INTELSAT EARTH STATION STANDARDS (IESS)

Document IESS–309 (Rev. 8)

PERFORMANCE CHARACTERISTICS FOR
INTELSAT BUSINESS SERVICES (IBS)
(Standard A, B, C, E, F, H and K Earth Stations)

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Note: Technical Notes are not routinely distributed with the IESS–309 module.

INTELSAT EARTH STATION STANDARDS (IESS)

PERFORMANCE CHARACTERISTICS FOR INTELSAT BUSINESS SERVICES (IBS)

1. INTRODUCTION

Intelsat Business Services (IBS) are defined for two distinct offerings: IBS and VSAT IBS. This document provides the performance characteristics for both:

(a) Intelsat Business Services (IBS) employ digital carriers, which use Quadrature Phase–Shift–Keying (QPSK) modulation with Frequency Division Multiple Access (FDMA) technique.

IBS is designed for communication between Standard A, B, C, E and F earth stations, which may function as national gateways, urban gateways and/or as customer–premise installations. The service is not intended to be used for public switched telephony. IBS networks can be operated in either Open Network or Closed Network configuration.

(b) VSAT IBS (IBS to/from Small Earth Stations) employ digital carriers, which use Quadrature Phase–Shift–Keying (QPSK) or Binary Phase–Shift–Keying (BPSK) modulation, with Frequency Division Multiple Access (FDMA) technique. BPSK modulation is used, whenever necessary, to reduce signal power density, thereby maximizing the number of possible VSAT IBS earth station connectivities which can be established. VSAT IBS networks can be operated in either Open Network or Closed Network configuration.

VSAT IBS carriers are defined as those which terminate at or originate from Standard E–1*, F–1*, H and K earth stations only.

A comparison of the general features of IBS and VSAT IBS is shown in the table on the next page:

* The technical requirements for Intelsat standard earth stations are defined in IESS–207 (C-Band) and IESS–208 (Ku–Band). Standard E–1 and F–1 earth stations can be used for both IBS and VSAT IBS.

CHARACTERISTIC	IBS	VSAT IBS
Network Types	Open, Closed	Open, Closed
Satellites	VI, VII/VIIA, VIII & IX	VI, VII/VIIA, VIII & IX
Beams	All beams	All beams, except Global
Transmit or Receive Earth Station Standards	A, B, C, E & F	Standards E–1, F–1, H and K
Terrestrial Network Connectivity	No connection to Public–Switched Network (PSN)	Connectivity to Public–Switched Packet Data Network (PSPDN)
Information Rate	64 kbit/s to 2.048 Mbit/s (Open Network) 64 kbit/s to 8.448 Mbit/s (Closed Network)	64 kbit/s to 8.448 Mbit/s (Open & Closed Network)
Overhead Framing	1/15 x Information Rate (Open Network) 0 – 10% x Information Rate (Closed Network)	None (Open & Closed Network)
Forward Error Correction (FEC)	Rate 1/2 & 3/4 Convolutional encoding / Viterbi decoding (Open Network) Unspecified (Closed Network)	Rate 1/2 & 3/4 Convolutional encoding / Viterbi decoding* (Open Network) Unspecified (Closed Network)
Reed–Solomon (219, 201) Outer Coding	Optional (Open & Closed Network)	Mandatory* (Open Network) Optional (Closed Network)
Modulation	QPSK	QPSK, BPSK
Quality (Open Network)	Clear Sky: $\leq 10^{-8}$ BER (≥ 95.9% of the year) Threshold: 10^{-3} BER (≥ 99.96% of the year)	Clear Sky: $<< 10^{-10}$ BER (≥ 95.9% of the year) Threshold: $\leq 10^{-10}$ BER (≥ 99.6% of the year)

* For delay–sensitive applications using information rates of 384 kbit/s or less, VSAT IBS carriers may, on an exceptional basis, use Rate 1/2 (or 3/4) FEC convolutional encoding with sequential decoding. The quality (Open Network) achieved in this configuration is: Clear sky (≥ 95.9% of the year) $\cong 4 \times 10^{-9}$ BER (Rate 1/2) and 5×10^{-10} (Rate 3/4); Threshold (≥ 99.6% of the year) $\cong 10^{-6}$ (Rate 1/2) and 10^{-7} (Rate 3/4).

VSAT IBS takes into consideration the performance requirements of modern digital services and the need for efficient utilization of transponder resources in networks employing small antennas. As a consequence, some performance requirements for VSAT IBS are different from IBS. Throughout this document, distinctions between the two services have been demarcated, as necessary.

Mandatory requirements in these specifications are signified by the placement of a thick bar in the left–hand margin of the text, as illustrated for this sentence. Revisions to the previous version of the module are indicated by a bar placed in the right-hand margin, as illustrated for this paragraph.

2. SERVICE DESCRIPTION

2.1 IBS and VSAT IBS Network Types

There are two types of IBS and VSAT IBS networks: Closed Network and Open Network. Regardless of the network type, the earth station antenna and RF requirements are the same.

(a) A Closed Network provides users with the freedom to select the digital parameters required for their particular needs. The performance characteristics for this type of service do not require specifications related to interconnection with other users and can be defined in terms of RF transmission characteristics. The requirements given in Appendix B are sufficient to define a Closed Network. In general, the only requirements which are mandatory in a Closed Network are those which ensure that one user's emissions do not interfere with others.

(b) An Open Network requires a certain degree of common terminal features to be defined to enable one user's network to interface with another. The Open Network requirements are defined in Section 4 and are necessary to ensure successful equipment interoperability. There are differences between the IBS Open Network and the VSAT IBS Open Network specifications.

2.2 Quality of Service

2.2.1 IBS Quality

Intelsat Business Services (IBS) are offered on Intelsat VI, VII, VIIA, VIII and IX satellites for all beam connections and for information rates ranging from 64 kbit/s to 8.448 Mbit/s. Connections are designed to provide a BER of better than 10^{-3} for more than 99.96% of the year (i.e., the service will be unavailable for no more than 0.04% of a typical year). The clear–sky BER performance of IBS is typically less than 10^{-8} at C–Band and virtually error–free at Ku–Band due to the higher rain margins. IBS performance on Intelsat VI, VII, VIIA, VIII and IX satellites is shown in Table 1 and Table 2.

The C–Band and Ku–Band uplink and downlink margins for IBS are provided in Appendix D (IBS Propagation Margin Allocations).

2.2.2 VSAT IBS Quality

VSAT IBS services are offered on Intelsat VI, VII, VIIA, VIII and IX satellites for all beam connections, except those involving the Global beam, and for information rates ranging from 64 kbit/s to 8.448 Mbit/s.

The baseline coding/modulation scheme for VSAT IBS is Rate 1/2 convolutional encoding/Viterbi decoding concatenated with Reed-Solomon (219, 210) outer coding and QPSK modulation.

For VSAT IBS carrier transmissions to receiving earth stations larger than Standards E–1, F–1, H and K, users can request, as an alternative, the use of Rate 3/4 convolutional encoding/Viterbi decoding concatenated with Reed-Solomon (219, 210) outer coding. Users should be aware, however, that the earth station's maximum EIRP requirement will be 1.3 higher than that for the baseline coding/modulation. Furthermore, the off–axis emission margins shown in Appendix I and Technical Note TN309.8 for the baseline coding/modulation will be reduced by 3.1 dB as a result of the higher EIRP density associated with such carriers.

Connections are designed to provide a BER of equal to better than 10^{-10} (Rate 1/2 or 3/4 FEC) for more than 99.6% of the year (i.e., the service will be unavailable for no more than 0.4% of a typical year). The C–Band clear–sky BER performance provided is much better than 10^{-10} (i.e., practically error–free) due to using Rate 1/2 (or 3/4) convolutional encoding/Viterbi decoding concatenated with Reed–Solomon (219, 201) outer coding.

For delay–sensitive applications operating at information rates of 384 kbit/s or lower, users may utilize, on an exceptional basis, Rate 1/2 (or 3/4) convolutional encoding with sequential decoding because of its lower throughput delay. This FEC alternative provides a BER of better than 10^{-6} (Rate 1/2) or 10^{-7} (Rate 3/4) for more than 99.6% of the year. The clear–sky BER is equal to or better than 4×10^{-9} (Rate 1/2) or 5×10^{-10} (Rate 3/4). Figure 1 compares the processing delay for Reed–Solomon outer coding versus sequential decoding.

At Ku–Band, the clear–sky BER performance using either FEC scheme is essentially error–free for all information rates by virtue of the larger link margin allocated to mitigate the effects of rain attenuation.

2.2.2.1 Propagation Margins for VSAT IBS

For VSAT IBS services, Intelsat will provide a C–Band propagation margin of 1 dB on the uplink and 1 dB on the downlink. For Ku–Band transmissions, a margin of up to a maximum of 5.5 dB on the uplink and up to a maximum of 8 dB on the downlink will be provided. The actual margin provided at Ku–Band will be determined by Intelsat on a case–by–case basis, based on the particulars of the transmission path.

These margins will provide an uplink and a downlink path availability of 99.8%, which corresponds to an overall link availability of 99.6%, assuming that propagation effects on the uplink and downlink are independent of each other.

2.2.2.2 Additional G/T Requirement

Within a given beam coverage area, the downlink degradation* due to the local rain statistics at a particular earth station site may be larger than the maximum downlink margin provided at Ku–Band. Users operating with such earth stations need to provide improved RF performance in the form of a G/T exceeding the minimum required, as discussed below.

