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INTELSAT EARTH STATION STANDARDS (IESS)
Document IESS–316

PERFORMANCE CHARACTERISTICS FOR DIGITAL CARRIERS USING 16QAM MODULATION

(16QAM)

(Standard A, B and F Earth Stations)

Editorial Note: This is a new module.

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INTELSAT EARTH STATION STANDARDS (IESS)

PERFORMANCE CHARACTERISTICS FOR
DIGITAL CARRIERS USING 16QAM MODULATION
(16QAM)

1.   INTRODUCTION

This document provides the performance characteristics of digital carriers, which use inner convolutional encoding/Viterbi decoding and Reed–Solomon outer coding with 16 Quadrature Amplitude Modulation (16QAM), for operation with Standard A, B and F earth stations on Intelsat IX[*]. Performance characteristics for carriers using turbo coding with 16QAM modulation shall be determined on a case by case basis, in consultation with Intelsat.

2.   16QAM DIGITAL CARRIER SYSTEM REQUIREMENTS, GENERAL

16QAM digital carriers in the Intelsat system utilize coherent 16QAM modulation operating at information rates of 1.544 Mbit/s and above. The information rate is defined as the bit rate entering the channel unit, prior to the application of any channel coding.

Any information rate above 1.554 Mbit/s, inclusive, may be transmitted. Intelsat has, however, defined a set of recommended information rates that are based upon ITU–T hierarchical rates (G Series) and ITU–T ISDN rates (I Series). The Intelsat–recommended information rates are 1544, 2048, 6312, 8448, 32064, 34368 and 44736 kbit/s.

The noise bandwidth for 16QAM carriers is equal to 0.25 times their transmission rate[†]. To provide guardband between adjacent carriers, the nominal allocated satellite bandwidth is equal to 1.35 times[‡] the symbol rate. The actual carrier spacing may be larger and will be determined by Intelsat, based on the particular transponder frequency plan.

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[*]   Performance characteristics for other spacecraft series will be included in subsequent versions of this document. Until then, the performance characteristics shall be determined on a case–by–case basis, in consultation with Intelsat.

[†]   The transmission rate (R) is defined as the bit rate entering the 16QAM modulator at the earth station (i.e., after the application of channel coding) and is equal to four times the symbol rate at the output of the 16QAM modulator. Figure 1 is a block diagram of a non–DVB channel unit and illustrates the definitions of information rate, transmission rate and symbol rate.

[‡]   A smaller guardband may be used if supported by the modem filter design (i.e., sharper filter rolloff).

16QAM carriers may share transponders with carriers employing other approved modulation techniques and/or with other 16QAM carriers. Receiving earth stations should be designed so that carriers can be received in the presence of adjacent carriers that may use any approved modulation technique.

IF equipment should be configured for maximum flexibility since changes in service patterns may require the reallocation of carriers. Stations equipped with synthesizers should be capable of transmitting and receiving carriers whose frequency spacings are multiples of 22.5 kHz (for carriers with information rates up to and including 10 Mbit/s). Frequency spacings based on 125 kHz should be used for information rates above 10 Mbit/s. Actual operating carrier frequencies will be determined in consultation with Intelsat.

The use of 16QAM improves spectrum utilization but requires more satellite power than TCM/IDR and QPSK/IDR carriers. The use of 16QAM may be advantageous for bandwidth–limited transponders loaded with carriers using lower order modulation and/or in new services.

Users shall ensure that compatible 16QAM modems are used at each end of the satellite link.

Since 16QAM carriers are sensitive to nonlinearities in the transmission chain, the earth station and satellite HPAs must be operated in the quasi–linear region of their transfer characteristics by properly backing off from saturation. These backoffs shall be determined in consultation with Intelsat and per guidelines given in Table 1.

The transmission characteristics for 16QAM digital carriers are summarized in Table 1.

3.   EQUIVALENT ISOTROPICALLY RADIATED POWER (EIRP)

The maximum earth station transmit EIRPs and associated transmission parameters and margins are specified in APPENDIX B. The actual operating EIRPs will be equal to or less than the maximum values listed in this Appendix, taking into account the adjustments described in Sections 3.1 and 3.2.

3.1   EIRP Correction Factors

The EIRP values listed in APPENDIX B apply to earth stations operating with a 10° elevation angle and located at beam edge.

For elevation angles other than 10° and earth station locations other than at satellite antenna beam edge, the correction factors K_1 and K_2 given in IESS–402 (EIRP Correction Factors) can be used.

Users should note that Intelsat may from time to time either change the location of a satellite or require an earth station to transfer operations from one satellite to another. In either case, the change may result in new correction factors such

that the EIRP requirements will be increased, but within the limits of
APPENDIX B.

3.2   EIRP Adjustment

The necessary EIRP per carrier during clear–sky conditions is a function of the
satellite sensitivity and the fractional amount of satellite power required for the
corresponding satellite–to–earth portion of the transmission path. Depending on
these characteristics, Intelsat will specify the earth station EIRP for each carrier
that is necessary to develop the required satellite EIRP to be assigned to each
link.

Intelsat may ask for changes in the nominal uplink EIRP and the means shall be
provided for effecting such changes expeditiously and for maintaining the new
level constant to within the EIRP stability requirements of Section 3.3. The
means shall also be provided for monitoring the level of each transmitted carrier
and for adjusting their EIRP over a range of 15 dB below the mandatory
maximum value. In determining the earth station transmitter power
requirements, it is necessary not only to meet the EIRP requirements in
Section 3, but also to meet the emission requirements of Section 4.

3.3   EIRP Stability

Tropospheric scintillation can occur in C–Band under both adverse weather and
clear–weather conditions and 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°.

3.3.1   Clear Sky

The EIRP in the direction of the satellite shall, under clear–sky conditions and
light wind, be maintained to within ± 0.5 dB (for Standard A, B) and to within
± 1.5 dB (for Standard F stations) of the nominal value assigned by Intelsat. The
tolerance includes all factors causing variation, such as HPA output power
instability, antenna transmitting gain instability, antenna beam pointing error and
tracking error, added on a root–sum–square basis.

3.3.2   Adverse Weather Conditions (At 6 GHz)

In the event of severely adverse local weather conditions, the 6 GHz power flux density at the satellite may be permitted to drop to 2 dB below the nominal value, recognizing, however, that this will result in a degraded channel performance at cooperating receiving earth stations.

3.4   Transponder Gain Step

The saturation flux density of the Intelsat IX transponders may be adjusted by varying the gain of the transponder. For Intelsat IX, there are twelve (12) step increments (approximately 2 dB per step). Intelsat will use these gain adjustments to optimize transponder operation for various frequency plans as they may occur over the lifetime of the spacecraft.

