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INTELSAT EARTH STATION STANDARDS (IESS)

Document IESS–308 (Rev. 11)

PERFORMANCE CHARACTERISTICS FOR INTERMEDIATE DATA RATE DIGITAL CARRIERS USING CONVOLUTIONAL ENCODING/VITERBI ENCODING AND QPSK MODULATION
(QPSK/IDR)

(Standard A, B, C, E and F Earth Stations)

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INTELSAT EARTH STATION STANDARDS (IESS)

PERFORMANCE CHARACTERISTICS FOR INTERMEDIATE DATA RATE DIGITAL CARRIERS USING CONVOLUTIONAL ENCODING / VITERBI DECODING AND QPSK MODULATION (QPSK/IDR)

1. INTRODUCTION

This document provides the performance characteristics of intermediate data rate digital carriers which use convolutional encoding/Viterbi decoding and QPSK modulation (i.e., QPSK/IDR) operation with Standard A, B, C, E–3, E–2, F–3 and F–2 earth stations. Standards E–1 and F–1 earth stations are also included, but only for Intelsat VII, VIIA, VIII and IX.

2. QPSK/IDR DIGITAL CARRIER SYSTEM REQUIREMENTS, GENERAL

QPSK/IDR digital carriers in the Intelsat system utilize coherent QPSK modulation operating at information rates ranging from 64 kbit/s to 44.736 Mbit/s. The information rate is defined as the bit rate entering the channel unit, prior to the application of any overhead or forward error correction (FEC). (See Section 9.3 for FEC requirements.)

Any information rate from 64 kbit/s to 44.736 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 shown in Table 1.

For certain information rates, namely, 1.544, 2.048, 6.312, 8.448, 32.064, 34.368 and 44.736 Mbit/s, an overhead structure has also been defined to optionally provide engineering voice/data orderwire channels and maintenance alarms*. This overhead increases the data rate of these carrier sizes by 96 kbit/s. The overhead adds its own frame alignment signal and thus passes the information data stream transparently.

The noise bandwidth for QPSK/IDR carriers is equal to 0.5 times the transmission rate†. To provide guardband between adjacent carriers, the

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* Since the Intelsat Engineering Service Circuit (ESC) network no longer exists (IESS–403 has been retired), providing the 96 kbit/s overhead on QPSK/IDR carriers for engineering orderwire channels and maintenance alarms features is now optional. Its usage should be mutually agreed upon between users.

† The transmission rate (R) is defined as the bit rate entering the QPSK modulator at the earth station (i.e., after the addition of any overhead or forward error correction (FEC) coding) and is equal to twice the symbol rate at the output of the QPSK modulator. Figure 1 is a block diagram of the channel unit and illustrates the definitions of information rate, transmission rate and symbol rate.

allocated satellite bandwidth is equal to 0.7 times the transmission rate. The actual carrier spacing may be larger and will be determined by Intelsat, based on the particular transponder frequency plan. In particular, for the case of two 45 Mbit/s Rate 3/4 FEC QPSK/IDR carriers within a 72 MHz C–Band transponder, the allocated RF bandwidth will be 36 MHz for each carrier.

IF equipment should be configured for maximum flexibility since changes in service patterns may require the relocation of carriers. Stations equipped with frequency 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, and can be accommodated as low as 2.048 Mbit/s. Actual operating carrier frequencies will be determined in consultation with Intelsat.

2.1 QPSK/IDR Performance

QPSK/IDR carriers have been designed to provide a service in accordance with Recommendations ITU–R S.522–4, ITU–RS.614–2, ITU–R S.1062* and ITU–R S.579–2. To achieve these requirements, Intelsat will provide the performance described below.

2.1.1 Intelsat VI

For Intelsat VI, the BER performance is shown in Table 2. Depending on the transponder resources available and subject to any uplink EIRP constraints, a BER performance will be provided with a quality range between G.826 (equivalent to that offered on Intelsat VII, VIIA, VIII and IX) and G.821 (equivalent to that presently specified in Table 2).

2.1.1.1 TCM/IDR Operation on INTELSAT VI

Users may employ TCM/IDR on Intelsat VI and will be assigned space segment EIRP resources identical to those currently used for QPSK/IDR. The earth station maximum EIRP requirements for TCM/IDR on Intelsat VI are the same as those for QPSK/IDR, which are provided in Appendix C of this module. The allocated RF carrier bandwidths for TCM/IDR carriers are defined in Table 2 of Appendix C to IESS–310. The performance of such carriers will not be sufficient to meet the G.826 Plus performance level defined for TCM/IDR carriers on Intelsat VII, VIIA, VIII and IX. The service quality of TCM/IDR on Intelsat VI will, with most commercial modems, meet the performance objectives of ITU-T Rec. G.821 shown in Table 2. The resultant clear–sky BER performance for TCM/IDR carriers on Intelsat VI will be superior to that achieved today with QPSK/IDR.

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* Recommendation ITU–R S.1062 has been developed by the ITU Radiocommunication Sector for satellite links, operating at or above the primary rate, which are designed to meet Rec. ITU–T G.826.

2.1.2 Intelsat VII, VIIA, VIII and IX

For Intelsat VII, VIIA, VIII and IX, which have enhanced satellite performance compared to previous Intelsat spacecraft, a greater margin has been added to provide a more robust level of performance that is designed to meet the requirements of Note 1 of Recommends 3 of Rec. ITU–R S.1062 (Table 3). If the performance defined in Note 2 of Recommends 3 of Rec. ITU–R S.1062 (see Table 4) is desired, users must either:

(a) employ Reed–Solomon outer coding, as defined in Appendix H

or,

(b) provide earth station equipment that exceed the minimum IESS performance requirements (e.g., larger G/T, better modems), as discussed in Appendix I.

Neither of these options requires additional satellite EIRP or bandwidth resources.

2.1.3 Additional G/T Requirement For Ku–Band QPSK/IDR Services Operating Under Adverse Local Weather Conditions

To ensure the best utilization of the space segment, the aim is to achieve an earth station gain–to–noise temperature ratio (G/T) that is sufficient to ensure that applicable performance criteria are met. During adverse climatic conditions, such as rain, snow, strong winds, etc., the nominal channel performance will not necessarily be met. The percentage of time during which these values will be exceeded will depend, *inter alia*, upon the statistics of the local weather, antenna performance characteristics and the relationship between the weather parameters and channel performance.

This requires a consideration of the long–term rainfall data and associated attenuation and sky noise temperature data at each earth station. Due to the format in which propagation information is available, it is more convenient to express the monthly channel performance criteria in terms of percentage–of–a–year relationships which are chosen to be equivalent to the ITU–R values.

Channel performance criteria are associated with clear–sky performance requirements and degraded performance requirements for a small percentage of the time in a year.

For each Ku–band Spot beam, Intelsat has developed a maximum downlink degradation margin* taking into consideration the rain statistics and elevation angles typical of earth stations operating in the particular beam coverage area. These margins are the maximum that will be provided by Intelsat. The actual margins provided on a particular transmission path will be determined by

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* 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.

Intelsat, taking into consideration the rain statistics of the uplink and downlink transmission path and the performance objectives of Section 2.1.

Within a given beam coverage area, the rain statistics of a particular earth station may be more severe than the maximum provided margins. Users operating with such earth stations will need to provide improved RF performance in the form of a G/T exceeding the minimum required.

The additional G/T requirement for operation under degraded weather conditions is determined after reviewing local yearly rain statistics and comparing them against the reference downlink degradation margins given in Appendices C through G*. If the local weather statistics show that the downlink degradation will exceed these values, then the required G/T of that earth station is determined according to the equations below:

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

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

Where: G is the receiving antenna gain referred to the input of the low–noise amplifier relative to an isotropic radiator; T is the receiving system noise temperature referred to the input of the low–noise amplifier relative to 1 kelvin; f is the frequency in GHz; and X is the excess of the downlink degradation predicted by local rain statistics over the reference downlink degradation margin from the tables in Appendices C through G for the same percentage of time. (See Appendix J for the method for calculating X.)

3. EQUIVALENT ISOTROPICALLY RADIATED POWER (EIRP)

The maximum 6 GHz and 14 GHz EIRPs and associated transmission parameters and margins are specified in the Appendices. The actual operating EIRPs will be equal to or less than the maximum values listed in these Appendices, taking into account the adjustments described in Sections 3.1 and 3.2.

3.1 EIRP Correction Factors

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

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* See Appendices C, D, E, F and G for the reference downlink degradation margins applicable to Intelsat VI, VII, VIIA, VIII and IX, respectively.

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 operation 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 Appendices C through G (except when uplink power control is used at 14 GHz).

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 for adjusting the EIRP over a range of 15 dB below the mandatory maximum value shall be provided. 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 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 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 C stations) and to within ± 1.5 dB (for Standard E–3, E–2, E–1, F–3, F–2 and F–1 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 (RSS) basis.

3.3.2 Adverse Weather Conditions

(a) 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 degraded channel performance at cooperating receiving earth stations.

(b) At 14 GHz

At 14 GHz, in order to meet the short–term ITU–R performance criterion, it is mandatory that 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 Appendices C through G.

It is the user's responsibility to decide if the above requirement should be met by providing diversity earth stations or uplink power control. If provided by the latter method, it is recommended that when the up–path excess attenuation is greater than 1.5 dB, control of the transmitter power should be applied to restore the power flux density at the satellite to within –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.

For users who are able to view their own carriers on a loopback from the satellite, closed–loop uplink power control can be utilized to control the carrier flux density impinging on the satellite under uplink or downlink fade conditions. For those who are unable to view their own transmissions, open–loop* uplink control 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 description in IESS–400 series modules provides additional beacon information.

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* The term "open–loop" refers to uplink power control systems which derive the excess uplink path attenuation experienced by a given carrier by measurement of the downlink power of another carrier (such as, the spacecraft beacon).

3.4 Transponder Gain Step

(a) Intelsat VI

In 1986, smaller Standard A and C antennas were introduced into the Intelsat network with the expectation that the system would transition over the ensuing years to a growing percentage of antennas designed to these new standards. During this time frame, it will be necessary to gradually switch some satellite transponders from the low–gain mode of operation, to the high–gain mode in order to keep uplink EIRP requirements as low as possible. For this reason, two sets of EIRP tables have been prepared for Appendix C, one for the low and one for the high, with the understanding that users will work with Intelsat in planning their earth station design and thus determining the appropriate EIRP tables to be employed.

(b) Intelsat VII, VIIA, VIII and IX

The saturation flux density of the Intelsat VII, VIIA, VIII and IX transponders may be adjusted by varying the gain of the transponder. For Intelsat VII and VIIA, there are fifteen (15) step increments (approximately 1 dB per step) while, for Intelsat VIII and IX, there are twelve (12) step increments (approximately 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 and 14,000 to 14,500 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 QPSK/IDR carriers are not activated (carrier “off”) shall not exceed 4 dBW/4 kHz anywhere within the following frequency ranges:

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

Those spurious products (excluding the multicarrier intermodulation products and spectral spreading due to earth station nonlinearities) that are generated whenever the QPSK/IDR 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). A separate module has been prepared because the intermodulation products can be formed by the combination of carriers from the various modulation techniques used in the Intelsat system.