To optimize usage of the space segment while simultaneously ensuring that applicable service performance criteria are met, the earth station's receiving antenna gain–to–system noise temperature ratio (G/T) must be adequate. During adverse climatic conditions (rain, snow, strong winds, etc.), the nominal service performance criteria may not necessarily be met. The percentage of time that the downlink margin is exceeded will depend upon, inter alia, the earth station's location, the local weather statistics (long–term rainfall data) and the antenna subsystem characteristics.

Service performance criteria are defined in terms of a clear–sky BER performance requirement and a small percentage of the time in a year during which this performance may be allowed to be degraded below a given threshold.

For each Ku–Band Spot beam, Intelsat has determined a maximum downlink margin by considering the local rain statistics and elevation angles of typical earth stations operating in its coverage area. The actual margins provided by Intelsat for any particular transmission path will be determined on the basis of the rain statistics of the uplink and downlink transmission paths and the service performance objectives.

Since the downlink degradation due to the local rain statistics at a particular earth station site may exceed the maximum downlink margin determined by Intelsat for a given beam coverage area, the affected earth station will need to provide improved RF performance in the form of a G/T exceeding the minimum required.

The additional G/T which may be required for operation under degraded weather conditions is determined by computing the downlink degradation based on the local yearly rain statistics and comparing them against the reference downlink margins given in Appendix D for IBS and Section 2.2.2.1 for VSAT IBS. If the local rainfall statistics indicate that the downlink degradation will exceed these values, then the required G/T of that earth station shall be determined by the following equations:

Standard C: $G/T \geq 37.0 + 20 \log 10\ f/11.2 + X$ dB, dB/K

* Downlink degradation is defined as the sum of the precipitation attenuation (in dB) and the increase in the receiving system noise temperature (in dB) for the given percentage of time.

Standard E–3: G/T $\geq$ 34.0 + 20 log 10 f/11.0 + X dB, dB/K

Standard E–2: G/T $\geq$ 29.0 + 20 log 10 f/11.0 + X dB, dB/K

Standard E–1: G/T $\geq$ 25.0 + 20 log 10 f/11.0 + X dB, dB/K

Standard K–3: G/T $\geq$ 23.3 + 20 log 10 f/11.0 + X dB, dB/K

Standard K–2: G/T $\geq$ 19.8 + 20 log 10 f/11.0 + X dB, dB/K

Where:

G = receiving antenna gain (relative to an isotropic radiator) referred to the input of the low–noise amplifier;

T = receiving system noise temperature (relative to 1 Kelvin) referred to the input of the low–noise amplifier;

f = receive frequency in GHz; and

X = the amount by which the downlink degradation predicted by local rain statistics exceeds the reference downlink margin shown in the tables in Appendix D (IBS) and Section 2.2.2.1 (VSAT IBS) for the same percentage of time. (See Technical Note TN309.6 for the method for calculating X.)

2.3 Applicable Satellites

IBS services between Standards A, B, C, E and F earth stations are offered on Intelsat VI, VII, VIIA, VIII and IX satellites for all beam connections.

VSAT IBS services to/from Standards E–1, F–1, H and K are offered on Intelsat VI, VII, VIIA, VIII and IX satellites for all beam connections, except those involving the Global beam.

2.4 Connectivity Considerations for Small Earth Stations

The off–axis emission density radiated by an earth station is constrained by Recommendation ITU–R S.524–7. These constraints limit the allowable connectivities between small antennas. In order to maximize the number of allowable connectivities, BPSK, as well as QPSK, modulation, is used for VSAT IBS.

BPSK modulation reduces carrier EIRP density by 3 dB relative to QPSK, thus improving the number of possible connectivities to small earth stations. To assist users in the planning of their earth stations, connectivity matrices showing the off–axis emission indicators* for Intelsat VI, VII/VIIA, VIII and IX are provided in Appendix I. The earth station–to–earth station off–axis emission indicators provided in Appendix I assume satellite antenna beam–edge parameters and the earth station sidelobe radiation patterns described in IESS-207 and IESS–208. The connectivity constraints identified in Appendix I can be relaxed if earth stations have certain geographical advantage and/or have demonstrated sidelobe radiation patterns better than those described in IESS–207 and IESS–208.

To maximize transponder utilization, QPSK modulation is mandatory on those transmission links where its use does not result in a violation of the off–axis EIRP density criteria of Rec. ITU–R S.524–7. In cases where the ITU criteria are exceeded, BPSK modulation is mandatory.

3. CLOSED NETWORK PERFORMANCE CHARACTERISTICS (IBS AND VSAT IBS)

In IBS or VSAT IBS Closed Networks, Intelsat will permit the use of a variety of encoding and/or encryption techniques. When operating in a Closed Network, the user may employ different FEC schemes, or even none, to achieve performance other than the nominal Open Network values. This is acceptable, provided the reference transmission rate and bandwidth units† are not exceeded (see Appendix C, IBS Transmission Parameters and Appendix H, VSAT IBS Transmission Parameters).

Carrier sizes not meeting one of the reference units will be considered by Intelsat on a case–by–case basis and will be evaluated by taking into account the satellite resources that are required in relation to the reference link parameters identified in Appendix C or H.

In general, Intelsat will provide the satellite resources (downlink EIRP and allocated bandwidth) up to those required for the reference carrier upon which the user's utilization charge is based.

In the event that the IBS or VSAT IBS Open Network reference parameters are exceeded, Intelsat will provide the downlink EIRP up to the level equivalent to the reference carrier upon which the user's utilization charge is based. If more powerful FEC systems are needed, the information capacity may be reduced for a given transmission rate.

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* The off–axis emission indicators indicate the amount by which the transmit earth station emission conforms with (positive margin) or exceeds (negative margin) the requirements of Rec. ITU–R S.524-7.

† A reference unit is defined as an integer multiple, n (n = 1 to 132), of the smallest carrier size. For example, for Rate 1/2 FEC IBS, the smallest carrier size is 140.8 kbit/s ≅ 141 kbit/s. Example reference units are shown in Appendices C (IBS) and H (VSAT IBS). In the case of 1.544 Mbit/s and 6.312 Mbit/s, which are not integer multiples, an allocated bandwidth based on n = 25 and n = 99, respectively, is assigned.

Detailed performance characteristics for Closed Network operation are defined in Appendix B (Closed Network Performance Characteristics).

4. OPEN NETWORK PERFORMANCE CHARACTERISTICS

4.1 Overview

This Section provides the requirements for participation in IBS and VSAT IBS Open Networks. It establishes the common terminal features which will allow one user's network to interface with another. Unless specifically noted otherwise, all requirements in Section 4 apply to both IBS and VSAT IBS Open Networks.

A functional overview of an IBS terminal used in an Open Network concept is depicted in Figure 2 and Figure 3. The corresponding diagrams for VSAT IBS Open Network are depicted in Figure 4 and Figure 5. An Open Network channel unit consists of the following:

- modulator/demodulator (modem)
- FEC encoder/decoder (codec)
- Reed–Solomon outer encoder/decoder (codec) (optional for IBS)
- scrambler/descrambler
- encrypter/decrypter (optional – IBS only)

Detailed technical characteristics for the IBS Open Network Channel Unit are defined in Appendix F while those for the VSAT IBS Channel Unit are defined in Appendix K.

4.2 Environmental Specifications

Given the geographical coverage of the Intelsat system, VSAT IBS Terminals* may be installed in a wide variety of environmental conditions. Any single environmental specification will probably be too stringent for certain installations yet insufficient for others. The recommended environmental specification for VSAT IBS Terminals is provided in Technical Note TN309.10. None will be provided, however, for IBS earth stations since they are typically installed in environmentally–controlled conditions.

* To conform with the terminology used in SSOG-220, a VSAT IBS Terminal comprises an earth station model [antenna, plus broadband RF equipment (HPA, LNA)] together with its associated upconverter(s), downconverter(s), interfacility link (IFL) cabling and VSAT IBS compliant modem(s).

4.3 Reference Transmission Parameters

4.3.1 IBS

To provide users with the flexibility in selecting a transmission mode to satisfy their requirements, a set of reference transmission parameters (see Appendix C) have been established for IBS Open Networks based on:

(a) information rates of 64 kbit/s to 2.048 Mbit/s

(b) 10% overhead framing;

(c) Rate 1/2 and Rate 3/4 convolutional encoding/Viterbi decoding;

(d) Reed–Solomon (219, 201) outer coding (optional); and

(e) QPSK modulation.

Maximum uplink EIRPs and associated bandwidth units have been derived to ensure efficient transponder utilization.

The use of Reed–Solomon (219, 201) outer coding is an option which has been introduced for IBS to facilitate users wishing to enhance the performance of their links. Its usage shall be determined on the basis of bilateral agreement between correspondent users. See Technical Note TN309.5 for details on Reed–Solomon (RS) outer coding requirements and performance.

4.3.2 VSAT IBS

Reference transmission parameters (see Appendix H) have been established for VSAT IBS based on:

(a) information rates of 64 kbit/s to 8.448 Mbit/s;

(b) no transmission level overhead framing;

(c) Rate 1/2 (or 3/4) convolutional encoding/Viterbi decoding;

(d) Reed–Solomon (219, 201) outer coding; and

(e) QPSK/BPSK modulation.

VSAT IBS carriers transmitted to or from Standards E–1, F–1, H and K shall employ Rate 1/2 (or 3/4) convolutional encoding/Viterbi decoding concatenated with Reed–Solomon (219, 210) outer coding in conjunction with QPSK/BPSK modulation, with the exception of Standards E–1 and F–1, which can also support Rate 1/2 and 3/4 FEC IBS carriers.

For delay–sensitive applications using information rates of 384 kbit/s or less, users may employ, on an exceptional basis, Rate 1/2 convolutional encoding/sequential decoding, without Reed–Solomon outer coding, in conjunction with QPSK/BPSK modulation.

