A polarization (RHCP), which includes global, hemispheric, and 4 GHz spot beams.

B–pol = B polarization (LHCP), which includes global, zone, and 4 GHz spot beams.

Linearly Polarized Spacecraft (INTELSAT VIIIA)

A–pol = Hemi A which is vertically polarized on the downlink.

B–pol = Hemi B which is horizontally polarized on the downlink.

APPENDIX A

ITU REFERENCES

Radiocommunication Sector Recommendations:

Rec. ITU–R S.465–5 Published 1993

Rec. ITU–R S.524–5 Published 1994

Rec. ITU–R S.580–5 Published 1994

Rec. ITU–R S.733–1 Published 1993

ITU Radio Regulations:

Radio Regulation Article 1 Numbers 148 and 149

Radio Regulation Annex III to Appendix 29

APPENDIX B

REVISION HISTORY

Revision No.	Approval Date	Major Purpose
Original	19 May 1994	• New module
1	25 Aug 1994	• Incorporate INTELSAT VIII and VIIIA, including bandwidth requirements for operation in the extended C–bands of INTELSAT VIIIA. • Add recommendation that antennas used for links with elevation angles below 20° equip with program track capability. (para. 1.4.3) • Add section describing the effects of Faraday rotation on linearly polarized waves in the 6/4 GHz bands of INTELSAT VIIIA. (para. 1.3.3.1 and 1.3.3.2).
2	10 Nov 1995	• Incorporate requirements for Standard H.
3	30 Nov 1998	• Delete references to Standard D*. • Delete references to INTELSAT VA(IBS) and satellites transferred to New Skies Satellite.
4	10 Feb 2000	• Include INTELSAT IX.

* Existing Standard D earth stations must meet the requirements contained in IESS–207 (Rev. 2).