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. In the case of Standard C and E stations, this 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 which may experience re-growth due to earth station nonlinearities. The EIRP density in the frequency range from 0.35 R to 0.5 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 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.

4.2.1 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.

4.2.2 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 given in Section 9.2.1 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 VI, VII, VIIA, VIII and IX 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 (see Section 9.1.2).

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, the group delay response of the satellite input and output multiplexers may need to be compensated with equalizers in the earth station transmit chains. These equalizers should be separate from those referred to in Section 6.1.

Intelsat will provide information on the amount of parabolic and linear group delay equalization. However, transmit earth stations shall be equipped for the limits shown in Table 5 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 QPSK/IDR carriers with noise bandwidths greater than 10 MHz.

Table 5 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 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 0.25 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 met also for receive earth stations.

8. TRANSMISSION PERFORMANCE

Parameters for Intelsat's recommended information rates are provided in Appendices C (Intelsat VI), D (Intelsat VII), E (Intelsat VIIA), F (Intelsat VIII) and G (Intelsat IX).

9. CHANNEL UNIT CHARACTERISTICS

The channel unit consists of the following:

(1) modulator/demodulator (modem)

(2) FEC encoder/decoder (codec)

(3) Scrambler / descrambler

(4) optional* overhead framing unit (for information rates ≥ 1.544 Mbit/s)

(5) optional Reed–Solomon outer encoder/decoder.

The channel unit shall utilize coherent QPSK modulation along with Rate 3/4 FEC (see Section 9.3 regarding the use of FEC and Appendix H for the use of the optional Reed–Solomon outer coding). The FEC shall be convolutional encoding with Viterbi decoding. Data rates at the input to the FEC encoder range from 64 kbit/s to 44.736 Mbit/s.

For certain information rates (i.e., 1.544, 2.048, 6.312, 8.448, 32.064, 34.368, and 44.736 Mbit/s), an overhead framing structure has also been defined for optionally providing Engineering Service Circuits (ESC) and maintenance alarms. The overhead data rate is 96 kbit/s. These same carrier sizes have characteristics identified for multi–destinational applications (Section 11.3).

9.1 Modulator

For reference purposes, it is assumed that the modulator accepts two parallel data streams from the FEC encoder, designated the P channel and the Q channel.

9.1.1 Output Characteristics

The relationship between the bits to be transmitted and the carrier phase of the modulator output is given below:

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* Since the Intelsat Engineering Service Circuit (ESC) network no longer exists (IESS–403 has been retired), providing the 96 kbit/s overhead on QPSK/IDR carriers for engineering orderwire channels and maintenance alarms features is now optional. Its usage should be mutually agreed upon between users.

TRANSMITTED BITS		RESULTANT PHASE
P CHANNEL	Q CHANNEL	
1	1	0°
0	1	+ 90°
0	0	+ 180°
1	0	+ 270° (–90°)

The phase accuracy at the modulator output shall be ± 2°. The amplitude accuracy at the modulator output shall be ± 0.2 dB.

The above specification has been written in terms of absolute phase encoding rather than differential encoding because carrier phase ambiguities are resolved by means of the FEC coding, as discussed in Section 9.3.

9.1.2 Modulator Spectrum Output

The transmitted IF spectrum within the frequency range ± 0.35 R Hz from the nominal center frequency shall be equivalent to a spectrum present at the output of a filter following an ideal modulator, under the following conditions:

(a) The input to the QPSK ideal modulator is a R bit/s non–return–to–zero (NRZ) random sequence (with equal probability of 0 or 1);

(b) The filter has amplitude characteristics given in Figure 5;

(c) The filter has group delay characteristics given in Figure 7 or a phase response with less than ± 4 degrees departure from a linear phase shift over the frequency range ± 0.25 R about the nominal center frequency.

Within the bandwidth 0.35 R to 0.75 R Hz away from the nominal center frequency, the envelope of the transmitted IF spectrum shall not exceed that obtained at the output of a filter following an ideal modulator, under the conditions given in (a), (b) and (c) above. Outside the bandwidth ± 0.75 R Hz from the nominal center frequency, the transmitted IF spectral density shall be at least 40 dB below the peak spectral density, measured in a 4 kHz band.

Over the frequency range ± 0.35 R Hz from the nominal center frequency (b) and (c) above are met by a filter consisting of the cascade of a group delay equalized 6–pole Butterworth filter (BT_s = 1.0) and sinc^{-1} compensation (the overall BT_s of cascaded elements is equal to 1.5), where:

$$\text{sinc}^{-1} = \frac{\pi \, \Delta f \, T_S}{\sin\left(\pi \, \Delta f \, T_S\right)}$$

and: B = 3 dB double–sided bandwidth of filter

T_s = Symbol period = 2/R

Δf	=	Displacement from center frequency
R	=	Transmission rate in bits per second.

It should be noted that the transmitted IF spectrum requirement is mandatory, not the modulator filter response.

A mask of the power spectral density, which will result from a modulator meeting the amplitude characteristics outlined above, is shown in Figure 8.

9.2 Demodulator

A coherent QPSK demodulator shall be used. Bit timing shall be recovered and presented to the FEC decoder. The demodulator shall provide an output that is compatible with the soft–decision decoder (see Section 9.3.2).

9.2.1 Operating Conditions

The channel unit shall meet the performance requirements of Section 9.5 in the presence of adjacent channel interferers and when both the desired carrier and interfering carriers are subject to a common carrier frequency drift of ± 25 kHz. This includes the frequency tolerance of all elements, including the earth station transmitter, the satellite local oscillator, Doppler shift and the earth station receive chain. For the purpose of demonstrating compliance with this requirement, the adjacent channel interferers shall be assumed to operate at the same transmission rate as the desired carrier, at nominal center frequencies of ± 0.7 R Hz about the desired carrier and at a level + 7 dB higher than the desired carrier.

If the AFC function is performed in the downconverter, then the downconverter is considered to be part of the channel unit for the purpose of meeting this performance requirement.

9.2.2 Demodulator Filter Characteristics

For the development of BER requirements, the amplitude characteristics for the demodulator receive filter have been assumed as given in Figure 6. The group delay characteristics have been assumed as given in Figure 7.

The demodulator receive filter characteristics are nominally equivalent to a group delay equalized 6–pole Butterworth filter ($BT_s = 1.0$).

9.3 Forward–Error–Correction

Rate 3/4 convolutional encoding with Viterbi decoding shall be employed by all QPSK/IDR carriers.

The function of the data codecs is threefold:

1) to generate appropriate coding bits and to interface with the modulator;

2) to accept the demodulated signal and to recover correct code synchronization and correct carrier phase; and

3) in conjunction with the demodulator to make use of the code for reliable decisions about the transmitted sequence of data bits.

For QPSK/IDR carriers above 10 Mbit/s, there is a need to parallel 3 (three) encoders and decoders to operate up to 45 Mbit/s. The method for paralleling encoders and decoders is presented in Figure 9. To avoid an increase in the number of ambiguities, the serial to parallel (S/P) conversions are performed separately on the P and Q Channels on the satellite side of the encoders and decoders. The serial–to–parallel (S/P) converters of the encoders and decoders do not need to be synchronized. The signal format at the output of the encoders is shown in Figure 9.

9.3.1 Encoder

The Rate 3/4 convolutional encoder, as shown in the functional diagram of Figure 10, shall be employed. This is a “punctured” type of convolutional code and is constructed from a Rate 1/2 encoder by periodically deleting specific bits from the Rate 1/2 output bit sequence. The code has a memory of six that, together with the incoming data bit, forms a constraint length of seven.

The encoder consists of a binary differential encoder followed by a 7–stage shift register with the outputs of selected stages being added modulo–2 to form the Rate 1/2–encoded data. The code generator polynomials of the Rate 1/2 code are 133 and 171 in octal notation. Since the code is transparent to 180º carrier phase ambiguities, the incoming data stream is differentially encoded before encoding by the Rate 1/2 convolutional encoder.

The Rate 3/4 code is constructed by periodically deleting two specified bits from among six bits contained in three consecutive blocks of the original Rate 1/2 code. The bit deletion is performed in the following manner:

(a) In the first block, both coded bits are transmitted;

(b) In the second block, the bit generated by generator polynomial 133 is transmitted and the bit generated by generator polynomial 171 is deleted;

(c) In the third block, the bit generated by generator polynomial 133 is deleted, and the bit generated by generator polynomial 171 is transmitted.

For carriers having information rates greater than 10 Mbit/s, three encoders shall be paralleled as shown in Figure 9.

9.3.2 Decoder

The decoding is performed by first re–constructing the Rate 1/2 coded data by inserting “erasure” bits into the received data stream at the positions in which the original Rate 1/2 coded bits were deleted on the transmitting side. The re–constructed Rate 1/2 coded data is then decoded by a soft–decision Viterbi (maximum likelihood) decoder.

The decoder shall have the following characteristics:

- The coding gain shall be compatible with the required E_b/N_o. For this type of decoder, 3 bit (8 level) quantization may be required as an input, and hence the demodulator would provide such an interface.

- Internal resolution of 90° carrier phase ambiguity and code synchronization shall be provided.

- Binary differential decoding of the serial output data stream shall be provided.

- It is recommended that an indication of the rate of error correction be provided for monitoring the performance of the carrier.

- The decoder shall be able to operate with the signal format shown in Figure 9. This implies that it will be necessary to operate the decoders in parallel, as shown in Figure 9.

9.3.3 Reed–Solomon Outer Coding (Optional)

As an option, users may wish to enhance the BER performance of QPSK/IDR links under certain operational conditions by concatenating an outer Reed–Solomon code with the existing inner FEC.

The performance characteristics and operational requirements for employing this Reed–Solomon outer coding are defined in Appendix H.

9.4 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 scrambler shall have a logic diagram equivalent to that shown in Figure 24, and the descrambler shall have the impulse response shown in Figure 25. It should be noted that this is a self–synchronizing scrambler and that a single error in the received data stream can produce 3 errors over an interval of 20 bits. For this reason the FEC encoder shall follow the scrambler at the transmit earth station. At the receive earth station, the descrambler shall follow the decoder.

9.5 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 and with forward error correction coding, and under the conditions outlined in Section 9.2.1.

BER better than:	Composite Data Rate E_b/N_o (dB) (Rate 3/4 FEC)
10^{-3}	5.3
10^{-6}	7.6
10^{-7}	8.3
10^{-8}	8.8
10^{-10}	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.

9.6 Overhead Framing for Orderwire and Alarms (Optional)

An overhead framing structure has been defined for certain QPSK/IDR carrier sizes (1.544, 2.048, 6.312, 8.448, 32.064, 34.368, and 44.736 Mbit/s) to facilitate the optional provision of orderwire channels and maintenance alarms*. The information data stream is passed transparently by the overhead unit and, therefore, no knowledge of the framing imbedded within the information stream is assumed or required.