It is not necessary for a single VSAT IBS modem to incorporate all features over the full range of information rates. A VSAT IBS modem may, for example, transmit only a subset of the full range of information rates. A VSAT IBS modem, however, must provide all required features for the information rate(s) for which it is equipped.

4.4 RF Transmission Performance Characteristics

4.4.1 IBS

The following information rates are, as a minimum, supported in the IBS Open Network: 64, 128, 256, 384, 512, 768, 1024, 1536, 1544, 1920 and 2048 kbit/s. Lower rates are available to the customer (i.e., 300, 600 bit/s, 1.2, 2.4, 4.8, 9.6, 48 and 56 kbit/s) but these are multiplexed to form at least a 64 kbit/s carrier prior to transmission through the satellite.

Transmission parameters for IBS Open Network carriers are given in Appendix C for Rate 1/2 and Rate 3/4 FEC. The values of C/T, C/No, C/N and EIRP assume the addition of 1/15 overhead* (transmission level framing) and Rate 1/2 or Rate 3/4 FEC. The FEC is convolutional encoding with Viterbi decoding.

4.4.2 VSAT IBS

The following information rates are supported, as a minimum, for VSAT IBS: 64, 128, 256, 384, 512, 768, 1024, 1536, 1544, 2048, 4096, 6312 and 8448 kbit/s. Lower rates are available to the customer (i.e., 300, 600 bit/s, 1.2, 2.4, 4.8, 9.6, 48 and 56 kbit/s) but these are multiplexed to form at least a 64 kbit/s carrier prior to transmission through the satellite.

Transmission parameters for VSAT IBS carriers are given in Appendix H for both Rate 1/2 and Rate 3/4 convolutional encoding/Viterbi decoding [with Reed–Solomon (219, 201) outer coding] as well as Rate 1/2 and 3/4 convolutional encoding/sequential decoding. The C/T, C/No, C/N and EIRP values assume no overhead framing is used.

4.5 Earth Station IF and RF Requirements

4.5.1 Equivalent Isotropic Radiated Power (EIRP)

The necessary EIRP per carrier during clear–sky conditions is a function of satellite sensitivity, outage margins, and optimized loading of the entire transponder. The nominal uplink EIRP will, therefore, vary from time–to–time and will be established in coordination with the Technical Operations Control Center (TOCC). For the purpose of earth station planning, the maximum clear-sky uplink EIRP levels, for some typical beam connections, are specified in Appendix E (IBS) and Appendix J (VSAT IBS). The maximum EIRP level must be available, if requested.

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* Except for a carrier with 1544 kbit/s information rate, which will have a slightly lower overhead.

A comprehensive listing of the IBS earth station maximum EIRP tables for Intelsat VI, VII, VIIA, VIII and IX is provided in Technical Note TN309.7. Although the Open Network includes an overhead of 1/15 (about 6.7%) times the information rate, as compared to the 10% assumed for the Closed Network, the difference in the EIRP levels given in these tables is insignificant (≅ 0.1 dB).

A comprehensive listing of the VSAT IBS earth station maximum EIRP tables for Intelsat VI, VII, VIIA, VIII and IX is provided in Technical Note TN309.9.

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. For these and other reasons, Intelsat may ask for changes in the nominal EIRP. The capability shall be provided for effecting such changes expeditiously and for maintaining the new level constant to within the EIRP stability tolerance. The capability for adjusting the EIRP over a range of 15 dB below the mandatory maximum value shall be provided.

For transmitting Standard A, B, C, E or F earth stations, the capability for monitoring the level of each transmitted carrier shall be provided. This requirement is considered satisfied if a directional coupler of known coupling factor, across the RF band, is placed between the HPA output and the antenna feed input.

In determining the earth station's HPA sizing, both the EIRP requirements above as well as the out–of–band emission requirements shall be satisfied.

4.5.2 EIRP Correction Factors

The EIRP values listed in Appendices E (IBS) and J (VSAT IBS), and Technical Notes TN309.7 (IBS) and TN309.9 (VSAT IBS) apply to earth stations that have a 10° elevation angle and are located at the edge of the satellite antenna beam coverage. For elevation angles other than 10° and earth station locations other than at beam edge, the EIRP correction factors K_1 and K_2 given in IESS–402 (EIRP Correction Factors) can be used to reduce the maximum required EIRP

4.5.3 EIRP Stability

4.5.3.1 Clear Sky

The EIRP in the direction of the satellite shall, except under adverse weather conditions, be maintained to within the values given below:

Transmit Earth Station Type	EIRP Stability (dB)
A, B, C	± 0.5
E, F, H, K	± 1.5

This tolerance includes all earth station factors contributing to EIRP variation, e.g., HPA output power level instability, antenna beam pointing and/or tracking error, added on a root–sum–square basis.

To meet the EIRP stability requirements, users of Standard F–2 and F–3 earth stations that are not equipped with autotracking capability will need to perform antenna alignment when the satellite is near the center of its stationkeeping box. Satellite position can be calculated using the method described in IESS-412.

4.5.3.2 Adverse Weather Conditions

(a) 6 GHz Uplinks

In the event of severely adverse local weather conditions, the 6 GHz power flux density at the satellite may be permitted to drop below the nominal value (up to 2 dB for IBS). This will result, however, in degraded channel performance at the correspondent receiving earth stations.

(b) 14 GHz Uplinks

To meet the required performance objective at 14 GHz, it is mandatory that the means be provided to prevent the power flux density at the satellite from falling by more than M dB below the nominal clear–sky value for more than K percent of the time in a year. Values of M and K are given in Appendix D (IBS Propagation Margin Allocations).

It is the user's responsibility to decide whether the above requirement should be met by providing diversity earth station(s) or uplink power control. If uplink power control is used, it is recommended that, when the up–path excess attenuation is greater than 1.5 dB, control of the transmitter's power should be applied to restore the power flux density at the satellite to -1.5 dB, ± 1.5 dB of nominal, to the extent that it is possible with the total power control range available.

Regardless of which method is used to maintain the flux density at the satellite, the flux density level obtained for clear–sky EIRP shall not be exceeded by more than 0.5 dB (Standard C stations) or 1.5 dB (Standard E stations) prior to or following cessation of precipitation, except for a brief interval following recovery from propagation conditions.

4.5.3.3 Scintillation Effects

Tropospheric scintillation can occur in C–Band or Ku–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. Program track is recommended as the primary tracking method for antennas with elevation angles below 10°.

4.5.3.4 Ku–Band Beacons

For users who are able to view their own carriers (i.e., loopback), closed–loop uplink power control (UPC) can be utilized. UPC maintains a constant carrier flux density impinging on the satellite during uplink or downlink fade conditions. For users unable to view their own transmissions, open–loop* UPC could be used instead.

To assist in the application of open–loop uplink power control, two unmodulated beacons are provided on the Intelsat VI and IX spacecraft in the 11 GHz frequency band and on Intelsat VII, VIIA and VIII in both the 11 and 12 GHz bands. The spacecraft descriptions in the IESS 400 series modules provide additional beacon information.

4.5.4 EMISSION CONSTRAINTS

4.5.4.1 Spurious Emissions Within The Satellite Band (5,850 to 6,425 MHz and 14,000 to 14,500 MHz)

4.5.4.1.1 Spurious Emissions — Non–Intermodulation Products

The following frequency ranges apply for all specifications in this section:

Operating Satellite	Frequency Range
Intelsat VII & VIIA	5,925 to 6,425 MHz 14,000 to 14,500 MHz
Intelsat VI, VIII & IX	5,850 to 6,425 MHz 14,000 to 14,500 MHz

4.5.4.1.2 Carrier Not Activated (“Off”)

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 non–linearities, that are present when the IBS or VSAT IBS carriers are not activated (carrier “off”) shall not exceed 4 dBW/4 kHz anywhere within the specified frequency ranges.

* The term “open–loop” refers to uplink power control systems which derive the excess uplink path attenuation experienced by a given carrier by measuring the downlink power of another carrier (e.g. a spacecraft beacon).

4.5.4.1.3 IBS Carrier Activated ("On")

Spurious products, excluding the multicarrier intermodulation products and spectral spreading due to earth station non–linearities, that are generated whenever IBS carriers are activated (carrier "on") and which lie within the specified frequency ranges, shall be:

(a) 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

(b) 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.

4.5.4.1.4 VSAT IBS Carrier Activated ("On")

Spurious products, excluding the multicarrier intermodulation products and spectral spreading due to earth station non–linearities, that are generated whenever VSAT IBS carriers are activated (carrier "on") and which lie within the specified frequency ranges, shall be at least 50 dB below the level of an unmodulated carrier (i.e., –50 dBc) for carriers having information rates up to and including 8.448 Mbit/s.

4.5.4.1.5 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).

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

To limit interference into adjacent carriers, the EIRP density outside the satellite bandwidth allocated for each carrier which results from spectral regrowth due to earth station nonlinearities shall be at least 26 dB below the main carrier spectral density measured in a 4 kHz band, when transmitted from a Standard A, B, C, E–3, E–2, F–3 or F–2 earth station.

For transmissions from Standard E–1, F–1, H or K earth stations, the EIRP density shall be at least 23 dB below the main carrier spectral density.

In the case of Standard C and E stations, the 26 dB value may be exceeded whenever uplink power control is activated, but by no more than 9 dB under any circumstances.