4.   EMISSION CONSTRAINTS

4.1   Spurious Emissions Within the Satellite Band (5,850 to 6,425 MHz)

4.1.1   Spurious Emissions (Except Intermodulation Products)

The EIRP resulting from spurious tones, bands of noise or other undesirable products, but excluding multicarrier intermodulation products and spectral spreading due to earth station nonlinearities, that are present when the 16QAM carriers are not activated (carrier "off") shall not exceed 4 dBW/4 kHz anywhere within the following frequency ranges:

Operating Satellite	Frequency Range
Intelsat IX	5,850 to 6,425 MHz

Those spurious products (excluding the multicarrier intermodulation products and spectral spreading due to earth station nonlinearities) that are generated whenever the 16QAM carriers are activated (carrier "on") shall be: at least 40 dB below the level of an unmodulated carrier (i.e., –40 dBc) for carriers having information rates up to and including 2.048 Mbit/s, or at least 50 dB below the level of an unmodulated carrier (i.e., –50 dBc) for carriers having information rates above 2.048 Mbit/s.

4.1.2   Spurious Emissions – Intermodulation Products

The mandatory EIRP limits for intermodulation products resulting from multicarrier operation of the earth station wideband RF equipment are addressed in a separate module (IESS–401).

4.1.3   RF Out–of–Band Emission (Carrier Spectral Sidelobes)

To limit interference into adjacent carriers, the EIRP density outside of the satellite bandwidth allocated for each carrier that results from spectral re-growth due to earth station nonlinearities shall be at least 26 dB below the main carrier spectral density measured in a 4 kHz band.

The above limits apply only to the spectral sidelobes which may experience re-growth due to earth station nonlinearities. The EIRP density in the frequency range from 0.175 R to 0.25 R Hz away from the nominal center frequency shall be at least 16 dB below the peak EIRP density, measured in a 4 kHz band.

4.2   Unwanted Emissions Outside the Satellite Band

The definition of unwanted emissions (out–of–band and spurious) from both earth stations and spacecraft operating in the Fixed Satellite Service (FSS) are defined in Article 1 of the Radio Regulations, Nos. 1.144 and 1.145, respectively.

The out–of–band (OOB) domain comprises the region extending from the edge of the earth station amplifier's passband to the boundary between the OOB domain and the spurious domain. This boundary is normally located at a frequency offset from the edge of earth station high power amplifier's passband that is equal to twice the amplifier's bandwidth. The spurious emissions domain extends from the boundary with the OOB domain outwards. (Refer to Recommendations ITU–R SM.329, SM.1539 and SM.1541.)

Users should note that national regulators may impose additional domestic constraints on earth stations beyond those listed in this section. Users should, therefore, consult with their domestic regulatory authority to determine if such limits exist and to comply with them.

4.2.1   Out–Of–Band (OOB) Emissions

The Radio Regulations provide some general guidance on the need to limit OOB emissions to protect those services operating in the adjacent frequency bands (see RR No. 4.5).

The level of undesirable emissions in the out–of–band (OOB) domain should conform to the requirements of Annex 5 of ITU–R Recommendation SM.1541.

4.2.2   Spurious Emissions in the Spurious Domain – For Earth Stations Brought Into Service after 1 January 2003

All earth stations brought into service after 1 January 2003 shall ensure that spurious emissions in the spurious domain meet the mandatory requirements of Section 2 of Appendix 3 of the Radio Regulations.

4.2.3   Spurious Emissions in the Spurious Domain – For All Earth Stations After
1 January 2012

After 1 January 2012, all earth stations shall meet the mandatory requirement of
Section 2 of Appendix 3 of the Radio Regulations.

5.   FREQUENCY TOLERANCES AND SPECTRUM INVERSION

The carrier frequency tolerances discussed below and the demodulator
operating conditions have been formulated to eliminate the necessity for a
reference pilot for AFC. Under these conditions, and with the satellite translation
frequency tolerance discussed below, it is expected that earth station transmit
and receive chain frequency adjustments will be required periodically.

5.1   Carrier RF Tolerance

The RF tolerance (maximum uncertainty of initial frequency adjustment plus
long–term drift) on all earth station transmitted carriers shall be ± 0.025 R Hz up
to a maximum of ± 3.5 kHz, where R is the transmission rate in bits per second.
Long term is assumed to be at least one month.

The earth station receive chain frequency stability should be consistent with the
frequency acquisition and tracking range of the demodulator but, as a minimum,
it is recommended that it be no greater than ± 3.5 kHz.

5.2   Satellite Transponder Frequency Tolerance

The translation frequency tolerance due to the satellite should be assumed to be
no worse than ± 25 kHz for the Intelsat satellites over their lifetime. The
translation frequency tolerance over any one–month is typically about ± 2.5 kHz
for Intelsat satellites.

5.3   Spectrum Inversion

The transmitted RF carrier spectrum shall not be inverted with respect to the
modulator output spectrum.

6.   AMPLITUDE AND GROUP DELAY EQUALIZATION

6.1   Earth Station

The amplitude and group delay response requirements apply separately to the
transmit chain(s) measured from the modulator output to the transmit antenna
feed ports and to the receive chain(s) measured from the receive antenna feed
ports to the demodulator input.

The amplitude response and group delay response shall be separately equalized and maintained on the transmit chain(s) within the limits shown in Figure 2 and Figure 3.

It is also recommended that the amplitude response and group delay response be equalized and maintained on the receive chain(s) within the limits shown in Figure 2 and Figure 3.

6.2   Satellite Channel

Depending on the position of the carrier within the transponder and its bandwidth, the group delay response of the satellite input and output multiplexers may need to be compensated with equalizers in the earth station transmit and/or receive chains. This equalization is in addition to the requirements referred to in Section 6.1.

Intelsat will provide information on the amount of parabolic and linear group delay equalization. Transmit earth station, however, shall be equipped for the limits shown in Table 6 and must be able to adjust their equalization for any carrier position within the transponder through appropriate line–up procedures with all receive earth stations. It is anticipated that equalization of this type will only be required for some 16QAM carriers with noise bandwidths greater than 10 MHz.

Table 6 shows the maximum linear and parabolic group delay values for a range of carrier sizes assuming the transmit earth station equalizes for the total satellite group delay (input and output multiplexers). Although current operational guidelines assume that the transmit earth station will equalize for the total satellite group delay, experience may indicate the need to perform some equalization at the receive earth station. This should be considered during the earth station planning process.