The overhead framing structure described in Section 9.6.1 may be optionally employed by QPSK/IDR carriers having information rates of 1.544, 2.048, 6.312, 8.448, 32.064, 34.368 and 44.736 Mbit/s. Other QPSK/IDR carrier sizes between 1.544 and 44.736 Mbit/s may also employ at least 96 kbit/s of overhead for providing orderwire channels and maintenance alarms.

If the optional overhead framing is employed, the mandatory requirements detailed in this Section shall apply to ensure that equipment provided by different manufacturers will be compatible.

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* Small IDR carriers (n x 64 kbit/s, where n = 1, 2, 4, 6, 8, 12, 16 or 24) may use IBS overhead framing (see Appendix B).

9.6.1 Overhead Frame Structure

The QPSK/IDR frame structure is derived by synchronously adding 96 kbit/s of overhead to the transmitted data stream.

In order to preserve the proper clock accuracy over the satellite channel, the timing of the transmitted composite stream (information plus overhead) shall be derived from the incoming information data stream. In the event of a failure of the clock from the incoming information stream, a back–up clock with a long–term stability of at least 1 part in 10^5 per month shall be used to generate the timing needed to keep the overhead unit operational. The overhead unit shall be designed such that it will continue to operate in the absence of either (or both) the incoming transmit data or clock. The required timing accuracy of the information stream is specified in Section 10.2.

On the receive side the overhead unit shall derive its timing from a clock recovered from the received data. The frame structure is derived by adding 12 bits every 125 microseconds resulting in a 96 kbit/s overhead rate.

The overhead bits are allocated as follows:

- 4 bits for frame and multiframe alignment, backward alarm, and digital orderwire data for a total rate of 32 kbit/s; the rates applicable to each are:
    - i) 20 kbit/s for frame and multiframe alignment;
    - ii) 4 kbit/s for backward alarm to up to four destinations (1 kbit/s to each destination);
    - iii) 8 kbit/s for digital data.
- 8–bits for either two 32 kbit/s voice channels for a total rate of 64 kbit/s or one 64 kbit/s data channel for voice and data networking application*.
- An 8–frame multiframe is defined, in order to increase the uniqueness of the alignment signal, and to allocate the backward alarm to four destinations.

The details of the overhead structure shall be as shown in Figure 11 (for 1.544 and 2.048 Mbit/s information rates), Figure 12 (for the 6.312 Mbit/s information rate), Figure 13 (for the 8.448 Mbit/s information rate) and Figure 14 (for the 32.064, 34.368 and 44.736 Mbit/s information rates). It is not necessary for a single unit to provide overhead framing for all information rates. The structure has been designed, however, to facilitate such operation.

On the transmit side, the overhead unit, shall take as input the incoming information stream, add the framing, alarm and orderwire bits, as described above, and pass the composite stream to the scrambler. No knowledge of the

* See Figure 11.

framing imbedded within the information stream is assumed or required. On the receive side, the reverse process shall occur.

The unit shall have the capability for providing two 32 kbit/s channels for digitized voice or voiceband data and one 8 kbit/s data channel. The two 32 kbit/s channels may be combined to provide a single 64 kbit/s data channel*.

The 8 kbit/s data channel bits shall be set to "all ones" when not in use. Separate receive and transmit clocks shall be provided at 32, 8 and 1 kHz. The 1 kHz clock shall be synchronized to the multiframe rate. The other outputs shall be synchronized to this 1 kHz clock. The unit shall also detect the fault conditions and take the consequent actions described in Section 9.6.3 for maintenance purposes. It shall also have the capability for providing four separate backward alarm input/outputs.

Some users have found the 8 kbit/s data channel useful as a real–time diagnostic tool for in–service monitoring of the short–term performance of the satellite link. When not being used for other purposes, the 8 kbit/s data channel can be used to count the number of "1" to "0" bit transitions as a method of easily recognizing common bit patterns or signatures resulting from such events as equipment switchovers, tracking problems and sun outages.

9.6.2 Frame and Multiframe Alignment

Frame and multiframe alignment shall be carried out simultaneously using the alignment signal, comprising the eight bit code inserted in the first bit of every frame and the three bit code inserted in the second, third, and fourth bits of every other frame, as depicted in Figure 11, Figure 12, Figure 13 and Figure 14. Frame and multiframe alignment shall be assumed to be lost when four consecutive alignment signals have each been received with one or more errors. Frame and multiframe alignment shall be assumed to have been recovered when, for the first time, the presence of the correct alignment signal is detected. In the event of loss of alignment, a continuous alignment signal search shall be initiated. On correct receipt of an alignment signal, the recovery sequence given in the previous paragraph shall be initiated.

9.6.3 Maintenance Alarm Concept for the QPSK/IDR Channel Unit (With 96 kbit/s ESC Overhead)

The basis for this maintenance alarm concept is Rec. ITU–T G.803. The maintenance entity is defined as the digital equipment between interfaces "A" and "D" (for the transmit earth station) and interfaces "E" and "H" (for the receive earth station) of Figure 1 and as illustrated in Figure 15.

The fact that the signal is subject to FEC and scrambling is not to be considered with respect to the maintenance alarm concept, i.e., AIS (Alarm Indication Signal) applied across interface "D" as an "all ones" condition is still scrambled and encoded prior to transmission to the satellite.

9.6.3.1 Fault Conditions and Consequent Actions (For Carriers with 96 kbit/s ESC Overhead)

Table 6 shows the actions to be taken after the detection of specific fault conditions for each carrier. It is anticipated that these functions will be performed by the overhead framing unit. The faults shown in Table 6 are defined as follows:

In the earth station

FS1 failure of uplink equipment

FS2 failure of downlink equipment.

From the terrestrial side across interface “A”

FA1 loss of incoming signal (data or clock).

From the satellite across interface “E”

FE1 loss of incoming signal.

FE2 loss of overhead frame and multiframe alignment.

FE3 BER of 1 in 10^3 exceeded. Measured on the overhead alignment signal during any 1–minute period.

FE4 alarm indication received from the distant earth station (in bit 2 of even frames in the QPSK/IDR overhead structure).

The actions shown in Table 6 are defined as follows:

In the earth station

AS1 prompt maintenance alarm generated, as defined in Rec. ITU–T G.803.

AS2 deferred maintenance alarm generated, as defined in Rec. ITU–T G.803.

To the terrestrial link (across interface “H”)

AH1 AIS (alarm indication signal) applied across interface “H” on the information stream to indicate that a fault has been detected, and to be used as a service alarm by the terrestrial link.

To the satellite (across interface “D”)

AD1 AIS applied across interface “D” to indicate that a fault has been detected and to be used as a service alarm at the distant end. The AIS is sent in the information bit stream (not including the overhead bits).

AD2 alarm indication to the remote earth station to be used as a service alarm at the distant end (i.e., backward alarm). It is to be transmitted as state 1 in bit 2 of even frames. In the case of multi–destinational carriers this is to be transmitted only in those frames of the multiframe that have been assigned to that particular earth station.

9.6.3.2 Definition of AIS (Alarm Indication Signal)

AIS is transmitted as an "all ones" condition, except in the case of a 44.736 Mbit/s information rate carrier. In the case of a 44.736 Mbit/s information rate carrier, the equivalent binary content of AIS is a signal with a valid frame alignment signal, parity and justification control bits, as defined in Table 2 of Rec. ITU–T G.752, with the tributary bits being set to a 1010... sequence, starting with a binary "1" after each frame alignment, multiframe alignment and justification control bit and with all justification control bits being set to a binary "0".

9.7 Timing Jitter

The transmit channel unit shall be able to accept input timing jitter up to the limits specified in Rec. ITU–T G.823 and G.824 appropriate for the information rate input to the channel unit. This jitter is in addition to any jitter generated by the channel unit itself. Under these conditions, the channel unit shall still meet the BER performance requirements given in Section 9.5. For information rates not listed in Rec. ITU–T G.823 and G.824, the specification defined in these recommendations for 64 kbit/s shall be followed.

10. BUFFERING, TIMING, AND SLIP CONTROL

In order to compensate for the effect of satellite movement and, in certain cases, disparity between the clocks at the originating and receiving ends, buffering may be required at the receiving end. 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. For example, in some cases the buffer may be located in (or immediately following) the channel unit, while in others it may be after the demultiplex equipment. The required buffer capacity will depend on the sources of timing, the satellite delay variations, the desired interval between slips, and the configuration of each particular channel or circuit. In general, buffering to compensate for the satellite transmission delay variation is not required if QPSK/IDR voice circuits are to be connected to an analog terrestrial network. However, buffering shall be required to connect QPSK/IDR voice or data to a synchronous digital terrestrial network.

10.1 Transmission Delay Variation

The nominal delay parameters to be expected from Intelsat satellites* are shown in Table 7. These correspond to the case of nominal satellite stationkeeping tolerances.

10.2 Timing Accuracy

The primary order 1.544 or 2.048 Mbit/s digital signals in both directions of transmission shall be derived in one of three ways:

(a) from a clock with an accuracy of 1 part in 10^{11}. This means that the clock may be derived from a national cesium beam reference or a widely available reference (such as LORAN–C or GPS) that have the required accuracy;

(b) from an incoming clock received from a remote earth station by satellite. In this case, the remote earth station must derive timing by method (a) above;

(c) In cases where there is no synchronous digital network at either end but the channels are converted to analog voice circuits, the internal clock of the PCM multiplex equipment is of sufficient accuracy (about 50 parts in 10^6).

As an emergency backup, a local clock (with a long–term stability of at least 1 part in 10^5 per month for Cases (a) and (b)) shall be available in order to keep the circuit operating in the event that the primary clock source fails. The emergency clock shall be slaved to the primary clock unless there is a failure of the primary clock. Whenever the emergency clock is used, expeditious action must be taken to place the system back on the primary reference.

Examples of these methods are shown in Figure 16 and Figure 17, as described in Section 10.3. Particular configurations should be determined by bilateral agreement between correspondents.

10.3 Buffer Capacity

Three examples of circuit configuration and applicable buffer sizes are shown in Figure 16, Figure 17 and Figure 18. Other configurations are possible, but these examples are expected to represent the majority of cases. Table 8 can be used to determine the approximate buffer capacity in each. Figure 19 is an example of a situation where there is no need for buffering.

<u>Case 1</u>: This case applies to any channel where there are independent national digital networks at the transmit and receive ends. The timing signal is derived from a clock with 1 part in 10^{11} accuracy, as discussed in Section 10.2. This is illustrated in Figure 16.

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* The Intelsat VII, VIIA, VIII and IX satellites are not planned to be operated in inclined orbit.

Case 2: This case applies to a circuit where the timing at one end of the satellite link is derived from the recovered clock from the demodulator and that recovered clock is used to transmit back to the end that originated the timing signal. This is illustrated in Figure 17.

Case 3: This case applies to a circuit where the timing at one end of the satellite link is derived from the recovered clock from the demodulator, but this recovered clock is used to transmit back to a station that is different from the one that originated the timing signal. This is illustrated in Figure 18.