The above limits apply only to the spectral sidelobes that may experience regrowth due to earth station nonlinearities. The EIRP density in the frequency range from 0.7 R to 1.0 R Hz for BPSK or 0.35 R to 0.5 R Hz for QPSK away from the nominal center frequency shall be at least 16 dB below the peak EIRP density, measured in a 4 kHz band, where R is the transmission rate in bits per second*.

In order to meet the requirements in this section and to ensure satisfactory VSAT IBS system performance, a minimum HPA output backoff of –3 dB is recommended.

4.5.4.2 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 Chapter 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.329–9, 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.

4.5.4.2.1 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 with the requirements of Annex 5 of ITU–R Recommendation SM.1541.

4.5.4.2.2 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.

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* The transmission rate (R) is defined as the bit rate entering the BPSK or QPSK modulator at the earth station (i.e., after any forward error correction (FEC) coding) and is equal to the symbol rate for a BPSK modulator and twice the symbol rate for a QPSK modulator.

4.5.4.2.3 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.

4.5.5 Frequency Tolerance and Spectrum Inversion

The carrier frequency tolerance discussed below and the demodulator operating conditions given in Channel Unit Appendices F (IBS) and K (VSAT IBS) have been formulated to eliminate the necessity for a separate reference pilot for automatic frequency control (AFC) purposes. Under these conditions and with the satellite translation frequency tolerance discussed below, it is expected that the time interval between earth station transmit and receive chain frequency adjustments will be on the order of several months.

4.5.5.1 Carrier RF Frequency Tolerance

The RF frequency tolerance (maximum uncertainty of initial frequency adjustment plus long–term drift) on all earth station transmitted carriers shall be ± 3.5 kHz. Long term is assumed to be at least one month.

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

4.5.5.2 Satellite Transponder Frequency Tolerance

The translation frequency tolerance due to the satellite should be assumed to be $\leq \pm$ 25 kHz for the Intelsat VI, VII, VIIA, VIII and IX satellites over their lifetime. The tolerance over any one month is typically $\leq \pm$ 2.5 kHz.

4.5.5.3 Spectrum Inversion

The transmitted RF carrier spectrum shall not be inverted with respect to the modulator output spectrum [See Channel Unit Appendices F (IBS) and K (VSAT IBS)].

4.5.6 Earth Station Amplitude and Group Delay Equalization

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 equalized and maintained on the transmit chain(s) within the limits shown in Figure 6 and Figure 7.

It is recommended that the amplitude response and group delay response be equalized and maintained on the receive chain(s) within the limits shown in Figure 6 and Figure 7.

4.6 Transmission Delay Variation Due to Satellite Motion

If carriers are to be interfaced with other synchronous data networks, it may be necessary to provide the receive station with elastic buffer storage facilities (or equivalent) to allow for time delay variations caused by satellite motion. The amount of storage necessary is affected by the satellite's maximum diurnal motion and longitudinal drift. It may be assumed that the maximum delay parameters to be expected from Intelsat satellites will be as shown in Table 3.

4.7 Frequency Planning

Since IBS and VSAT IBS carriers may share transponders with other carriers, e.g. IDR, IBS, etc., earth stations should be designed to receive carriers in the presence of adjacent carriers.

It is recommended that earth stations intended for part–time or occasional use be designed in such a way that changes in the transmit and receive frequencies can be accommodated expeditiously.

Stations equipped with synthesizers should have the capability for transmitting and receiving carriers whose frequency spacings are multiples of 22.5 kHz (for carrier information rates up to and including 8.448 Mbit/s). Actual operating carrier frequencies will be determined in consultation with Intelsat.

4.8 Satellite Channel Group Delay Equalization

The group delay response of the satellite input multiplexer may need to be compensated with equalizers in the earth station transmit chains. Similarly, the response of the satellite output multiplex may need to be compensated in the earth station receive chains. Intelsat will provide information on the amount of parabolic and linear group delay equalization. It is anticipated that equalization of this type will only be required for some IBS carriers with noise bandwidth greater than 10 MHz.

Table 4 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).

4.9 Phase Noise

4.9.1 Earth Station Transmit

The single sideband phase noise on the transmitted carrier shall satisfy either one 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 8. A spurious component at the fundamental AC line frequency shall not exceed –30 dB relative to the level of the transmitted carrier. The single 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 100 Hz to 0.5 R Hz for BPSK and to 0.25 R Hz for QPSK away from the center frequency, where R is the maximum carrier transmission rate in bits per second, shall not exceed 2.2 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.

4.9.2 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 4.9.1 be met.

4.10 Timing, Buffer Capacity and Slip Control

4.10.1 Timing

The timing of the digital signals at the earth station in both directions of transmission is assumed to be derived in one of three ways:

(a) from a national clock with an accuracy of 1 part in 10^{11} as recommended in Rec. ITU–T G.811;

(b) from a local earth station clock with an accuracy of at least 1 in 10^{9} over the 40 day interval between frame slips;

(c) from an incoming clock received from a remote earth station by satellite.

Examples of these methods are shown in Figure 9 and Figure 10 and described in Section 4.10.2. Particular configurations should be determined by bilateral agreement.

The clock accuracy should be maintained such that the slip requirements of Section 4.10.3 are met.

4.10.2 Buffer Capacity

Except in timing category 4.10.1 (a), data buffering is required at the receive earth station to compensate for the effects of satellite movement and, in certain cases, for the disparity between originating and receiving clocks.

The location of the buffer will depend upon the configuration of each channel or circuit and upon the point where transitions from one clock to another occur. The required buffer capacity depends on the sources of timing, the satellite delay variation, the interval between frame slips and the configuration of each particular channel or circuit.

It may be assumed that the maximum delay parameters to be expected from Intelsat satellites will be as shown in Table 3.

Two general categories of circuit configuration have been defined. Corresponding example configurations and applicable buffer sizes for each case are shown in Figure 9 and Figure 10.

Category 1: This category includes any channel where there is a different clock at the transmit and receive ends. The timing signal may be derived from the national digital network or from a local clock.

(a) Where both transmit and receive ends are timed from the national digital network, the buffer capacity should not be less than 2 ms or two frame periods, whichever is greater. This is illustrated by (1) and (4) in Figure 9.

(b) Where either or both ends are timed from the local clock, the buffer capacity should not be less than 16 ms. This is illustrated by (2) in Figure 10.

(c) Where one end is timed from the national digital network and the other end from a local clock, the buffer capacity should not be less than 10 ms, except for a 64 kbit/s channel, where, for slip control reasons 16 ms is required. This is illustrated by (3) in Figure 9.

(d) Where one or both ends are timed from more than one clock, additional buffers may be required. This is illustrated by (5) in Figure 9.

Category 2: This category includes any channel or circuit where the timing at one end of the satellite link is derived from the recovered clock from the demodulator.

(a) Where the channel is in one direction and has no associated return channel, no buffering is required. This is illustrated by (3) and (4) in Figure 10.

(b) A two–way circuit requires buffering at the end of the link from which timing is derived from an external source of capacity no less than 3 ms. This is illustrated by (1) and (2) in Figure 10.

4.10.3 Slip Control

The buffer shall be reset whenever the channel suffers loss of service. It shall also be reset when it reaches saturation or becomes empty.

Any slip, including those caused by resetting the buffer, shall be a multiple of one frame period (as defined in Appendix G, Section G.2) with an accuracy equal to that of the clock used to time the terrestrial side of the buffer. (IBS only). The time interval between frame slips shall be at least 40 days. (IBS only)

5. BASEBAND SUBSYSTEM CHARACTERISTICS

The baseband subsystem characteristics for IBS are defined in Appendix G.

VSAT IBS, which does not employ a transmission level overhead framing structure, should be capable of accommodating a variety of customer interfaces including low–rate synchronous and asynchronous data, high rate synchronous data (n x 64 kbit/s) and frame relay data. Lower rates are available to the customer (i.e., 300, 600 bit/s, 1.2, 2.4, 4.8, 9.6, 48 and 56 kbit/s) but these are multiplexed to form at least a 64 kbit/s carrier prior to transmission through the satellite.

Table 1

IBS PERFORMANCE (Intelsat VI)

	C–Band Uplinks (3)		Ku–Band Uplinks (4)	
Weather Condition	BER	Availability	BER	Availability
Clear Sky:				
– Typical (6)	$< 10^{-8}$	> 95.90	—	—
– Specified	10^{-8}	95.90	10^{-8}	—
Degraded	10^{-6}	99.36	10^{-6}	99.0
Degraded	10^{-3}	99.96	—	—

See Notes on the next page.

Table 2

IBS PERFORMANCE (Intelsat VII, VIIA, VIII & IX)

	C–Band Uplinks (3)		Ku–Band Uplinks (4)	
Weather Condition	BER	Availability	BER	Availability
Clear Sky:				
– Typical (6)	$< 10^{-8}$	> 95.90	$< 10^{-10}$	> 95.90
– Specified	10^{-8}	95.90	10^{-8}	95.90
Degraded	10^{-6}	99.36	10^{-6}	99.36
Degraded	10^{-3}	99.96	10^{-3}	99.96

See Notes on the next page.

NOTES TO TABLES 1 AND 2

(1) These performance values account for propagation–related effects only. They do not include the effect of earth station equipment problems or faulty operation, such as, improper tracking, etc.

(2) Availability = Percentage (%) of the time in one year.

(3) For a complete listing of the up–path and down–path margins used in the reference link budgets for the various beam connections (C–to–C, Ku–to–Ku and cross–strapped), refer to Appendix D.

(4) C–Band Uplinks = 6 to 4 GHz and 6 to 11/12 GHz links.

(5) Ku–Band Uplinks = 14 to 11/12 GHz and 14 to 4 GHz links.