7.   PHASE NOISE

7.1   Earth Station (Transmit)

The single sideband phase noise on the transmitted carrier shall satisfy either of the following two limits:

Limit 1: The single sideband phase noise is assumed to consist of a continuous component and a spurious component. The single sideband power spectral density of the continuous component shall not exceed the envelope shown in Figure 4[*]. A spurious component at the fundamental AC line frequency shall not exceed –30 dB relative to the level of the transmitted carrier. The single

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[*]   16QAM modulation requires more stringent phase noise performance. It is recommended that future upconverters and downconverters meet a better phase noise performance, such as the one shown in Figure 5. For existing upconverters and downconverters, sufficient margin has been allocated by Intelsat to compensate for any degradation due to the existing phase noise mask.

sideband sum (added on a power basis) of all other individual spurious components shall not exceed –36 dB relative to the level of the transmitted carrier. (The total phase noise including both sidebands can be up to 3 dB higher).

or,

Limit 2: The single sideband phase noise due to both the continuous and spurious components integrated over the bandwidth 10 Hz to 0.2 R Hz away from the center frequency, where R is the transmission rate in bits per second, shall not exceed 2.0 degrees RMS. (The total phase noise due to both sidebands shall not exceed 2.8 degrees RMS).

The option of satisfying either one of the two limits has been provided since it is possible for the phase noise spectrum to have various distributions which, when integrated, will have the same overall effect.

The phase noise requirements are not mandatory for carriers having information rates greater than 2.048 Mbit/s.

7.2   Earth Station (Receive)

The phase noise requirement for the receive earth station should be consistent with the carrier recovery system of the demodulator but, as a minimum, it is recommended that the phase noise requirement given in Section 7.1 be also met for receive stations.

8.   TRANSMISSION PERFORMANCE

The transmission parameters for Intelsat's recommended information rates are provided in Table 2 to Table 5.

The channel unit shall utilize coherent 16QAM modulation along with either: (a) Rate 3/4 or Rate 7/8 FEC concatenated with Reed–Solomon (219,201) or (204,188) outer coding or, (b) turbo coding. For option (a), the inner FEC shall be convolutional encoding with Viterbi decoding. The transmission parameters when using turbo coding shall be determined in consultation with Intelsat on a case–by–case basis.

8.1   Modulator Spectrum Output

The transmitted IF spectrum at the output of the modulator shall meet the power spectral density mask shown in Figure 6.

8.2   Energy Dispersal (Scrambling)

In order to reduce the maximum power flux density in accordance with Rec. ITU–R SF.358–4 and to meet the off–axis EIRP density criteria in accordance with Rec. ITU–R S.524–7, scrambling shall be applied. To accomplish this, a data scrambler shall be employed at the transmit earth station. The FEC encoder shall follow the scrambler at the transmit earth station. At the receive earth station, the descrambler shall follow the decoder. The scrambling shall be compliant with either IESS–308 or DVB–S.

8.3   Bit Error Rate Performance Characteristics

The channel unit shall meet the performance requirements given in this paragraph in an IF back–to–back mode. These values apply with the scrambler enabled, with forward error correction coding and with Reed–Solomon outer coding.

	Composite Data Rate E_b/N_o (dB)	
BER better than:	Rate 3/4 FEC	Rate 7/8 FEC
10^{-8}	8.7	10.3

The E_b/N_o is referred to the modulated carrier power and to the composite data rate (information rate plus overhead) entering the FEC encoder.

8.3.1   Echo Protection for Voice Channel Interfaces

Voice circuits shall be equipped with either echo cancellers conforming to Rec. ITU–T G.165 or echo suppressors conforming to Rec. ITU–T G.164.

Echo cancellers conforming to Rec. ITU–T G.165 on voice circuits are recommended. While echo suppressors conforming to Rec. ITU–T G.164 may be employed, their use will result in lower subjective voice quality.

9.   CARRIER LINE–UP AND IN–SERVICE MONITORING

Facilities shall be provided to measure the link parameters during carrier line–up. It is recommended that facilities also be provided to monitor the in–service communications performance.

As a minimum, the requirement for initial line–up may be satisfied by a provision for measuring the EIRP of the transmitted carrier, the E_b/N_o of the received carrier (either with a spectrum analyzer or through a filter of known noise bandwidth) and by the ability to perform bit–error–rate measurements using a pseudo– random test pattern.

The minimum requirement for in–service monitoring may be satisfied by providing a transmission rate BER indication through a facility built into the

channel unit (e.g., an indication of the rate of error correction or a pseudo–error measurement technique).

Alternatively, either a composite rate or information rate BER indication can be based upon observation of a low rate multiplexed channel containing a test pattern (e.g., the frame alignment signal in the overhead unit), or upon detection of pattern violations of the digital multiplex framing information.

Table 1

16QAM Carrier Performance Characteristics

Parameter			Units
1. Information Rate	1.544 and above		Mbit/s
2. FEC	Rate 3/4, or 7/8 Viterbi		
3. Reed–Solomon Outer Coding	RS (204, 188) (DVB–compliant) or RS(219, 201) (IESS 308–compliant)		
4. Energy Dispersal (Scrambling)	Synchronous (DVB–compliant) or IESS–308 compliant		
5. Modulation	16QAM		
6. Noise Bandwidth	1.0 x Symbol Rate		MHz
7. Allocated RF Bandwidth[*]	1.35 x Symbol Rate		MHz
8. Threshold Performance:			
• BER	10^{-8}		
• FEC	3/4	7/8	
• E_b/N_o (IF Loopback)	8.7	10.3	dB
• E_b/N_o (via Sat Chan) multicarrier	9.5	12.3	dB
• E_b/N_o (via Sat Chan) single carrier	10.7	15.6	dB
9. System Margin To Threshold:			
• C–Band	2.0		dB
10. Link Availability:			
• C–Band	≥ 99.9		% / yr

Notes:
The IF–to–RF degradations used in the table are based on a transponder input backoff (IBO) of –3 dB, an earth station HPA IBO of –15 dB and the phase noise mask in Figure 4. If the more stringent phase noise mask in Figure 5 is used, the IF–to–RF degradation decreases by 0.3 dB. For a transponder IBO of –6 dB, the following Eb/No (via satellite channel) can be used:

      9.3 dB and 11.9 dB for multicarrier operation with FEC rates of 3/4 and 7/8, respectively.
      9.4 dB and 13.2 dB for single carrier operation with FEC rates of 3/4 and 7/8, respectively.

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[*]   The allocated RF bandwidth is rounded to an odd integer multiple of 22.5 kHz (for information rates less than or equal to 10 Mbit/s) or an integer multiple of 125 kHz (for information rates greater than 10 Mbit/s).