Under the conditions of 1 part in 10^{11} clock accuracy and the buffer capacities given in Table 8, the theoretical interval between slips will be at least 70 days as referred to in Rec. ITU–T G.811.

Case 4: This case applies to a circuit where there is no synchronous digital network at either end and the received channels are converted to analog voice channels or where each direction of transmission is timed independently end–to–end. In this case, no buffering is required and the transmit timing is derived internally from the PCM channel banks, PCM/FDM transmultiplexers, digital terminals, or similar equipment that convert between the analog and digital modes. The receive timing is derived from the recovered clock from the demodulator. This is illustrated in Figure 19.

10.4 Buffer Location

It is anticipated that, in most cases, receive side buffering will be performed at the primary order bit rate (1.544 Mbit/s or 2.048 Mbit/s). This means that for higher order QPSK/IDR carriers (e.g., 6.312 or 8.448 Mbit/s), buffering will be performed after the demultiplex equipment. The reason for this is to rely solely on reference clocks at the primary order data rate, since higher order clocks with 1 part in 10^{11} accuracy are not readily available with existing national digital networks and because some existing higher order multiplex equipment do not allow timing from an external clock source. Although this approach is recommended, it can be agreed bilaterally to also transmit higher order streams with clock accuracies of 1 part in 10^{11} to allow buffering to be performed at either the higher order data rate or the primary order rates.

10.5 Slip Control

Buffers should be reset whenever the channel suffers loss of service and when they reach saturation or become empty. For 1.544 or 2.048 Mbit/s data streams that form part of an international plesiochronous digital network, slips shall consist of integer multiples of one complete multiframe to avoid the loss of synchronization of the multiplex equipment and to avoid disturbing the switching equipment. This requirement does not apply if buffering is not performed at this level, as stated in Section 10.4. In sizing the buffer, this needs to be considered as well as Doppler and plesiochronous requirements (see Table 8).

11. BASEBAND CHARACTERISTICS

The performance characteristics for QPSK/IDR carriers have been developed to provide a means of transmitting any type of information in digital form. This may include, for example, PCM–encoded telephony both with and without circuit multiplication (e.g., LRE/DSI), digital data, digital video or a multiplexed combination of these.

Transmission is carried out in a manner that is transparent to the digitally–encoded information being conveyed.

QPSK/IDR carriers are designed to operate in a single–destinational (SD) or multi–destinational (MD) mode. Any information rate from 64 kbit/s to 44.736 Mbit/s may be transmitted. To limit the possible sets of equipment configurations, however, performance requirements for a finite set of Intelsat–recommended carrier sizes have been developed but it is not necessary to restrict operation to the recommended carrier sizes. In such cases, however, appropriate performance characteristics must be agreed to among corresponding users.

11.1 Digital Hierarchies and Information Rates

There are three digital hierarchies recommended by Rec. ITU–T G.702: one based upon a primary level of 2.048 Mbit/s and the other two based upon a primary level of 1.544 Mbit/s. In the case of interworking between networks using different hierarchies, Rec. ITU–T G.802 recommends a particular hierarchy. These four hierarchies are shown in Table 9. Performance characteristics for MD QPSK/IDR carriers have been developed for the information bit rates listed in Table 9.

For interworking between networks with different digital hierarchies, Rec. ITU–T G.802 shall be followed. This means that the interworking hierarchy shown in Table 9 will normally be used. This recommendation recognizes, in the case of interworking between networks with different hierarchies but with 1.544 Mbit/s as the primary level, that other levels, e.g., 1.544 Mbit/s, may alternatively be employed.

11.2 Single–Destinational (SD) Operation

It is recommended that the baseband performance characteristics specified for MD operation also be followed for SD operation, especially if it is planned to later extend service to MD operation.

11.3 Multi–Destinational (MD) Operation

11.3.1 Examples

The term “multi–destinational” means that a carrier transmitted by one earth station is received by two or more earth stations. Examples of multi–

destinational QPSK/IDR applications are depicted in Figure 20 through Figure 23 for each level of the digital hierarchy.

In the example shown in Figure 20, primary order 2.048 Mbit/s streams are transmitted and individual 64 kbit/s channels or time slots are allocated among the receive stations. Thus, primary–order streams cross interfaces “b” and “c” (the QPSK/IDR channel unit interface) and 64 kbit/s channels cross interfaces “a” and “d” (the terrestrial interface).

In Figure 21, primary–order bit streams at 2.048 Mbit/s data rates are derived from the reception of a second–order bit stream at a 8.448 Mbit/s data rate by means of appropriate demultiplex equipment in stations B and C, while station A receives both an 8.448 Mbit/s stream and a 2.048 Mbit/s stream. The streams crossing the terrestrial interfaces are all primary order.

In the example of Figure 22, second–order 8.448 Mbit/s bit streams are derived from the reception of a third–order 34.368 Mbit/s stream at stations B and C. Station A receives a 34.368 Mbit/s stream and a 8.448 Mbit/s stream. All bit streams crossing the terrestrial interfaces are second order.

Figure 23 shows an example of MD QPSK/IDR application using the primary and second–order interworking hierarchy bit rates.

These examples are provided to illustrate the various possibilities that are available with MD QPSK/IDR carriers. It is important to note that the number and type of modulators, demodulators, multiplexers and demultiplexers are asymmetrical and, because of this, the “backward alarms” associated with some multiplex structures may not function properly. This situation needs to be treated by the maintenance or supervisory system, as discussed in Section 11.3.2.7.

It is possible to concatenate multiplexers and demultiplexers. Thus, for example, a 34.368 Mbit/s carrier could be received by two or more stations, some of which could demultiplex and pass to the terrestrial network, a second order level bit stream (8.448 Mbit/s), while other stations receiving the same carrier could demultiplex and pass on to the terrestrial network, primary order bit streams (e.g., 2.048 Mbit/s).

There are many other multiplex arrangements that can be postulated, depending upon such things as the amount and type of traffic, the capability of the terrestrial network and equipment availability and economics. In Figure 20, for example, rather than passing 64 kbit/s channels to the terrestrial network, it is also possible to employ a PCM channel bank rather than a digital multiplexer and thereby pass analog voice channels to the terrestrial network.

Additional equipment may be needed to interface to the terrestrial network. In Figure 21, for example, where 2.048 Mbit/s streams are shown crossing the terrestrial interface, it may be desirable to multiplex those primary order streams to a higher level. This would require an additional multiplexer / demultiplexer or a digital cross–connect.

11.3.2 Multiplex/Demultiplex Characteristics for Multi–Destinational Operation

Characteristics for MD QPSK/IDR carrier bit streams have been defined at the QPSK/IDR channel unit, i.e., at interfaces “b” and “c” in Figure 20 through Figure 23, as they are to be supplied to or received from the multiplex/demultiplex equipment. These characteristics have been based upon ITU–T G Series Recommendations, as summarized in Table 10, which also indicate the number of 64 kbit/s channels and/or the number of primary–order bit streams associated with each carrier size.

It is anticipated that the multiplex/demultiplex characteristics given in this section will normally be employed by MD QPSK/IDR carriers. In certain instances, e.g., when transmitting a digital video teleconferencing signal, it may be advantageous to employ a different set of characteristics. In these cases, it is incumbent upon the corresponding users to agree upon alternative arrangements.

It is not necessary that multiplex/demultiplex functions be implemented at the earth stations. They could be implemented on the terrestrial side of interfaces “a” and “d” in Figure 20 through Figure 23.

11.3.2.1 1.544 Mbit/s Bit Streams

When MD operation on a 64 kbit/s channel basis is performed by transmitting a 1.544 Mbit/s stream, the multiplex frame structure of Rec. ITU–T G.733 shall be followed for input to the QPSK/IDR channel unit. A 24–frame multiframe as defined in Rec. ITU–T G.704, Para. 3.1.1.3 A) shall be used.

11.3.2.2 2.048 Mbit/s Bit Streams

When MD operation on a 64 kbit/s channel basis is performed by transmitting a 2.048 Mbit/s stream, the multiplex frame structure of Rec. ITU–T G.732 shall be followed for input to the QPSK/IDR channel unit, except in the case of LRE/DSI transmission. In that instance, the MD (or multi–clique) capability is provided by the LRE/DSI system and the QPSK/IDR equipment will pass the 2.048 Mbit/s stream transparently.

It is recommended that bit 1 of the frame be used for a cyclic redundancy check (CRC) procedure, as specified in Rec. ITU–T G.704, Para. 2.3.3.

11.3.2.3 6.312 Mbit/s Bit Streams

6.312 Mbit/s bit streams may be composed of four 1.544 Mbit/s tributaries or three 2.048 Mbit/s tributaries.

Rec. ITU–T G.743 shall be followed for 6.312 Mbit/s bit streams at the input to the QPSK/IDR channel unit when composed of four 1.544 Mbit/s tributaries. Rec. ITU–T G.747 shall be followed for 6.312 Mbit/s bit streams at the input to the QPSK/IDR channel unit when composed of three 2.048 Mbit/s tributaries.

This recommendation applies to the interworking hierarchy as given in Rec. ITU–T G.802.

11.3.2.4 8.448 Mbit/s Bit Streams

Rec. ITU–T G.742 shall be followed for 8.448 Mbit/s bit streams at the input of the QPSK/IDR channel unit.

11.3.2.5 34.368 Mbit/s Bit Streams

Rec. ITU–T G.751 shall be followed for 34.368 Mbit/s bit streams at the input of the QPSK/IDR channel unit.

11.3.2.6 32.064 and 44.736 Mbit/s Bit Streams

Rec. ITU–T G.752 shall be followed for 32.064 and 44.736 Mbit/s bit streams at the input of the QPSK/IDR channel unit.

11.3.2.7 Fault Conditions and Consequent Actions Related to Multiplex Equipment (Backward Alarm)

In addition to the maintenance alarm concept of the QPSK/IDR channel unit described in Section 9.6.3, the multiplex equipment will normally have a set of fault conditions and consequent actions that are to be followed. These are described in the relevant ITU–T Recommendations applicable to the hierarchical rate and the type of service being provided (e.g., Rec. ITU–T G.732, G.733, etc.).

In certain instances, there may be an uncertainty involved in the recognition of the “alarm indication received from the remote end” or “backward alarm”, which is a fault condition described in the ITU–T Recommendations listed in Table 11. This uncertainty arises for MD carriers where a fault condition intended for one destination is also received by other destinations.

This situation may have an adverse impact upon switching / signalling equipment, depending upon the supervisory and maintenance systems employed. Careful consideration should be given to the actions to be taken by maintenance systems if and when this circumstance occurs.

In Figure 21, for example, if the demultiplexer in earth station “A” loses frame alignment on the 8.448 Mbit/s signal from station “B”, it will transmit a backward alarm to both stations “B” and “C”. Since this alarm is only intended for Station “B”, station “C” should ignore it.

The overhead framing structure described in Section 9.6 does not suffer this ambiguity, provided there are no more than four destinations, and may provide a means for resolving this ambiguity.