(6) The typical clear–sky performance values shown are based on specified modem performance characteristics and earth station G/T. In practice, the BER performance and availability can be even better, depending on the type of equipment and additional G/T performance selected by the user.

Table 3

TRANSMISSION DELAY VARIATION DUE TO SATELLITE MOTION

Satellite	Maximum Variation (1) (milliseconds)	Maximum Rate of Variations (2) (nanoseconds/second)
Intelsat VI	0.32	10.0
Intelsat VII, VIIA, VIII & IX	0.43	15.4

NOTES:

(1) Maximum = peak–to–peak, uplink plus downlink.

(2) Maximum = uplink plus downlink.

Table 4

EARTH STATION EQUALIZATION REQUIRED FOR SATELLITE GROUP DELAY

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

NOTES:

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

(2) These parameters apply if group delay compensation is provided for 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
REED SOLOMON vs. SEQUENTIAL DECODING PROCESSING DELAY

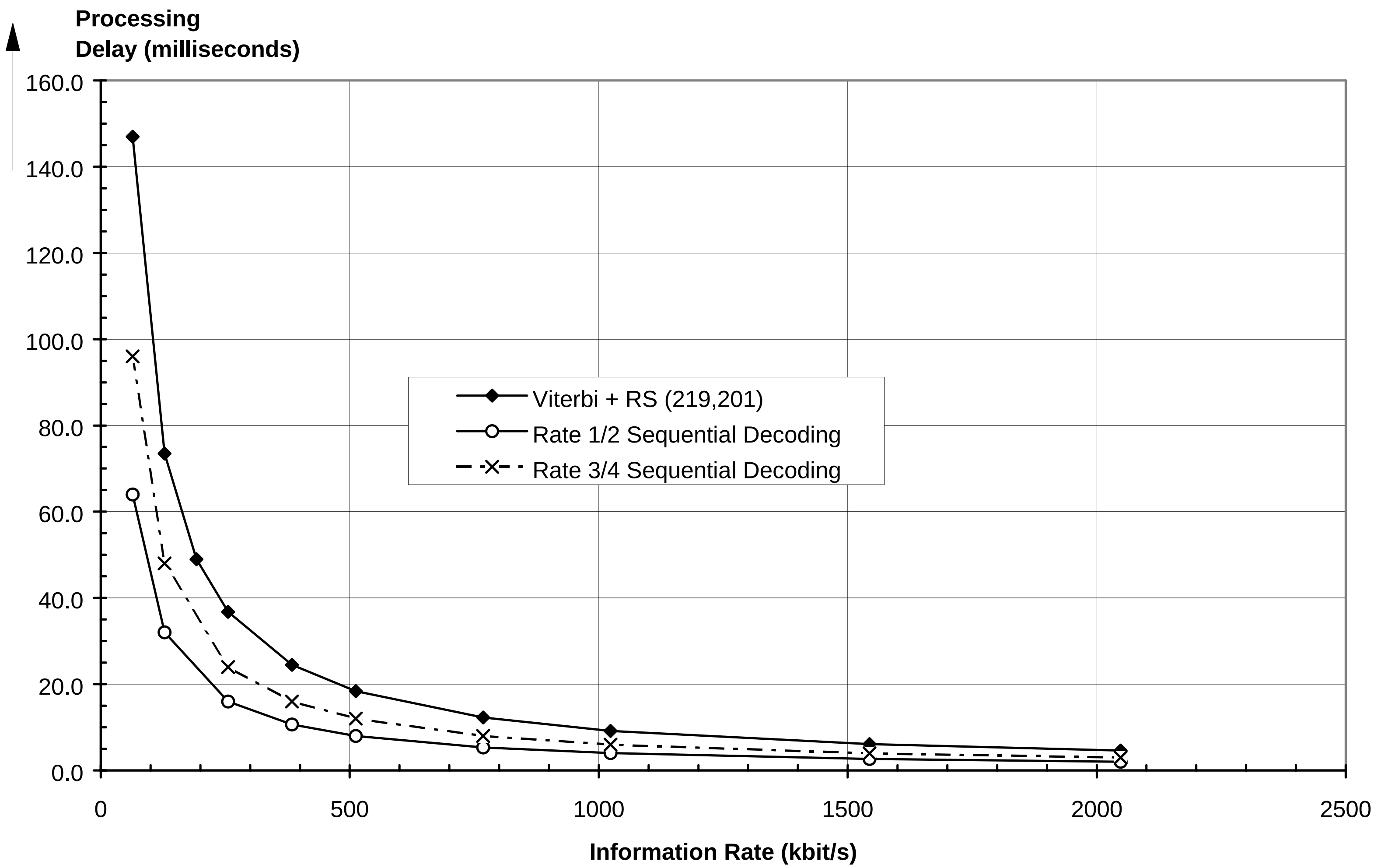
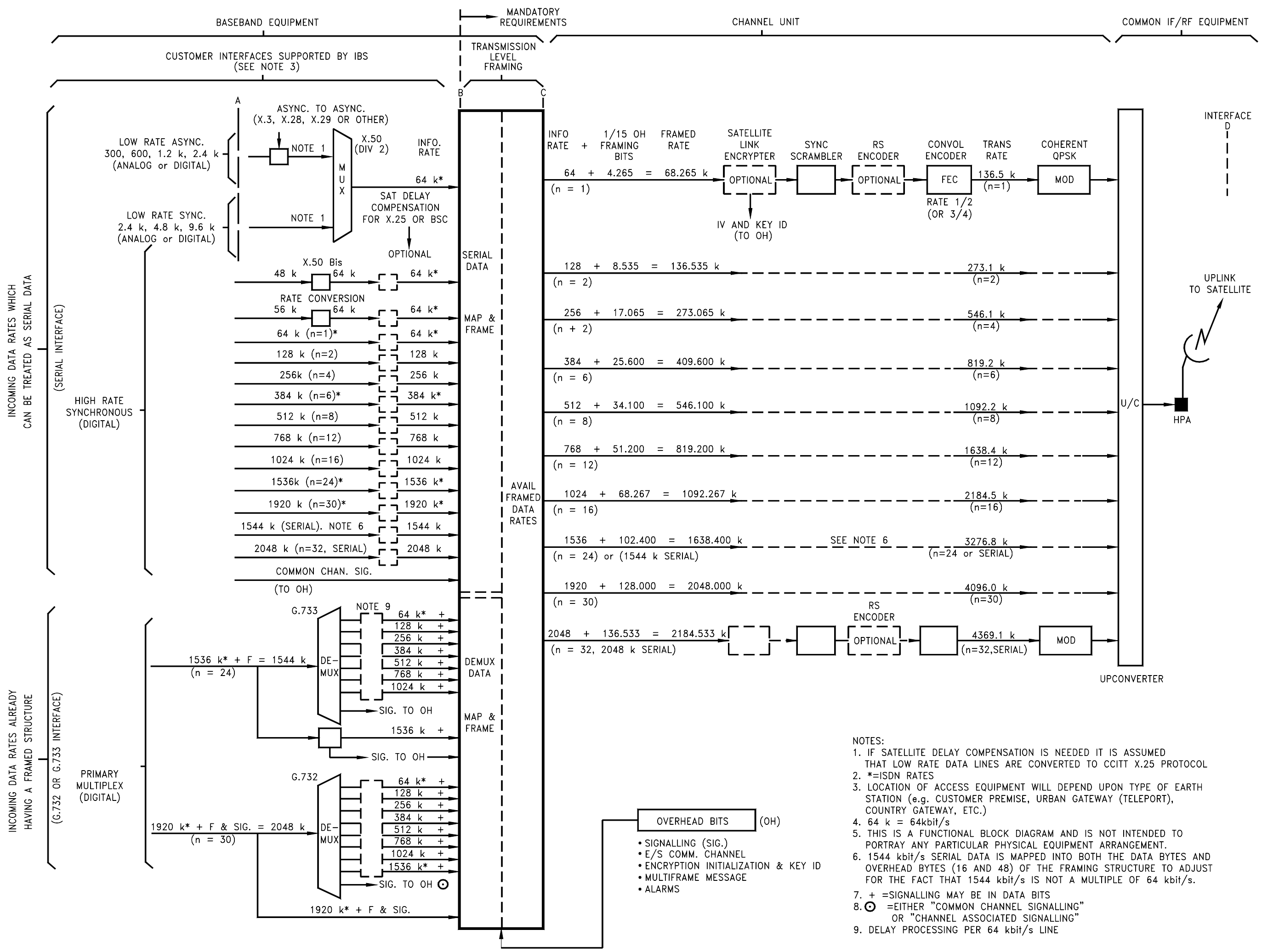


Figure 2
IBS FUNCTIONAL BLOCK DIAGRAM - TRANSMIT SIDE



NOTES:
1. IF SATELLITE DELAY COMPENSATION IS NEEDED IT IS ASSUMED THAT LOW RATE DATA LINES ARE CONVERTED TO CCITT X.25 PROTOCOL
2. *=ISDN RATES
3. LOCATION OF ACCESS EQUIPMENT WILL DEPEND UPON TYPE OF EARTH STATION (e.g. CUSTOMER PREMISE, URBAN GATEWAY (TELEPORT), COUNTRY GATEWAY, ETC.)
4. 64 k = 64kbit/s
5. THIS IS A FUNCTIONAL BLOCK DIAGRAM AND IS NOT INTENDED TO PORTRAY ANY PARTICULAR PHYSICAL EQUIPMENT ARRANGEMENT.
6. 1544 kbit/s SERIAL DATA IS MAPPED INTO BOTH THE DATA BYTES AND OVERHEAD BYTES (16 AND 48) OF THE FRAMING STRUCTURE TO ADJUST FOR THE FACT THAT 1544 kbit/s IS NOT A MULTIPLE OF 64 kbit/s.
7. + =SIGNALLING MAY BE IN DATA BITS
8. ⊙ =EITHER "COMMON CHANNEL SIGNALLING" OR "CHANNEL ASSOCIATED SIGNALLING"
9. DELAY PROCESSING PER 64 kbit/s LINE