Table 2

Carrier Transmission Parameters [Rate 3/4 FEC, RS (219, 201), 16QAM]

Info. Rate (IR) (kbit/s)	Tx Rate (kbit/s)	Noise BW (kHz)	Allocated BW (kHz)	Clear-sky C/T (dBW/K)	Clear-sky C/No (dBW–Hz)	Clear-sky C/N (dB)
1544	2243.02	560.76	787.5	–155.2	73.4	15.9
2048	2975.20	743.80	1012.5	–154.0	74.6	15.9
8448	12272.72	3068.18	4162.5	–147.8	80.8	15.9
32064	46580.54	11645.13	15750.0	–142.0	86.6	15.9
34368	49927.64	12481.91	16875.0	–141.7	86.9	15.9
44736	64989.61	16247.40	22000.0	–140.6	88.0	15.9

Table 3

Carrier Transmission Parameters [Rate 7/8 FEC, RS (219,201), 16QAM]

Info. Rate (IR) (kbit/s)	Tx Rate (kbit/s)	Noise BW (kHz)	Allocated BW (kHz)	Clear-sky C/T (dBW/K)	Clear-sky C/No (dBW-Hz)	Clear-sky C/N (dB)
1544	1922.59	480.65	652.5	–152.4	76.2	19.4
2048	2550.17	637.54	877.5	–151.2	77.4	19.4
8448	10519.47	2629.87	3577.5	–145.0	83.6	19.4
32064	39926.17	9981.54	13500.0	–139.2	89.4	19.4
34368	42795.12	10698.78	14500.0	–138.9	89.7	19.4
44736	55705.38	13926.35	18875.0	–137.8	90.8	19.4

NOTES:

1. The above tables illustrate parameters for recommended carrier sizes. Other information rates can also be accommodated.

2. C/T, C/N_o and C/N values have been calculated using a threshold Eb/No of 9.5 dB and 12.3 dB for a BER of 10^{-8}, assuming the use of Rate 3/4 and 7/8 FEC, respectively, with 16QAM and RS (219, 201) outer coding and a system margin of 2 dB.

3. For carrier information rates of 10 Mbit/s and below, carrier frequency spacings will be odd integer multiples of 22.5 kHz. For rates greater than 10 Mbit/s, they will be any integer multiple of 125 kHz.

Table 4

Carrier Transmission Parameters [Rate 3/4 FEC, RS (204,188), 16QAM]

Info. Rate (IR) (kbit/s)	Tx Rate (kbit/s)	Noise BW (kHz)	Allocated BW (kHz)	Clear-sky C/T (dBW/K)	Clear-sky C/No (dBW-Hz)	Clear-sky C/N (dB)
1544	2233.87	558.47	787.5	–155.2	73.4	15.9
2048	2963.06	740.77	1012.5	–154.0	74.6	15.9
8448	12222.64	3055.66	4162.5	–147.8	80.8	15.9
32064	46390.47	11597.62	15750	–142.0	86.6	15.9
34368	49723.91	12430.98	16875	–141.7	86.9	15.9
44736	64724.43	16181.11	21875	–140.6	88.0	15.9

Table 5

Carrier Transmission Parameters [Rate 7/8 FEC, RS (204,188) 16QAM]

Info. Rate (IR) (kbit/s)	Tx Rate (kbit/s)	Noise BW (kHz)	Allocated BW (kHz)	Clear-sky C/T (dBW/K)	Clear-sky C/No (dBW-Hz)	Clear-sky C/N (dB)
1544	1914.75	478.69	652.5	–152.4	76.2	19.4
2048	2539.77	634.94	877.5	–151.2	77.4	19.4
8448	10476.55	2619.14	3577.5	–145.0	83.6	19.4
32064	39763.26	9940.81	13500	–139.2	89.4	19.4
34368	42620.50	10655.12	14500	–138.9	89.7	19.4
44736	55478.08	13869.52	18750	–137.8	90.8	19.4

NOTES:

1. The above tables illustrate parameters for recommended carrier sizes. Other information rates can also be accommodated.

2. C/T, C/N$_o$ and C/N values have been calculated using a threshold Eb/No of 9.5 dB and 12.3 dB for a BER of 10^{-8}, assuming the use of Rate 3/4 and 7/8 FEC, respectively, with 16QAM and RS (204, 188) outer coding and a system margin of 2 dB.

3. For carrier information rates of 10 Mbit/s and below, carrier frequency spacings will be odd integer multiples of 22.5 kHz. For rates greater than 10 Mbit/s, they will be any integer multiple of 125 kHz.

Table 6

Earth Station Equalization Required For
Satellite Group Delay

Equalized Bandwidth (MHz)				Linear Equalization (nsec/MHz)			Parabolic Equalization (nsec/MHz^2)*		
0.0	<	BW	< 10.0	Not Req'd			Not Req'd		
10.0	≤	BW	< 15.75	0	to	± 5	0	to	0.5
15.75	≤	BW	< 22.5	0	to	± 3	0	to	0.5
22.5	≤	BW	< 30.0	0	to	± 2	0	to	0.5
30.0	≤	BW	≤ 45.0	0	to	±1	0	to	0.25
54.0	(Full Xpdr)†			0	to	± 0.2	0	to	0.1
72.0	(Full Xpdr)†			0	to	± 0.2	0	to	0.05

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* By convention, the sign of the parabolic component of the satellite group delay is positive and, therefore, the earth station should insert a negative value to achieve equalization.

† These parameters apply if group delay compensation is provided over the full transponder rather than on a per–carrier basis. Typical transponder group delay characteristics can be supplied upon request for transponder bandwidth units greater than 72 MHz.

Figure 1

Illustration of 16QAM Channel Unit

A ┄┄┄ Transmit Interfaces ┄┄┄ D

| a | Overhead Addition | b | Scrambler | c | Outer Encoder Interleaver | | FEC Encoder (rate 3/4 or 7/8) | d | 16QAM Modulator | e | To Up-Converter |

Transmit Channel Unit

Transmit Interfaces

| a | Overhead Removal | b | Descrambler | c | Outer Decoder De-interleaver | | FEC Decoder (rate 3/4 or 7/8) | d | 16QAM Demodulator | e | From Down-Converter |

Receive Channel Unit

H ┄┄┄ Receive Interfaces ┄┄┄ E

A	Information Rate, IR
b,c	Composite Rate, CR=IR plus Overhhead
d	Transmission Rate, R=CR/C (C=composite code rate)
e	Symbole Rate, SR=R/4