11.3.2.8 Circuit Supervision for Multi–Destinational 2.048 Mbit/s Streams not Using LRE/DSI

Rec. ITU–T G.803 and Q.33 provide guidance on the maintenance of digital links. Rec. ITU–T Q.33 underlines in particular, for the satellite link, the need for a supervision channel to be used in the case of ITU–T signalling systems No. 6 and 7.

Thus, there is a need for the definition of a supervision channel in all the cases where the 2.048 Mbit/s signal is multi–destinational, ITU–T signalling systems No. 6 or 7 are used and the 2.048 Mbit/s is not a DCME bearer. (In this last case, the supervision channel is included in the LRE/DSI specification.)

For SD primary order streams or for higher order streams (either SD or providing SD capability on a primary order basis (i.e., primary order streams are conveyed between switching centers)), this satellite supervision channel is not required.

One method of providing this supervisory function is to carry the alarm and supervision information over the satellite path in time slot 16 of each 2.048 Mbit/s bearer.

A specification for such a function is given below. The format of time slot 16 shall be in accordance with Rec. ITU–T G.704, Para. 3.3.3.2.2. The fault conditions and consequent actions shall be compliant with Table 11. These detections and actions should be undertaken in any equipment functionally equivalent to a digital cross–connect. Only the “a” and “b” bits of time slot 16 of frame 1 to 15 are used to carry the alarm and supervision information. The meaning of bits a and b is as follows:

a = b = 0 : normal condition

a = b = 1 : abnormal or fault condition.

11.4 Signalling

The signalling arrangements, including the allocation of the transmission paths and the selection of the signalling system, are the user’s responsibility. It is anticipated that ITU–T Signalling Systems No. 5, 6 or 7 will be used.

11.5 Voice Channel Interfaces

11.5.1 PCM Encoding

In cases where 64 kbit/s channels have been formed by PCM–encoding of analog voice channels, either μ–law or A–law encoding shall be used, as per Rec. ITU–T G.711. For conversion between the two, Rec. ITU–T G.711, which states that conversion will be performed by entities using the μ –law, shall be followed. The PCM multiplex equipment should adhere to Rec. ITU–T G.732 (for 2.048 Mbit/s) or Rec. ITU–T G.733 (for 1.544 Mbit/s).

11.5.2 Echo Protection

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.

11.6 LRE/DSI Interface

The interface between 2.048 Mbit/s LRE/DSI equipment and the QPSK/IDR channel unit shall be based upon a primary order 2.048 Mbit/s bit rate. LRE/DSI bit streams will be passed transparently by the QPSK/IDR equipment. This means that the multi–clique and MD capability of the LRE/DSI equipment will operate independently of the QPSK/IDR multiplex equipment. This concept should be considered when deciding what equipment may be needed to satisfy MD requirements.

12. 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 providing a means 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

Recommended QPSK/IDR Information Rates and Associated Overhead

		TYPE OF OVERHEAD		
Number of 64 kbit/s Bearer Channels (n)	Info. Rate (n x 64 kbit/s)	No Overhead (1)	With 96 kbit/s ESC Overhead (2)	With 6.7% IBS Overhead (2, 3)
1	64	X		X
2	128			X
3	192	X		
4	256			X
6	384	X		X
8	512			X
12	768			X
16	1024			X
24	1536			X
24	1544 (4)		X	
30 (31)	2048 (4)		X	
90 (93)	6312 (4)		X	
120 (124)	8448 (4)		X	
480	32064 (4)		X	
480 (496)	34368 (4)		X	
630 (651) or 672	44736 (4)		X	

X = Recommended rate corresponding to the type of overhead.

Notes:

(1) For rates less than 1544 kbit/s, it is possible to use any n x 64 kbit/s information rate without overhead, but the only Intelsat–recommended rates are 64 kbit/s, 192 kbit/s and 384 kbit/s. The use of the optional Reed–Solomon outer coding is not defined for any information rate less than 1.544 Mbit/s, which does not use overhead.

(2) The optional Reed–Solomon outer coding can be used with the information rates shown with an “X”.

(3) The carriers in this column are small QPSK/IDR carriers some of which can be used with the circuit multiplication concept described in Appendix B. [For a definition of the IBS overhead framing, see IESS–309 (IBS).]

(4) These are standard ITU–T hierarchical bit rates. Other n x 64 kbit/s information rates above 1.544 Mbit/s are also possible.

Table 2
QPSK/IDR Performance (G.821 Quality, Intelsat VI)
(See Notes 5, 6, 8 & 10)

Weather Condition	Minimum BER Performance (1, 4) (% of year)
Clear Sky	$\leq 10^{-7}$ for $\geq$ 95.90%
Degraded	$\leq 10^{-6}$ for $\geq$ 99.36%
Degraded	$\leq 10^{-3}$ for $\geq$ 99.96%

Table 3
QPSK/IDR Performance (G.826 Quality*, Intelsat VII, VIIA, VIII & IX)
(See Notes 5, 6 & 8)

Weather Condition	Minimum BER Performance (2) (% of year)	Typical BER Performance (4) (% of year)
Clear Sky	$\leq 2 \times 10^{-8}$ for $\geq$ 95.90%	$\leq 10^{-10}$ for $\geq$ 95.90%
Degraded	$\leq 2 \times 10^{-7}$ for $\geq$ 99.36%	$\leq 10^{-9}$ for $\geq$ 99.36%
Degraded	$\leq 7 \times 10^{-5}$ for $\geq$ 99.96%	$\leq 10^{-6}$ for $\geq$ 99.96%
Degraded	(7)	$\leq 10^{-3}$ for $\geq$ 99.98%

Table 4
QPSK/IDR Performance (Optional)
(G.826 Plus Quality†, Intelsat VII, VIIA, VIII & IX)
(See Notes 5, 6 & 9)

		Typical BER Performance (4) (% of year)	
Weather Condition	Minimum BER Performance (3) (% of year)	With Reed–Solomon Outer Coding (Appendix H)	With E/S Equipment Better Than IESS Min. Perform. Requirements
Clear Sky	$\leq 10^{-9}$ for $\geq$ 95.90%	$< 10^{-10}$ for $\geq$ 95.90%	
Degraded	$\leq 10^{-8}$ for $\geq$ 99.36%	$< 10^{-10}$ for $\geq$ 99.36%	(See Appendix I)
Degraded	$\leq 10^{-6}$ for $\geq$ 99.96%	$< 10^{-10}$ for $\geq$ 99.96%	
Degraded	(7)	$\leq 10^{-5}$ for $\geq$ 99.98%	

( ) See notes on the next page.

* G.826 Quality = Note 1 of Recommends 3 of Rec. ITU–R S.1062

† G.826 Plus Quality = Note 2 of Recommends 3 of Rec. ITU–R S.1062 (Since Note 2 has no equivalent in Rec. ITU–T G.826, the descriptor "G.826 Plus" has, therefore, been adopted for the purposes of this module).

<u>Notes to Tables 2, 3 and 4</u>

1. The minimum BER performance conforms with Rec. ITU–R S.614–2. For Intelsat VI satellites, Intelsat will endeavor to provide the minimum performance shown for Intelsat VII, VIIA, VIII and IX, whenever transponder capacity and earth station uplink EIRP constraints permit.

2. The minimum BER performance conforms with the bit rate dependent criteria given in Note 1 of Recommends 3 of Rec. ITU–R S.1062.* The performance shown in Table 3 applies to 2.048 Mbit/s QPSK/IDR carriers where the value of α (average number of errors per burst) is equal to 10. For the minimum performance applicable to other information rates, refer to Rec. ITU–R S.1062. The typical QPSK/IDR performance will either meet or exceed the minimum BER performance recommended for the information rates shown in Note 1 of Recommends 3 of Rec. ITU–R S.1062.

   For QPSK/IDR information rates of 8.448 Mbit/s, 32.064 Mbit/s, 34.368 Mbit/s and 44.736 Mbit/s, which are not listed in Note 1, the minimum performance requirements in the ITU–R Recommendation for 51.0 Mbit/s should be assumed. In the case of small QPSK/IDR carriers (information rates less than 1.544 Mbit/s), the minimum BER performance requirements for 2.0 Mbit/s in the ITU–R Recommendation should be assumed.

3. The minimum BER performance conforms with the bit rate independent criteria given in Note 2 of Recommends 3 of Rec. ITU–R S.1062. The performance shown in Table 4 applies to all QPSK/IDR carrier sizes of 45 Mbit/s or less, where the value of α (average number of errors per burst) is equal to 10. The typical QPSK/IDR performance will either meet or exceed the minimum BER performance recommended in Note 2.

4. The typical clear–sky performance values shown are based on specified modem performance characteristics and earth station G/T and are the basis of carrier lineups to ensure that the minimum performance requirements can be met under operational conditions. In practice, the BER performance and link availability can be even better, depending on the type of equipment and additional G/T performance selected by the user.

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

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

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* Recommendation ITU–R S.1062 has been developed by the ITU Radiocommunication Sector for satellite links, operating at or above the primary rate. Performance which meets the criteria of Note 1 of the Recommendation will fully comply with the requirements of Recommendation ITU–T G.826.

Notes to Tables 2, 3 and 4 (Continued)

7. Not specified in Recommendation ITU–R S.1062.

8. Refer to Appendix I for the QPSK/IDR performance expected for earth stations using equipment that exceed the minimum IESS performance requirements.

9. The QPSK/IDR performance (“G.826 Plus”) defined in Table 4 is optional. If this level of performance is desired, users must either: (a) employ Reed–Solomon outer coding, as defined in Appendix H or, (b) provide earth station equipment that exceed the minimum IESS performance requirements (e.g., larger earth station G/T or better QPSK/IDR modems), as discussed in Appendix I.

10. In the case of Intelsat VI, depending on the transponder resources available and subject to any uplink EIRP constraints, a BER performance will be provided with a quality range between G.826 (equivalent to that provided for Intelsat VII, VIIA, VIII and IX) and G.821 (equivalent to that presently specified in Table 2).

Table 5

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

* 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.

** 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 provided by Intelsat, upon request, for transponder bandwidth units greater than 72 MHz.

Table 6

Fault Conditions and Consequent Actions

FAULT (F) DETECTED		ACTION (A) TO BE TAKEN		
LOCATION	CONDITION	IN STATION	TO TERRESTRIAL LINK* (Across Interface H)	TO SATELLITE (Across Interface D)
IN STATION(S)	FS1† FS2[2]	AS1 AS1	— AH1	AD1 AD2
FROM TERRESTRIAL LINK (ACROSS INTERFACE A)	FA1	AS1	—	AD1
FROM SATELLITE (ACROSS INTERFACE E)	FE1 FE2 FE3 FE4	AS1 AS1 AS1 AS2	AH1 AH1 — —	AD2 AD2 AD2 —

* Actions to be taken to the terrestrial link (i.e., AH1) are not mandatory. See Figure 1 for location of interfaces.

† This function is to be performed only if practicable.