IBS FUNCTIONAL BLOCK DIAGRAM — TRANSMIT SIDE

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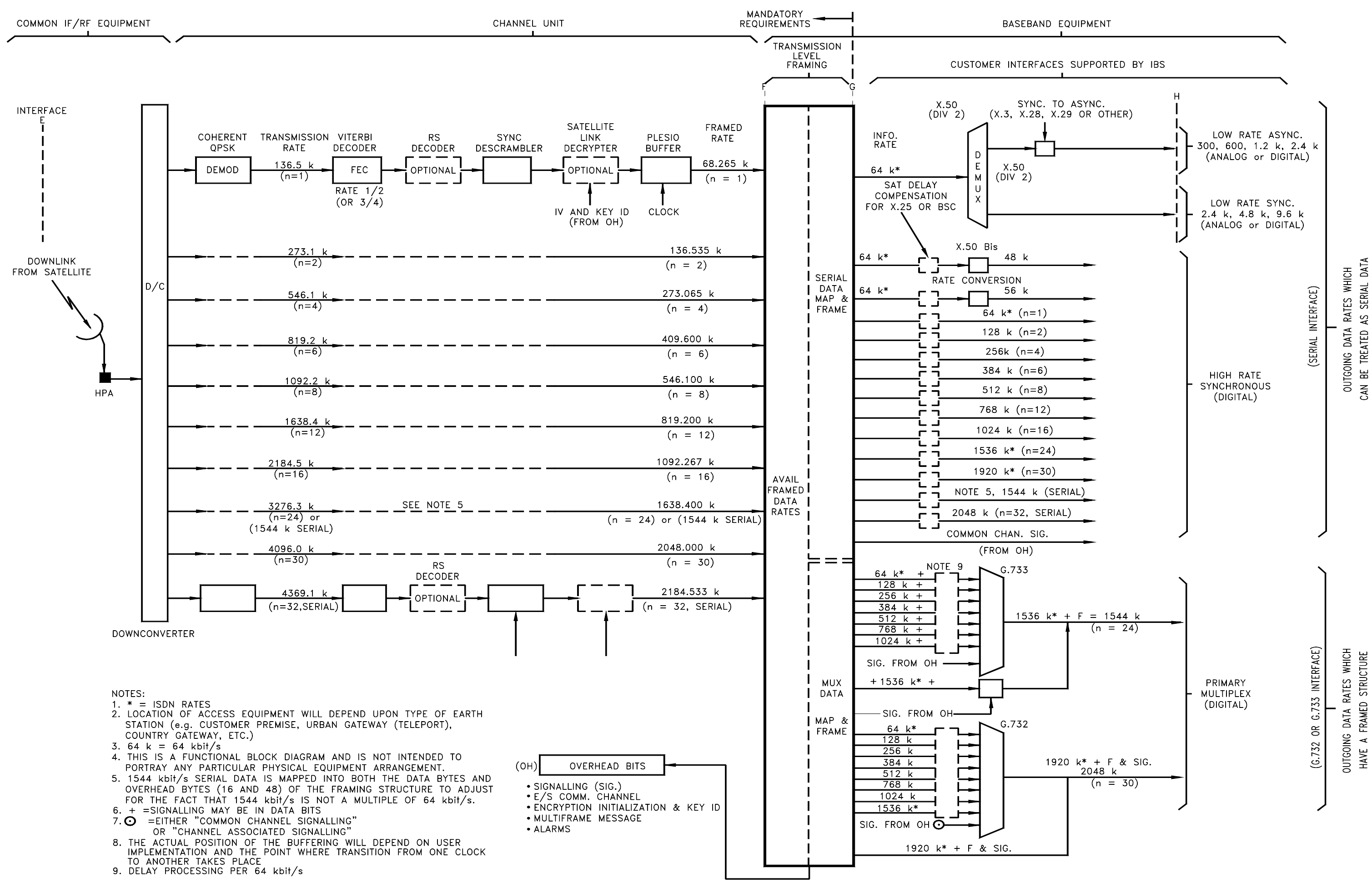
Figure 3
IBS FUNCTIONAL BLOCK DIAGRAM - RECEIVE SIDE



IBS FUNCTIONAL BLOCK DIAGRAM — RECEIVE SIDE

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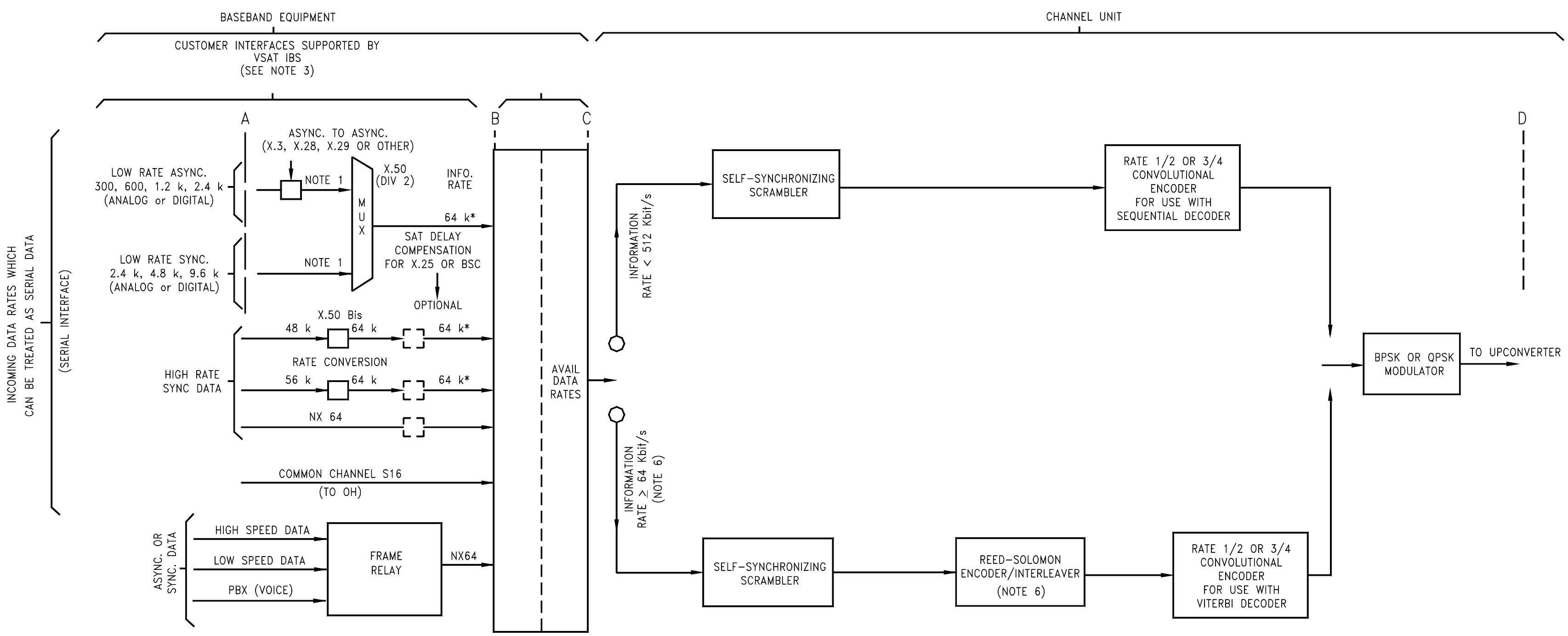
Figure 4
VSAT IBS FUNCTIONAL BLOCK DIAGRAM - TRANSMIT SIDE



NOTES:
1. IF SATELLITE DELAY COMPENSATION IS NEEDED IT IS ASSUMED THAT LOW RATE DATA LINES ARE CONVERTED TO CCITT X.25 PROTOCOL
2. *=ISDN RATES
3. LOCATION OF ACCESS EQUIPMENT WILL DEPEND UPON TYPE OF EARTH STATION (e.g. CUSTOMER PREMISE, URBAN GATEWAY (TELEPORT), COUNTRY GATEWAY, ETC.)
4. 64 k = 64 kbit/s
5. THIS IS A FUNCTIONAL BLOCK DIAGRAM AND IS NOT INTENDED TO PORTRAY ANY PARTICULAR PHYSICAL EQUIPMENT ARRANGEMENT.
6. USE OF RS OUTER CODING FOR INFO. RATES < 512 kbit/s MAY RESULT IN EXCESSIVE DELAYS