Figure 2

Earth Station IF and RF Amplitude Response

NORMALIZED FREQUENCY (Hz)
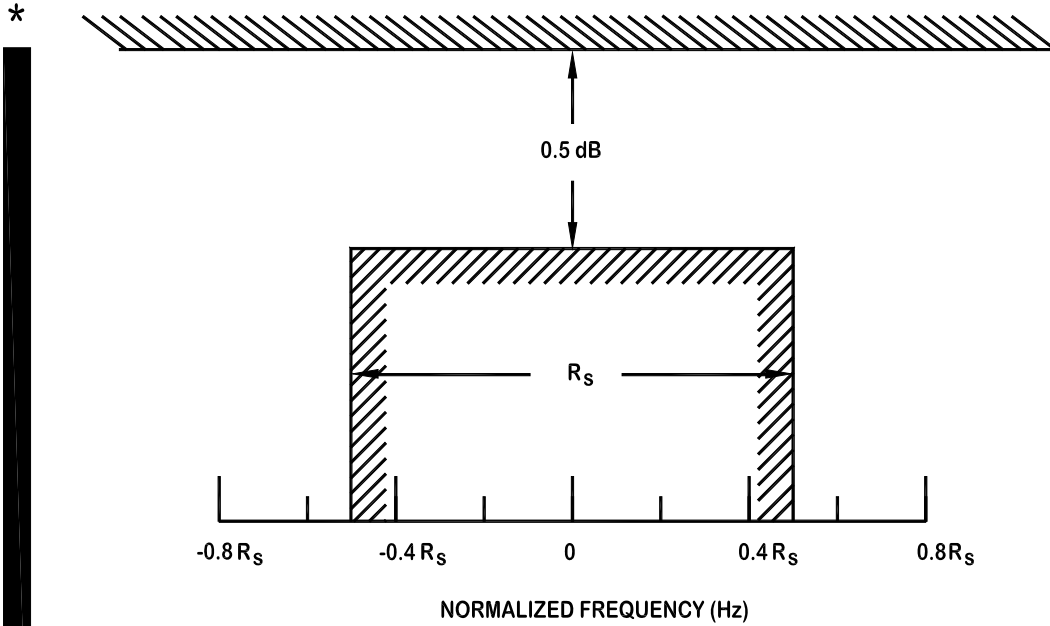
R_S = SYMBOL RATE IN SYMBOLS PER SECOND
* THE AMPLITUDE RESPONSE IS MANDATORY ONLY FOR THE TRANSMIT CHAIN

P:\CAD\IESS\316-01.DWG
TITLE: EARTH STATION IF AND RF AMPLITUDE RESPONSE

Figure 3

Earth Station IF and RF Group Delay Response

R_S

10 nsec

-0.8 R_S -0.4 R_S 0   0.4 R_S 0.8 R_S

NORMALIZED FREQUENCY (Hz)
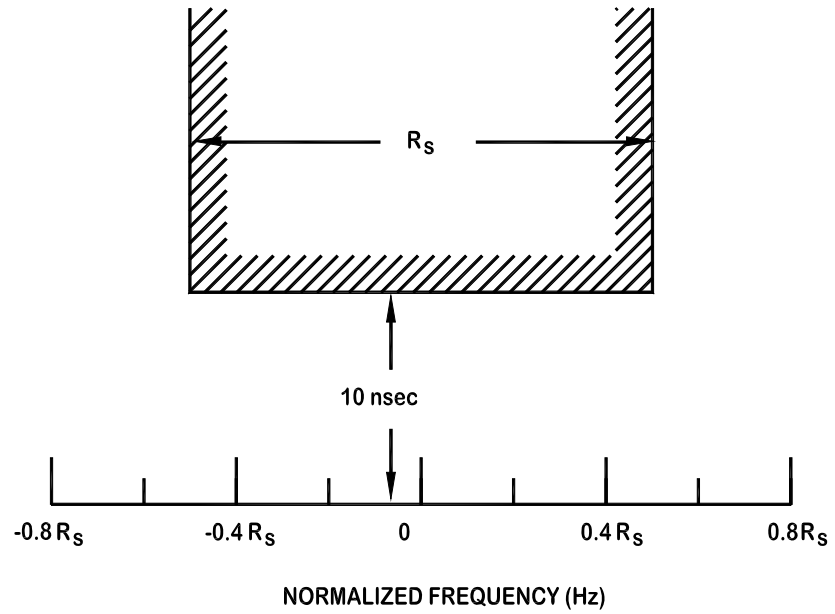
R_S = SYMBOL RATE IN SYMBOLS PER SECOND
* THE GROUP DELAY RESPONSE IS MANDATORY ONLY FOR THE TRANSMIT CHAIN

P:\CAD\IESS\316-02.DWG
TITLE: EARTH STATION IF AND RF GROUP DELAY RESPONSE

Figure 4

Continuous Single Sideband Phase Noise Requirement
(For carriers with information rates ≤ 2.048 Mbit/s)

COORDINATES OF POINTS

POINT	DENSITY (dBc/Hz)	FREQ. (Hz)
A	-60	100
B	-90	100K

SINGLE SIDEBAND PHASE NOISE DENSITY (dBc/Hz)

FREQUENCY FROM CENTER (Hz)
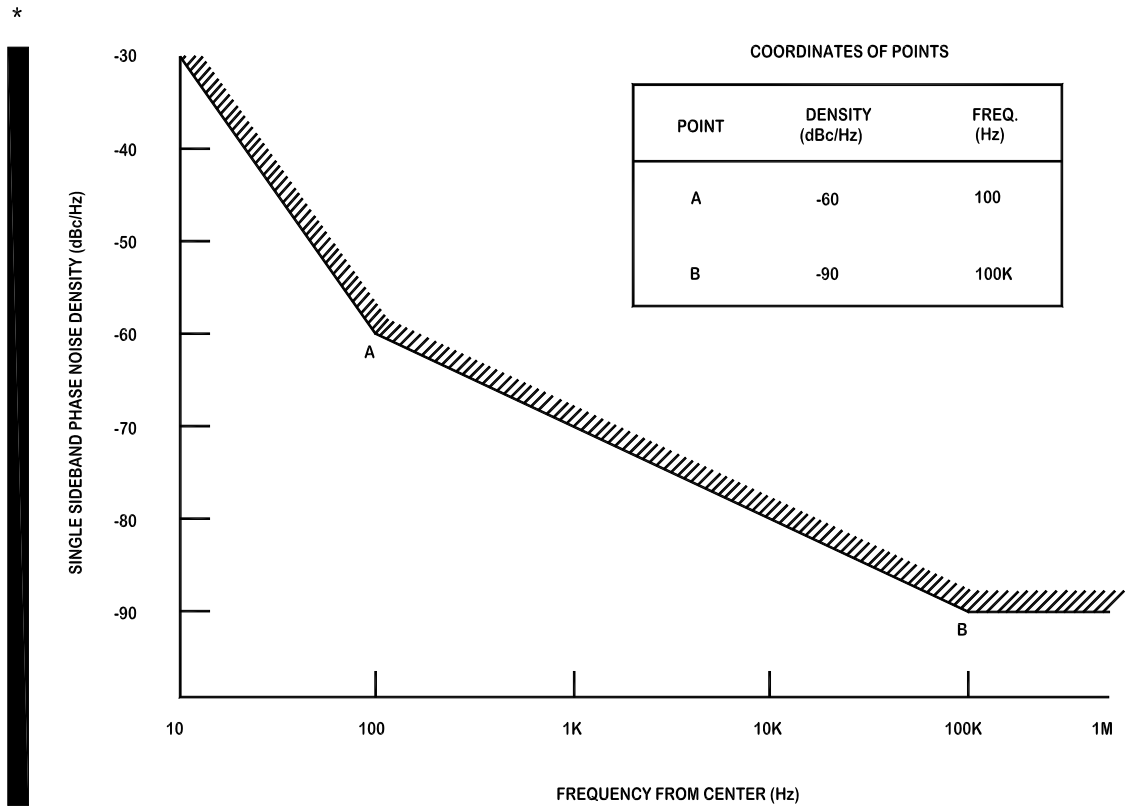
The transmitted phase noise requirement may be satisfied by meeting either of two limits (see Section 7.1). The above phase noise density requirement is mandatory only in the case that Limit 1 has been selected by the earth station applicant and only in the case of the transmit earth station.