Table 7

Intelsat Satellite Delay Parameters

(a) For Nominal Satellite Stationkeeping Limits (Note 3)

Satellite	Maximum Variations (msec)	Maximum Rate of Variations (nsec/sec)
VI	0.32	10.0
VII, VIIA, VIII & IX (Provisional)	0.43	15.4

(b) For Possible Higher Inclinations (Notes 4, 5)

	Inclination (Degrees)						
Parameter	0.5	1.0	1.5	2.0	2.5	3.0	Units
Maximum variations	1.1	1.8	2.6	3.3	4.1	4.8	msec
Maximum rate of variations	40	67	94	121	148	175	nsec/sec

NOTES:

1. Maximum variations = peak–to–peak uplink plus downlink.
2. Maximum rate of variations = uplink plus downlink.
3. The delay parameters are based upon the following orbital tolerances:

	Nominal Stationkeeping	
Satellite	North–South (degrees)	East–West (degrees)
VI, VII, VIIA, VIII & IX (Provisional)	± 0.05	± 0.05

4. The E–W drift will be maintained within ± 0.1°.
5. The Intelsat VII, VIIA, VIII and IX satellites are not planned to be operated in inclined orbit.

Table 8

Minimum Doppler/Plesiochronous
Buffer Capacity Requirements

Satellite Orbit Inclination (Degrees)	Buffer Capacity (ms) For Various Circuit Configurations			
	Case 1 (Figure 16)	Case 2 (Figure 17)	Case 3 (Figure 18)	Case 4 (Figure 19]
0.1 (Nominal)	1.5	2.4	2.7	No buffer required
0.5	2.5	4.4	4.7	
1.0	3.9	7.4	7.7	
1.5	5.5	10.4	10.7	
2.0	6.9	13.2	13.5	
2.5	8.5	16.4	16.7	
3.0	9.9	19.2	19.5	

Notes:

(1) The above minimum buffer capacities include a factor of two to allow the buffer to start in the center and then drift in either direction. In Cases 2 and 3, where the transmit timing at one end of the link is derived from the demodulator and used to transmit back to either the station that originated the timing signal or to a different station, another factor of two has been applied to the Doppler contribution to account for the passage of the timing signal twice through the satellite.

(2) The above capacities were derived by adding the buffer requirements due to satellite delay variations (Doppler) and that due to the interfacing of different national clocks (plesiochronous).

(3) Actual buffer capacity is likely to be larger due to the need to slip primary order streams on a multiframe basis.

Table 9

ITU–T Digital Hierarchies for Use With Recommended Intelsat Carriers

DIGITAL HIERARCHY LEVEL	HIERARCHICAL BIT RATES (Mbit/s) ASSOCIATED WITH EACH DIGITAL HIERARCHY BASED ON THE PRIMARY LEVEL			INTERWORKING HIERARCHY BIT* RATES (Mbit/s)
1 (Primary)	2.048	1.544	1.544	2.048
2	8.448	6.312	6.312	6.312
3	34.368	44.736	32.064	44.736

* As recommended in Rec. ITU–T G.802, the bit rates shown in this column will normally be used for interworking between networks with different hierarchies (see Section 11.1).

Table 10

Intelsat Multiplex Characteristics For
Multi–Destinational Operation

TRANSMITTED BIT RATE (Mbit/s)	NUMBER OF 64 kbit/s CHANNELS (Note 3)	NUMBER AND BIT RATE OF LOWER ORDER TRIBUTARIES	ITU–T MULTIPLEX RECOMMENDATION	NOTES
1.544	24	–	G.733	(1)
2.048	30 (31)	–	G.732	(4)
6.312	96	4 x 1.544	G.743	
6.312	90 (93)	3 x 2.048	G.747	
8.448	120 (124)	4 x 2.048	G.742	
32.064	480	5 x 6.312	G.752	
34.368	480 (496)	4 x 8.448	G.751	
44.736	630 (651) or 672	7 x 6.312	G.752	(2)

NOTES:

1. A 24–frame multiframe as defined in Rec. ITU–T G.704 Para. 3.1.1.3 A shall be used with the transmitted 1.544 Mbit/s bit rate.

2. 44.736 Mbit/s bit streams can carry 630 (651) 64 kbit/s channels (in cases where the 6.312 Mbit/s tributaries are composed of three 2.048 Mbit/s streams), or 672 64 kbit/s channels (in cases where the 6.312 Mbit/s tributaries are composed of four 1.544 Mbit/s streams).

3. The 2.048 Mbit/s bit stream is composed of 32 time slots (TS) or channels where TS 0 is reserved for frame alignment and alarms, and TS 16 can be used for signalling or to transport traffic. The number in parentheses includes the number of channels available when TS 16 is used to transport traffic.

4. It is recommended that bit 1 of the 2.048 Mbit/s frame be used for cyclic redundancy checking (CRC), as specified in Rec. ITU–T G.704, Para.2.3.

Table 11
Fault Conditions and Consequent Actions for MD 2.048 Mbit/s
Streams Using ITU–T Signalling Systems No. 6 or 7 and Not Carrying LRE/DSI

INTERFACE SIDE	FAULT CONDITION	GENERATED ON APPROPRIATE 2.048 Mbit/s STREAMS TOWARDS TERRESTRIAL SIDE			PROMPT MAINTENANCE ALARM	GENERATED ON OUTGOING 2.048 Mbit/s STREAMS TOWARD APPROPRIATE E/S	
		Alarm indication to remote end (Note 4)	Alarm indication on relevant circuits (e.g., Note 5)	AIS on all primary multiplexes		Alarm indication on relevant 64 kbit/s channels (e.g., Note 5)	AIS on outgoing stream
TERRESTRIAL INTERFACE SIDE	Failure of incoming primary multiplex	Yes			Yes (Note 2)	Yes	
	Remote alarm indication received from terrestrial side (Note 4)					Yes	
	Alarm indication received on relevant circuits (e.g., Note 5) Failure of incoming stream					Yes	
			Yes		Yes (Note 3)	Yes	
SATELLITE SIDE INTERFACE	Failure of the supervision channel (i.e., loss of multiframe alignment)		Yes		Yes (Note 3)		
	Indication of fault in relevant channels (i.e., Note 5)		Yes				
DACS EQUIPMENT	Functional or power supply failure			Yes (If Possible)			Yes (If Possible)

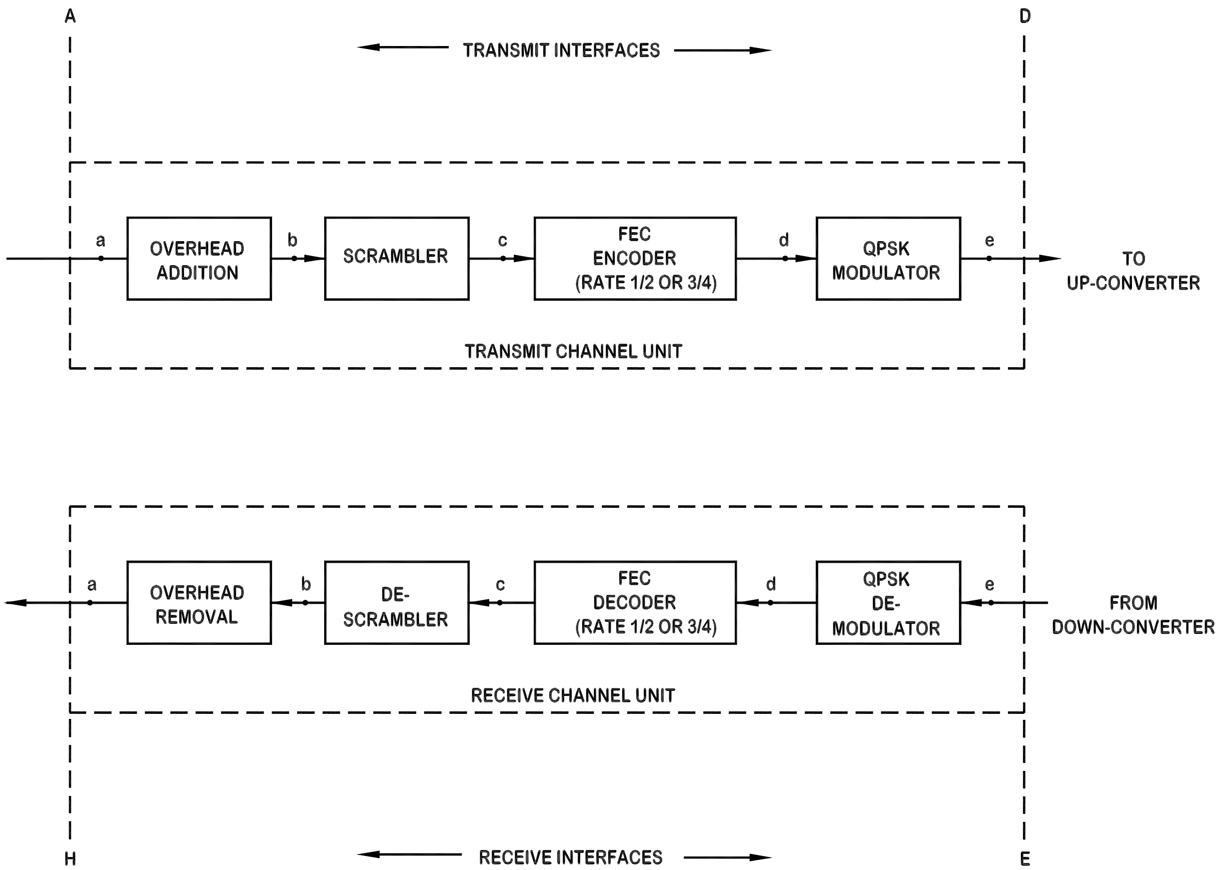
DACS = Digital Access and Cross Connect

Notes:

1. A "Yes" in the table signifies that an action shall be taken as a consequence of the relevant fault condition. An open space in the table signifies that the relevant action shall not be taken as a consequence of the relevant fault condition, if the condition is the only one present. If more than one fault condition is simultaneously present, the relevant action shall be taken if, for at least one of the conditions, a "Yes" is defined in relation to this action.
2. This action shall not be taken if AIS is detected on the incoming terrestrial side stream.
3. This action shall not be taken if AIS is detected on the incoming satellite side stream.
4. For example by setting bit 3 in time slot 0 to state 1, as defined in Rec. ITU–T G.732.
5. By setting the "a" and "b" bits of time slot 16 to state 1, as defined in Rec. ITU–T G.704, para. 3.3.3.2.2.