VSAT IBS FUNCTIONAL BLOCK DIAGRAM — TRANSMIT SIDE

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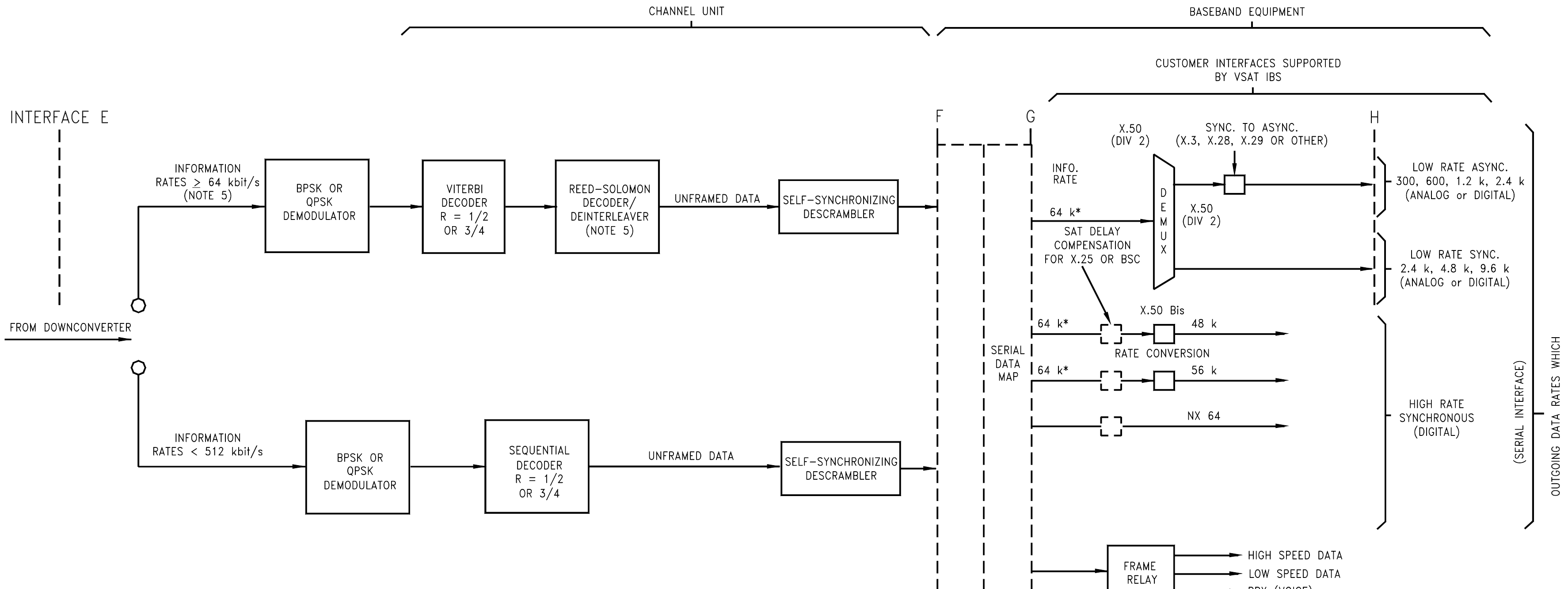
Figure 5

VSAT IBS FUNCTIONAL BLOCK DIAGRAM - RECEIVE SIDE



NOTES:
1. * = ISDN RATES
2. LOCATION OF ACCESS EQUIPMENT WILL DEPEND UPON TYPE OF EARTH STATION (e.g. CUSTOMER PREMISE, URBAN GATEWAY (TELEPORT), COUNTRY GATEWAY, ETC.)
3. 64 k = 64 kbit/s
4. THIS IS A FUNCTIONAL BLOCK DIAGRAM AND IS NOT INTENDED TO PORTRAY ANY PARTICULAR PHYSICAL EQUIPMENT ARRANGEMENT.
5. USE OF RS OUTER CODING FOR INFO. RATES < 512 kbit/s MAY RESULT IN EXCESSIVE DELAYS

VSAT IBS FUNCTIONAL BLOCK DIAGRAM – RECEIVE SIDE

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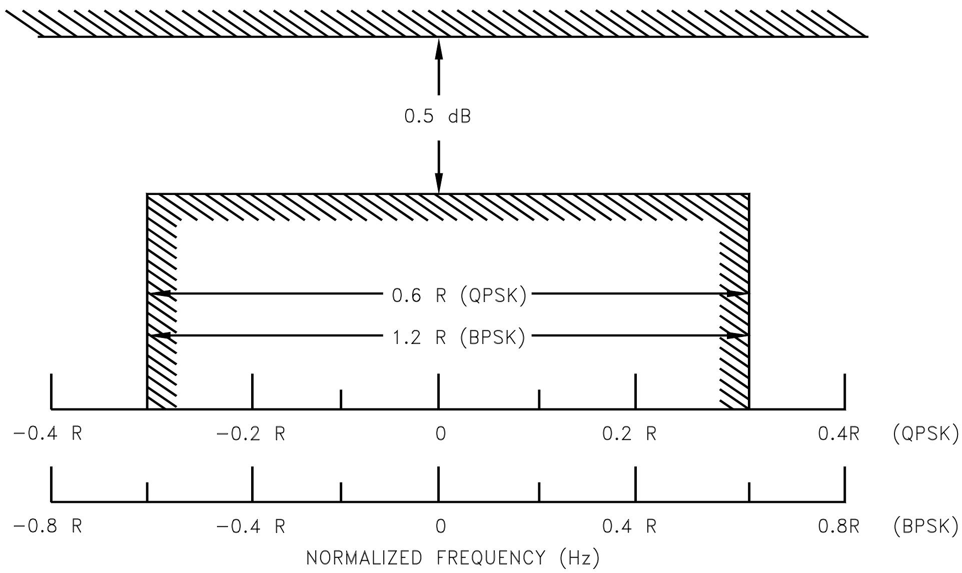
Figure 6

EARTH STATION IF AND RF AMPLITUDE RESPONSE

*



EARTH STATION IF AND RF AMPLITUDE RESPONSE

R = TRANSMISSION RATE IN BITS PER SECOND

* THE AMPLITUDE RESPONSE IS MANDATORY ONLY FOR THE TRANSMIT CHAIN.

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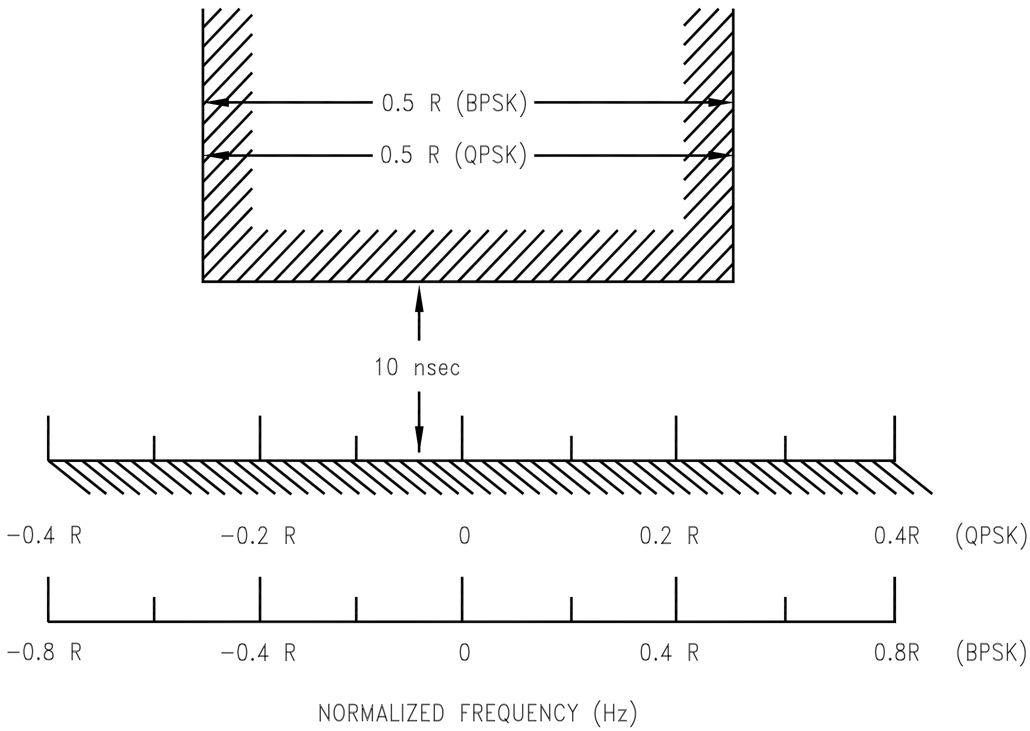
Figure 7

EARTH STATION IF AND RF GROUP DELAY RESPONSE

*



R = TRANSMISSION RATE IN BITS PER SECOND

* THE AMPLITUDE RESPONSE IS MANDATORY ONLY FOR THE TRANSMIT CHAIN.

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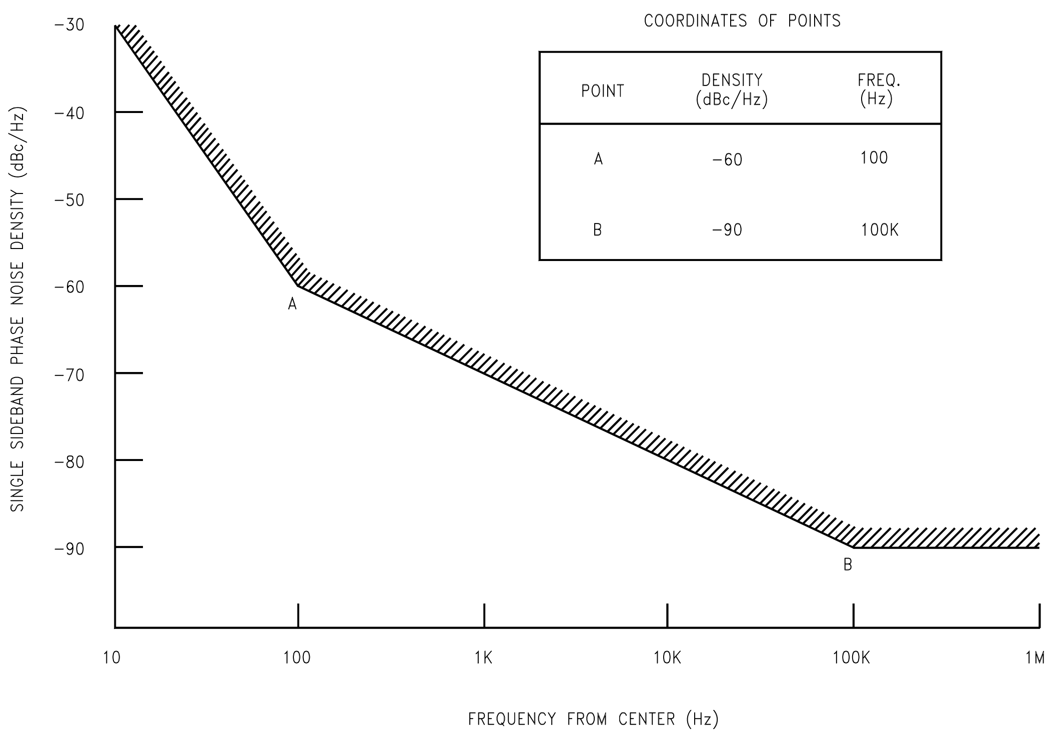
Figure 8