Figure 5

Recommended Continuous Single Sideband Phase Noise Requirement
for Future Upconverters and Downconverters
(For carriers with information rates ≤ 2.048 Mbit/s)

Point	Density (dBc/Hz)	Freq. (Hz)
A	-72	100
B	-90	10K
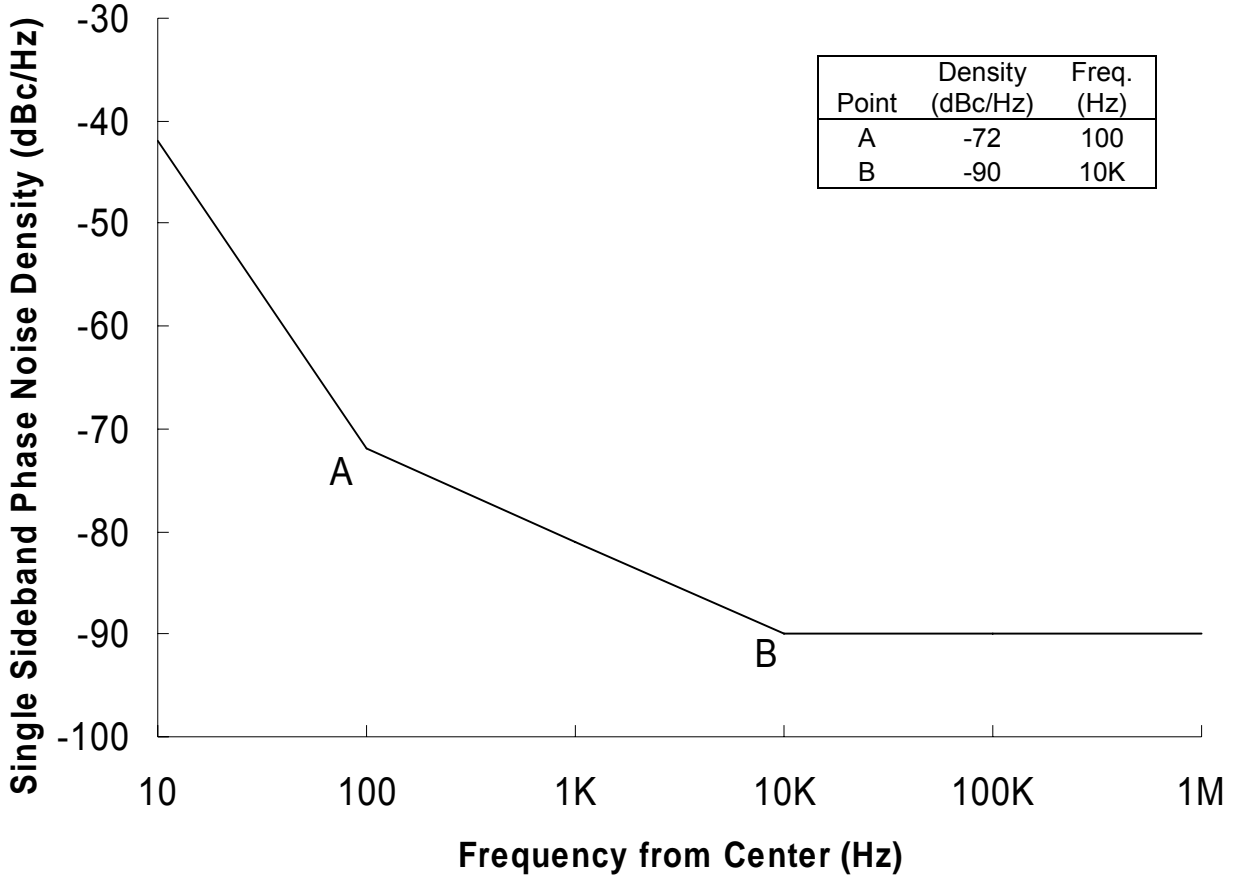
Figure 6

Power Spectral Density Mask At Modulator Output

COORDINATES OF POINTS

POINT	AMP. (dB)	NORM. FREQ. (Hz)
A	+ 0.25	0.0
B	- 0.25	0.0
C	+ 0.25	0.10 R_S
D	- 0.40	0.10 R_S
E	+ 0.25	0.20 R_S
F	- 0.40	0.20 R_S
G	+ 0.25	0.40 R_S
H	- 1.00	0.40 R_S
I	- 0.50	0.45 R_S
J	- 2.00	0.50 R_S
K	- 4.00	0.50 R_S
L	-16.00	0.70 R_S
M	-24.00	0.80 R_S
N	-35.00	0.90 R_S
O	-40.00	1.06 R_S