Figure 1

Illustration of QPSK/IDR Channel Unit



a	INFORMATION RATE, IR
b, c	COMPOSITE RATE, CR = IR PLUS OVERHEAD
d	TRANSMISSION RATE, R = CR/C (C = CODE RATE = 1/2 OR 3/4)
e	SYMBOL RATE, SR = R/2

P:\CAD\IESS\308NEW\308-01.DWG
TITLE: ILLUSTRATION OF IDR CHANNEL UNIT

Figure 2
Earth Station IF and RF Amplitude Response

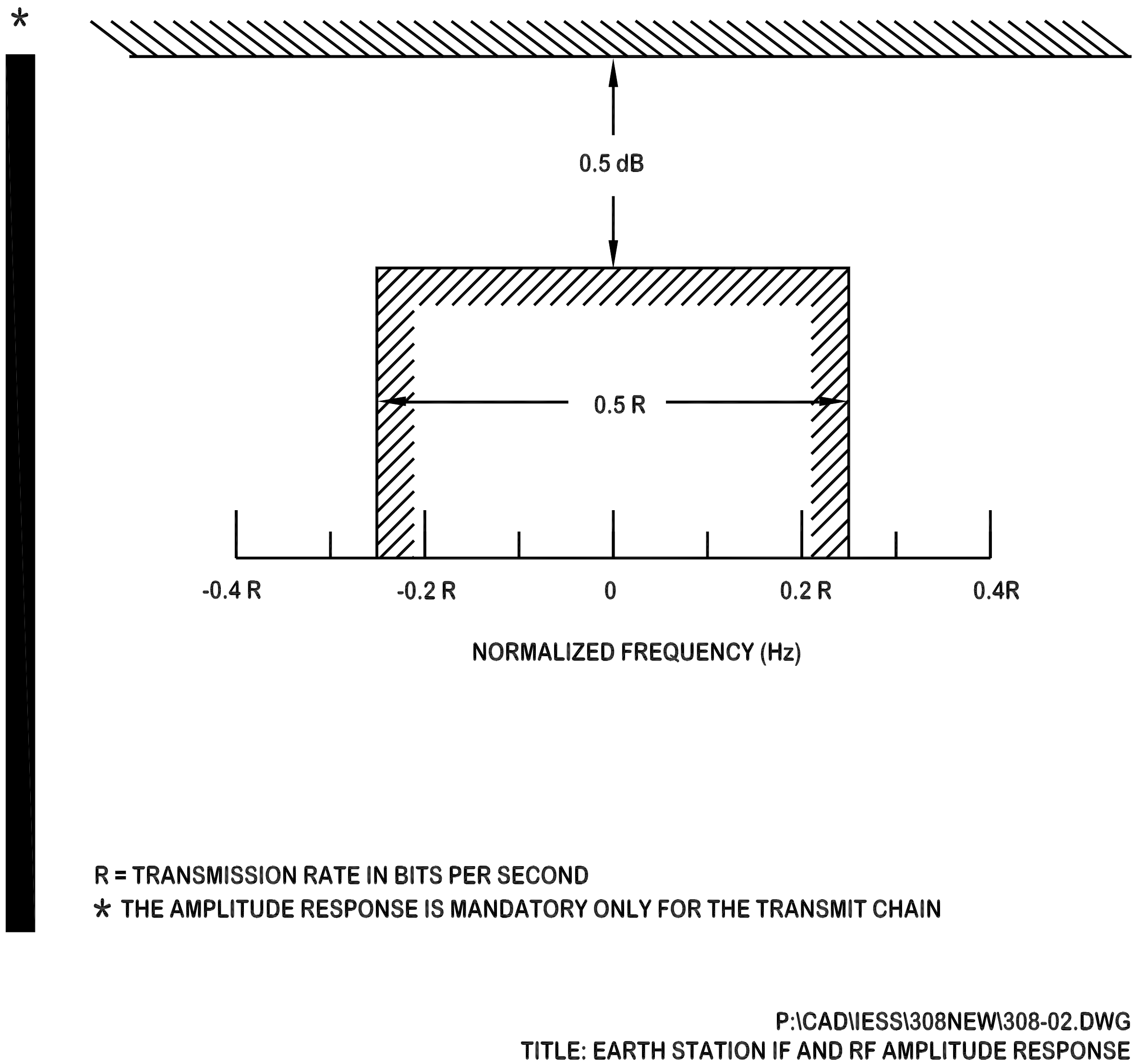
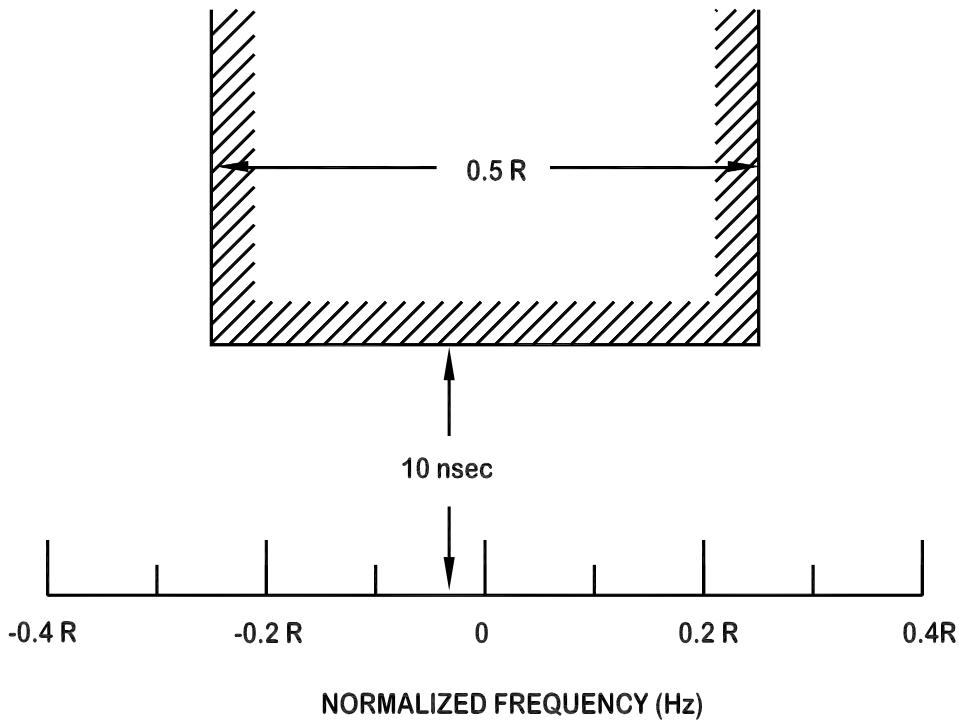


Figure 3
Earth Station IF and RF Group Delay Response

*



R = TRANSMISSION RATE IN BITS PER SECOND

*THE GROUP DELAY RESPONSE IS MANDATORY ONLY FOR THE TRANSMIT CHAIN

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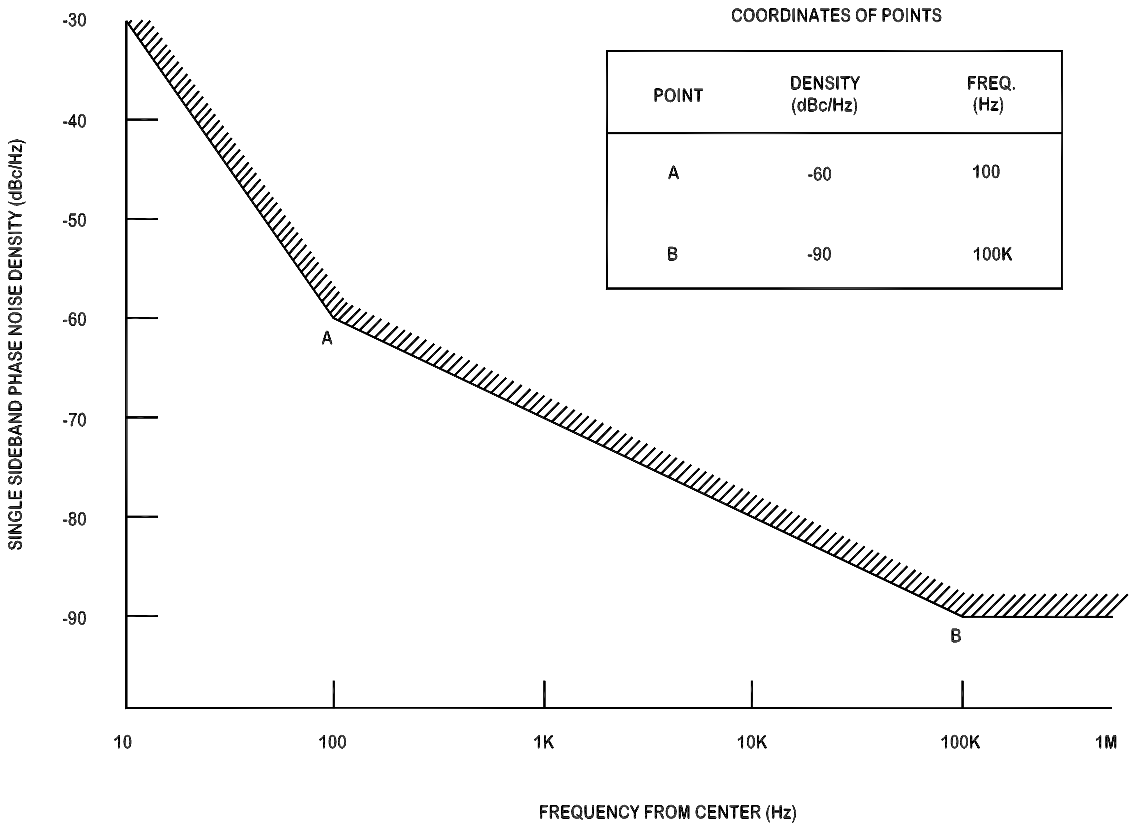
TITLE: EARTH STATION IF AND RF GROUP DELAY RESPONSE

Figure 4

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

*



* THE TRANSMITTED PHASE NOISE REQUIREMENT MAY BE SATISFIED BY MEETING EITHER OF TWO LIMITS (SEE SECTION 8.1). 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.