TRANSMIT EARTH STATION CONTINUOUS
SINGLE SIDEBAND PHASE NOISE REQUIREMENT



CONTINUOUS SINGLE SIDEBAND PHASE NOISE REQUIREMENT

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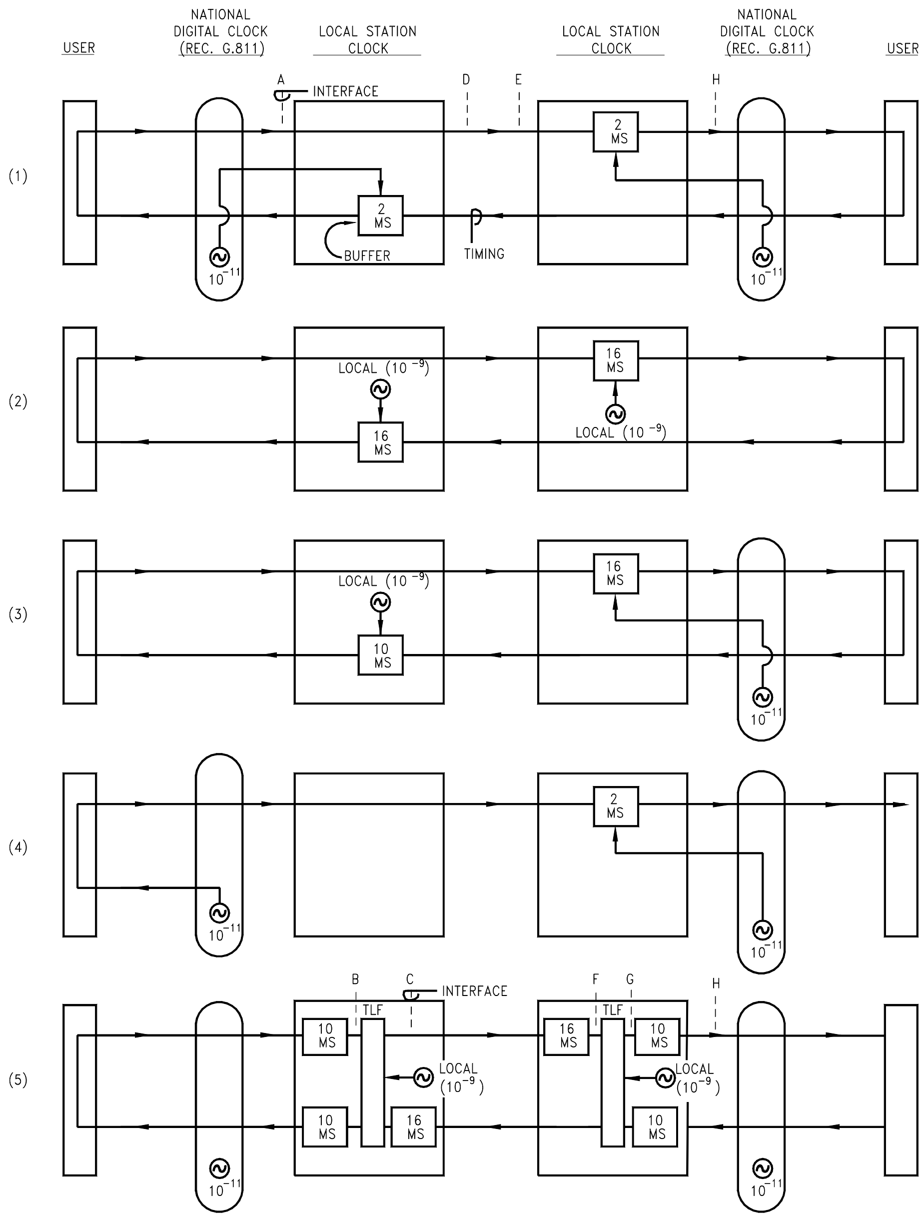
Figure 9
EXAMPLE TIMING & BUFFERING - CATEGORY 1



NOTE: LOCAL CLOCK ACCURACY OF 10^{-9} IS TAKEN TO BE OVER THE MINIMUM TIME INTERVAL BETWEEN FRAME SLIP (i.e., 40 DAYS). THIS MEANS THAT OVER A PERIOD OF ONE YEAR A LOWER LOCAL CLOCK ACCURACY COULD BE SUFFICIENT (e.g., 10^{-8})

EXAMPLES OF TIMING & BUFFERING – CATEGORY 1
(DIFFERENT CLOCK AT EACH END OF THE LINK)

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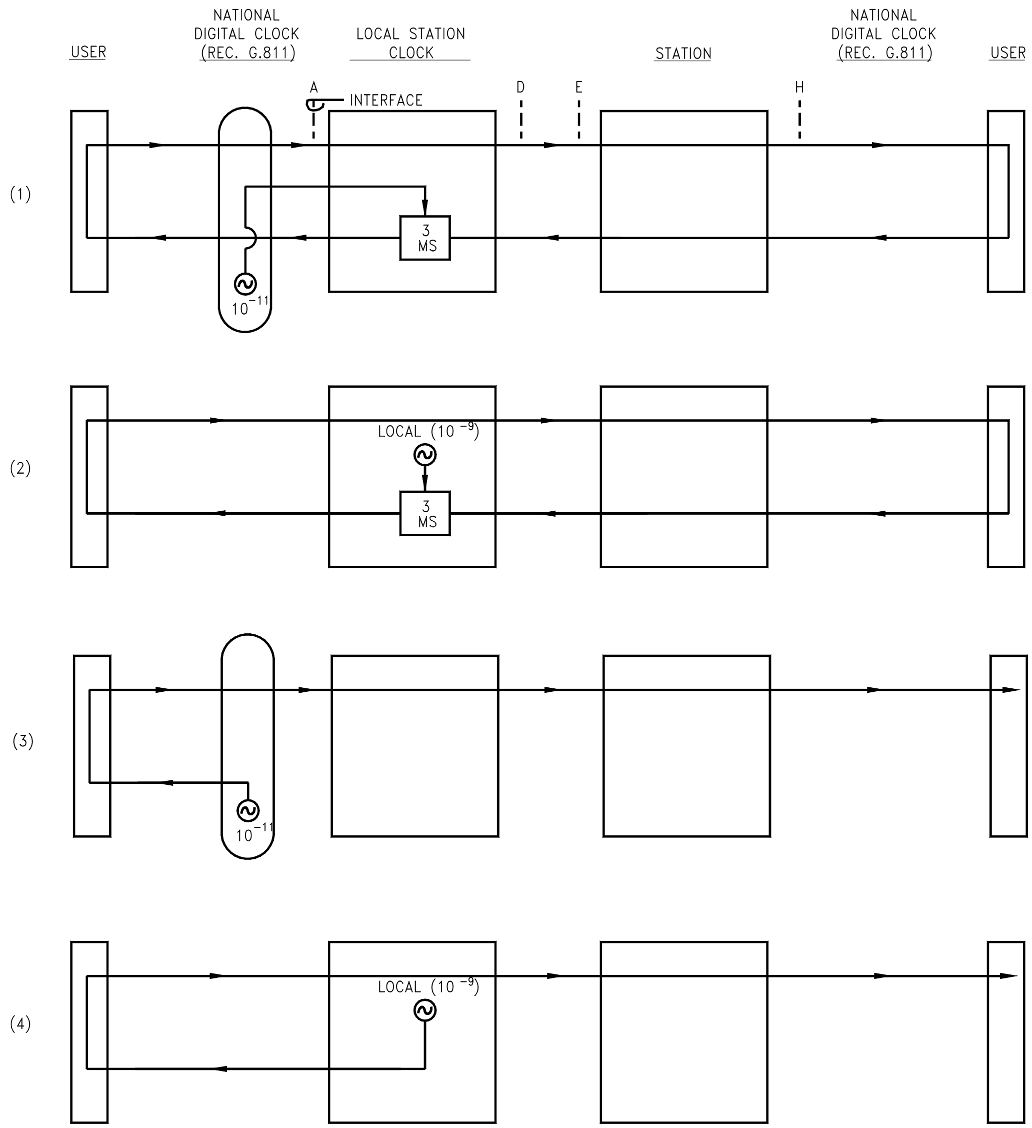
Figure 10
EXAMPLE TIMING & BUFFERING - CATEGORY 2



NOTE: TIMING AT ONE END DERIVED FROM THE RECOVERED CLOCK FROM THE DEMODULATOR

EXAMPLE TIMING & BUFFERING – CATEGORY 2
(ONE END OF THE LINK REMOTELY TIMED FROM OTHER END)

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