R_S = SYMBOL RATE IN SYMBOLS PER SECOND

NORMALIZED FREQUENCY FROM CENTER (Hz)
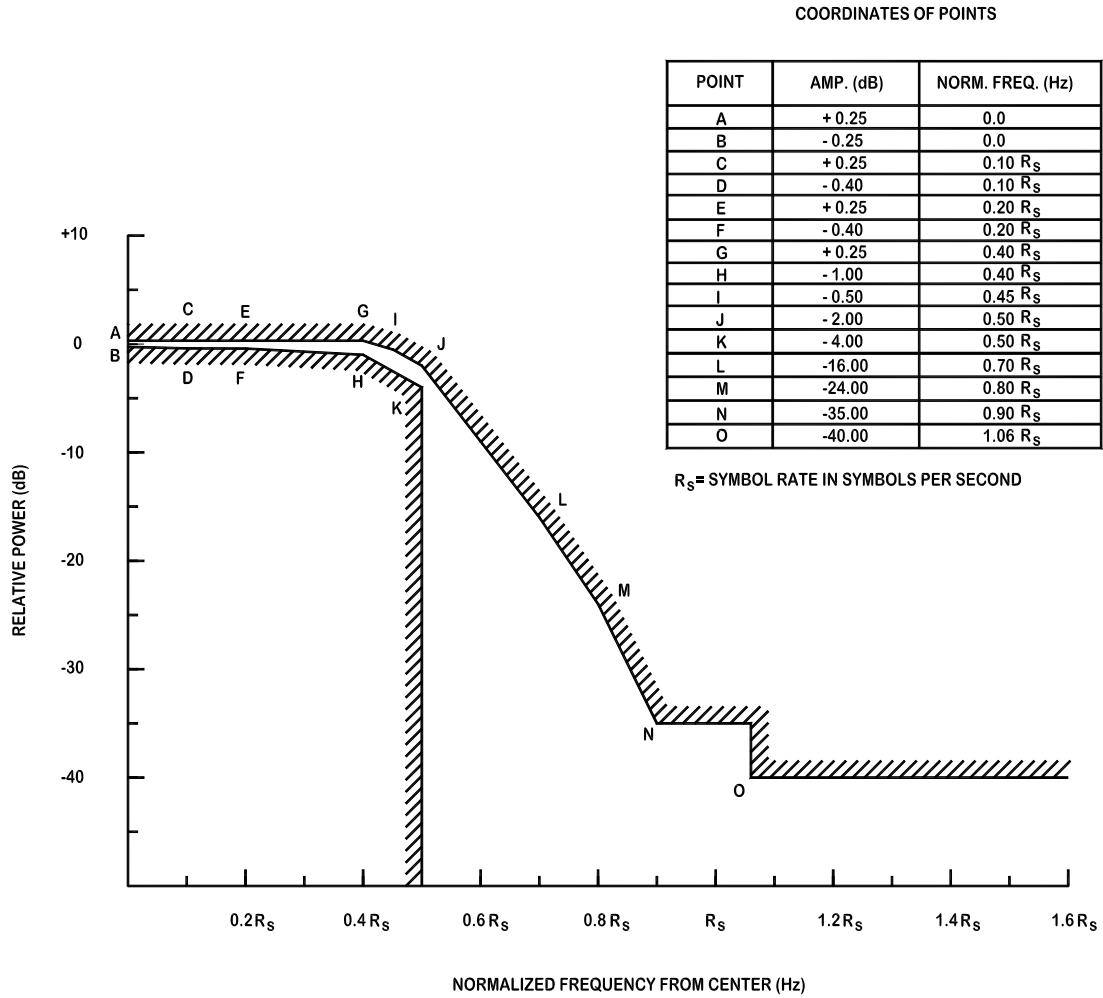
NOTES:
0 dB RELATIVE POWER CORRESPONDS TO -10 LOG R_S dB/Hz RELATIVE TO
THE UNMODULATED CARRIER POWER.

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APPENDIX A

ITU REFERENCES

ITU REFERENCES

Radio Regulations

Appendix 3	TABLE OF MAXIMUM PERMITTED SPURIOUS EMISSION LEVELS

Radiocommunication Sector:

Rec. ITU–R SF.358–4	MAXIMUM PERMISSIBLE VALUES OF POWER FLUX DENSITY AT THE SURFACE OF THE EARTH PRODUCED BY SATELLITES IN THE FIXED–SATELLITE SERVICE USING THE SAME FREQUENCY BANDS ABOVE 1 GHz AS LINE–OF–SIGHT RADIO–RELAY SYSTEMS
Rec. ITU–R S.524–7	MAXIMUM PERMISSIBLE LEVELS OF OFF–AXIS e.i.r.p. DENSITY FROM EARTH STATIONS IN GEOSTATIONARY–SATELLITE ORBIT NETWORKS OPERATING IN THE FIXED–SATELLITE SERVICE TRANSMITTING IN THE 6 GHz, 14 GHz AND 30 GHz FREQUENCY BANDS
Rec. ITU–R SM.329	SPURIOUS EMISSIONS
Rec. ITU–R SM.1539	VARIATION OF THE BOUNDARY BETWEEN THE OUT–OF–BAND AND SPURIOUS DOMAINS REQUIRED FOR THE APPLICATION OF RECOMMENDATIONS ITU–R SM.1541 AND ITU–R SM.329
Rec. ITU–R SM.1541	UNWANTED EMISSIONS IN THE OUT–OF–BAND DOMAIN

Telecommunications Standardization Sector*:

Rec. ITU–T G.151	CCITT Rec. G.151 (Red Book), 1984
Rec. ITU–T G.164	CCITT Rec. G.164 (Blue Book), 1988[†]
Rec. ITU–T G.165	New version of CCITT Rec. G.165, 1993[†]
Rec. ITU–T G.702	CCITT Rec. G.702 (Red Book), 1984
Rec. ITU–T G.704	CCITT Rec. G.704 (Red Book), 1984

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* Although these recommendations carry the new ITU–T nomenclature, it is not intended to refer users to the latest version of the recommendations, except where indicated. For the purpose of the applicable sections of this IESS module, reference is being made specifically to the applicable CCITT Red or Blue Books shown in this Appendix.

† Prior to 19 May 1994, these recommendations were Red Book Recommendations.

Rec. ITU–T G.711	CCITT Rec. G.711 (Red Book), 1984
Rec. ITU–T G.732	CCITT Rec. G.732 (Red Book), 1984
Rec. ITU–T G.733	CCITT Rec. G.733 (Red Book), 1984
Rec. ITU–T G.742	CCITT Rec. G.742 (Red Book), 1984
Rec. ITU–T G.743	CCITT Rec. G.743 (Red Book), 1984
Rec. ITU–T G.747	CCITT Rec. G.747 (Blue Book), 1988
Rec. ITU–T G.751	CCITT Rec. G.751 (Red Book), 1984
Rec. ITU–T G.752	CCITT Rec. G.752 (Red Book), 1984
Rec. ITU–T G.761	CCITT Rec. G.761 (Red Book), 1984
Rec. ITU–T G.763	CCITT Rec. G.763 (Blue Book), 1988
Rec. ITU–T G.802	CCITT Rec. G.802 (Red Book), 1984
Rec. ITU–T G.803	CCITT Rec. G.803 (Red Book), 1984
Rec. ITU–T G.811	CCITT Rec. G.811 (Red Book), 1984
Rec. ITU–T G.823	CCITT Rec. G.823 (Red Book), 1984
Rec. ITU–T G.824	CCITT Rec. G.824 (Red Book), 1984
Rec. ITU–T G.826	New recommendation; approved on 26 Nov. 1993.
Rec. ITU–T Q.33	CCITT Rec. Q.33 (Red Book), 1984

APPENDIX B

EARTH STATION NOMINAL EIRP TABLES

(Intelsat IX)

Table B.1

Earth Station Maximum EIRP Capabilities
[Rate 3/4 FEC, RS (219,201), 16QAM, Single Carrier Per HPA]

<u>C–Band Earth Stations</u>

Intelsat Standard	Nominal Antenna size (m)	Antenna Gain (dBi)	EIRP Limit (4) Per Rec. ITU–R S.524–7 (dBW / 2048 kbit/s)	EIRP (dBW)			
				HPA Size (Watts)			
				100	200	400	500
A	15	57.8	83.5	67.8	70.8	73.8	74.8
B	11	54.3	80.0	64.3	67.3	70.3	71.3
F–3	9	53.0	78.7	63.0	66.0	69.0	70.0
F–2	7	50.6	76.3	60.6	63.6	66.6	67.6
F–1	5	47.7	73.4	57.7	60.7	63.7	64.7

See Notes to Table B.1 on page B–4.

Table B.2

Earth Station Maximum EIRP Capabilities
[Rate 7/8 FEC, RS (219,201), 16QAM, Single Carrier Per HPA]

C–Band Earth Stations

Intelsat Standard	Nominal Antenna size (m)	Antenna Gain (dBi)	EIRP Limit (4) Per Rec. ITU–R S.524–7 (dBW / 2048 kbit/s)	EIRP (dBW)			
				HPA Size (Watts)			
				100	200	400	500
A	15	57.8	82.8	67.8	70.8	73.8	74.8
B	11	54.3	79.3	64.3	67.3	70.3	71.3
F–3	9	53.0	78.0	63.0	66.0	69.0	70.0
F–2	7	50.6	75.6	60.6	63.6	66.6	67.6
F–1	5	47.7	72.7	57.7	60.7	63.7	64.7

See Notes to Table B.2 on page B–4.

Notes to Tables B.1 and B.2

1. For nonlinearized earth station TWTAs, an input backoff of 15.0 dB is recommended and, for SSPAs and Linearized TWTAs, an input backoff of 10.0 dB (single or multicarrier carrier).

2. Transmit line loss and OBO = 10.0 dB

3. The ITU–R EIRP limits shown in Table B.1 and Table B.2 are based on a 2048 kbit/s Rate 3/4 16QAM carrier and a Rate 7/8 16QAM carrier, respectively. For other information rates higher than 2048 kbit/s, the ITU–R EIRP limit should be adjusted by adding a factor equal to 10 x $\log_{10}$ (Information rate (kbit/s) ÷ 2048 kbit/s).

Table B.3

Nominal Earth Station EIRP (dBW) for Rate 3/4 16QAM [RS (219, 201)]
(Intelsat IX, 72 MHz Hemi/Zone–to–Hemi/Zone, 2 dB U/L & D/L Antenna Pattern Advantage)

Rx Station	EIRP (dBW)				
	A	B	F–3	F–2	F–1
Information Rate (kbit/s)					
1544	63.9	65.6	67.4	69.4	73.6
2048	65.1	66.8	68.6	70.6	74.8
6312	70.0	71.7	73.5	75.5	79.7
8448	71.3	73.0	74.8	76.8	81.0
32064	77.0	78.7	80.5	82.5	86.7
34368	77.3	79.0	80.8	82.8	87.0
44736	78.5	80.2	82.0	84.0	+
X (for other info. rates)	2.0	3.7	5.5	7.5	11.7

NOTES:

1.   These nominal EIRP values have been computed using a saturation flux density of –76.0 dBW/m^2 and full transponder loading conditions. Other saturation flux densities may be used depending on the actual traffic loading.

2.   The above EIRP values are applicable for the following uplink/downlink beam connections, Ocean Regions and spacecraft locations:

UPLINK		DOWNLINK			D/L EIRP	U/L Margin	D/L Margin	S/C Location
BEAM	DIR.	BEAM	DIR.	REGION	(dBW)	(dB)	(dB)	(°E)
Hemi/Zone	All	Hemi/Zone	All	All	36.0	2.0	≥2.0	All

3.   See the General Notes on page B–7.

+   Denotes carriers not intended for this connection.

Table B.4

Nominal Earth Station EIRP (dBW) for Rate 7/8 16QAM [RS (219, 201)]
(Intelsat IX, 72 MHz Hemi/Zone–to–Hemi/Zone, 2 dB U/L & D/L Pattern Advantage)

Rx Station	EIRP (dBW)				
	A	B	F–3	F–2	F–1
Information Rate (kbit/s)					
1544	67.0	68.6	70.4	72.3	76.3
2048	68.2	69.8	71.6	73.5	77.5
6312	73.1	74.7	76.5	78.4	82.4
8448	74.4	76.0	77.8	79.7	83.7
32064	80.1	81.7	83.5	85.4	+
34368	80.4	82.0	83.8	85.7	+
44736	81.6	83.2	85.0	86.9	+
X (for other info. rates)	5.1	6.7	8.5	10.4	14.4

NOTES:

1. These nominal EIRP values have been computed using a saturation flux density of –76.0 dBW/m^2 for full transponder loading conditions. Other saturation flux densities may be used depending on the actual traffic loading.

2. The above EIRP values are applicable for the following uplink/downlink beam connections, Ocean Regions and spacecraft locations:

UPLINK		DOWNLINK			D/L EIRP	U/L Margin	D/L Margin	S/C Location
BEAM	DIR.	BEAM	DIR.	REGION	(dBW)	(dB)	(dB)	(°E)
Hemi/Zone	All	Hemi/Zone	All	All	36.0	2.0	2.0	All

3. See the General Notes on page B–7.

+   Denotes carriers not intended for this connection.

GENERAL NOTES FOR TABLES B.3 AND B.4

(Earth Station EIRP for Intelsat IX)

1.   The nominal EIRP values provided in these tables assume earth stations have an elevation look angle of 10° and are located away from the edge of the satellite antenna beam coverage (i.e., benefit from having an uplink / downlink beam pattern advantage). An uplink / downlink pattern advantage of 2 dB / 2 dB was assumed. To determine the proper sizing for their earth station HPA, users will need to perform link budget calculations taking into consideration the specific characteristics of their link.

2.   The EIRP values shown in Table B.3 and Table B.4 assume an aggregate adjacent satellite interference (ASI) contribution of 20% of the total noise. For 2° orbital spacing operation, the EIRP values may need to be increased to improve protection against ASI.

3.   The EIRP values are shown only for example information rates. For other information rates, the EIRP can be computed using the following formula:

$$\text{EIRP} = X + 10 \log (IR), \text{ in dBW.}$$

where: X = the value for other information rates (shown in Table B.3 and Table B.4).

IR = Information rate, in bits per second.

APPENDIX C

REVISION HISTORY

Revision No.	Approval Date	Major Purpose
Original	24 Oct 2003	• New module.