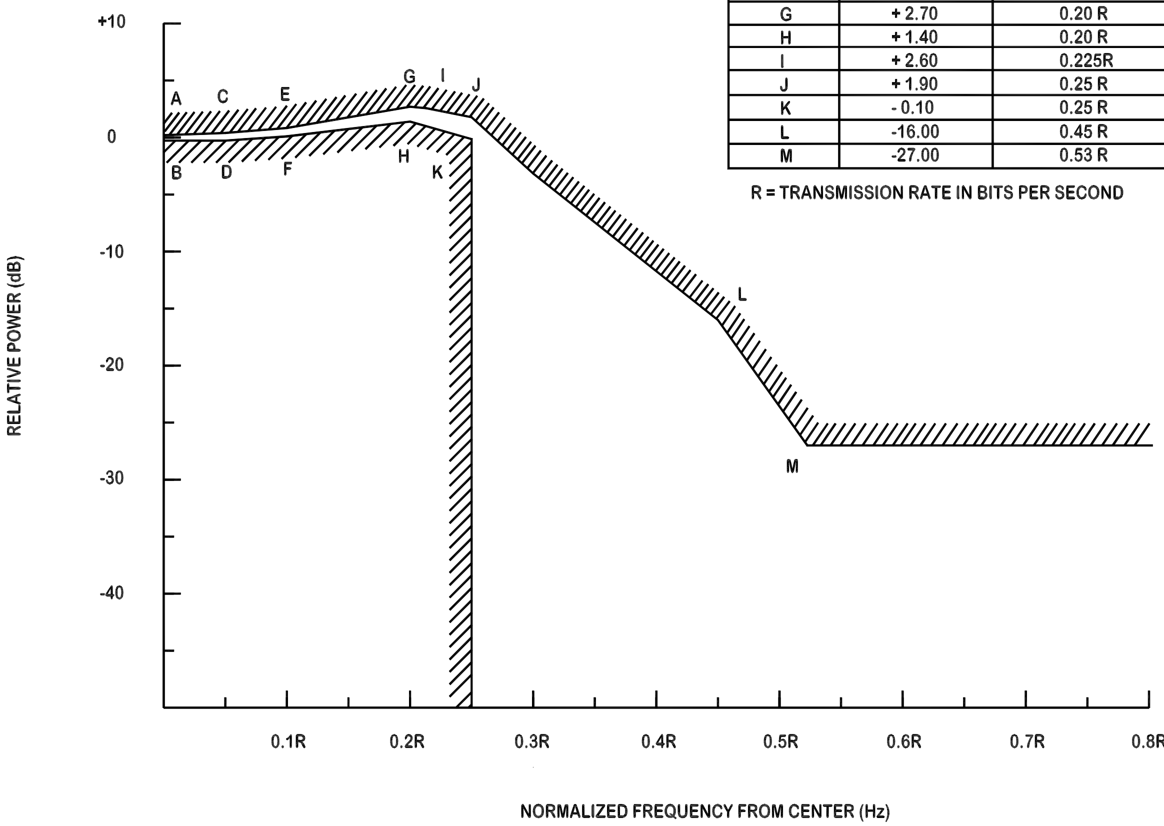
P:\CAD\IESS\308NEW\308-04.DWG
TITLE: CONTINUOUS SINGLE SIDEBAND PHASE NOISE REQUIREMENT
(For carriers with information rates less than or equal to 2.048 Mbit/s)

Figure 5
Modulator Filter Amplitude Response

COORDINATES OF POINTS

POINT	AMP. (dB)	NORM. FREQ. (Hz)
A	+ 0.25	0.0
B	- 0.25	0.0
C	+ 0.40	0.05 R
D	- 0.25	0.05 R
E	+ 0.80	0.10 R
F	+ 0.15	0.10 R
G	+ 2.70	0.20 R
H	+ 1.40	0.20 R
I	+ 2.60	0.225R
J	+ 1.90	0.25 R
K	- 0.10	0.25 R
L	-16.00	0.45 R
M	-27.00	0.53 R

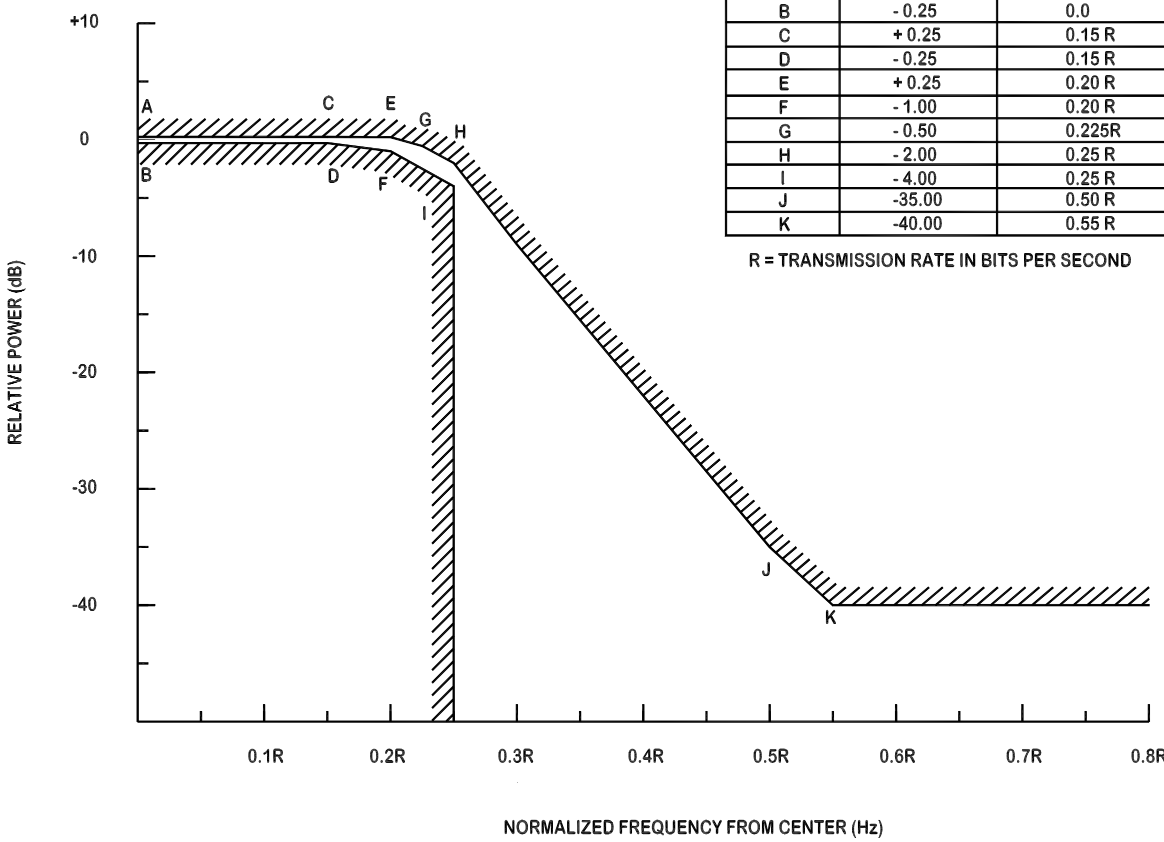
R = TRANSMISSION RATE IN BITS PER SECOND



NOTE: THE FILTER RESPONSE IS NOT A MANDATORY REQUIREMENT. IT IS USED TO SPECIFY THE TRANSMIT SPECTRUM, WHICH IS A MANDATORY REQUIREMENT.

P:\CAD\IESS\308NEW\308-05.DWG
TITLE: MODULATOR FILTER AMPLITUDE RESPONSE

Figure 6
Demodulator Filter Amplitude Response



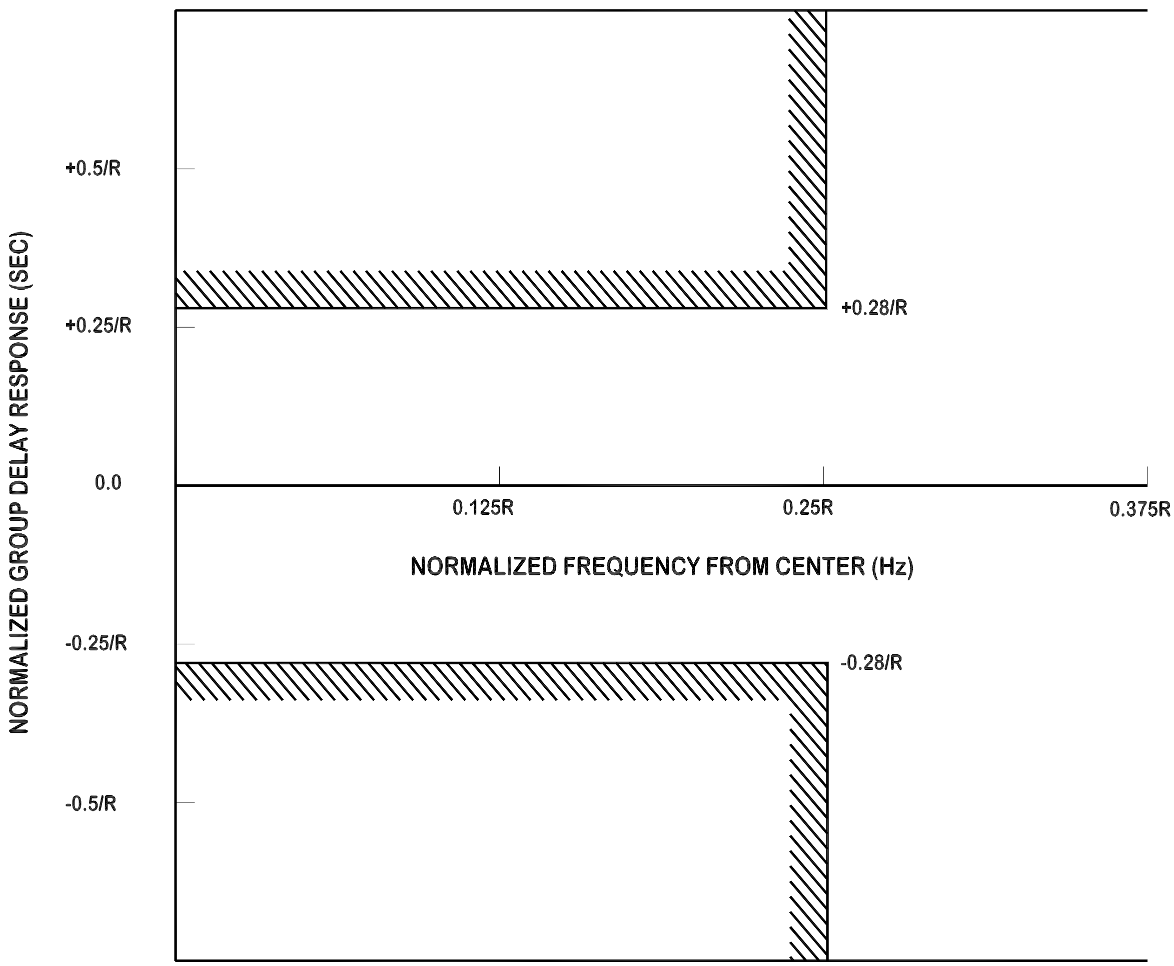
COORDINATES OF POINTS

POINT	AMP. (dB)	NORM. FREQ. (Hz)
A	+ 0.25	0.0
B	- 0.25	0.0
C	+ 0.25	0.15 R
D	- 0.25	0.15 R
E	+ 0.25	0.20 R
F	- 1.00	0.20 R
G	- 0.50	0.225R
H	- 2.00	0.25 R
I	- 4.00	0.25 R
J	-35.00	0.50 R
K	-40.00	0.55 R

R = TRANSMISSION RATE IN BITS PER SECOND

P:\CAD\IESS\308NEW\308-06.DWG
TITLE: DEMODULATOR FILTER AMPLITUDE RESPONSE

Figure 7
Modulator and Demodulator Filter Group Delay Response



R= TRANSMISSION RATE IN BITS PER SECOND

NOTES:

1. THE FILTER RESPONSE IS NOT A MANDATORY REQUIREMENT. IT IS USED TO SPECIFY THE TRANSMITTED CARRIER SPECTRUM, WHICH IS A MANDATORY REQUIREMENT.
2. EITHER THE ABOVE GROUP DELAY RESPONSE OR A PHASE RESPONSE WITH LESS THAN 4 DEGREES DEPARTURE FROM A LINEAR PHASE SHIFT (OVER THE FREQUENCY RANGE ± 0.25R Hz ABOUT THE CENTER FREQUENCY) MAY BE USED.

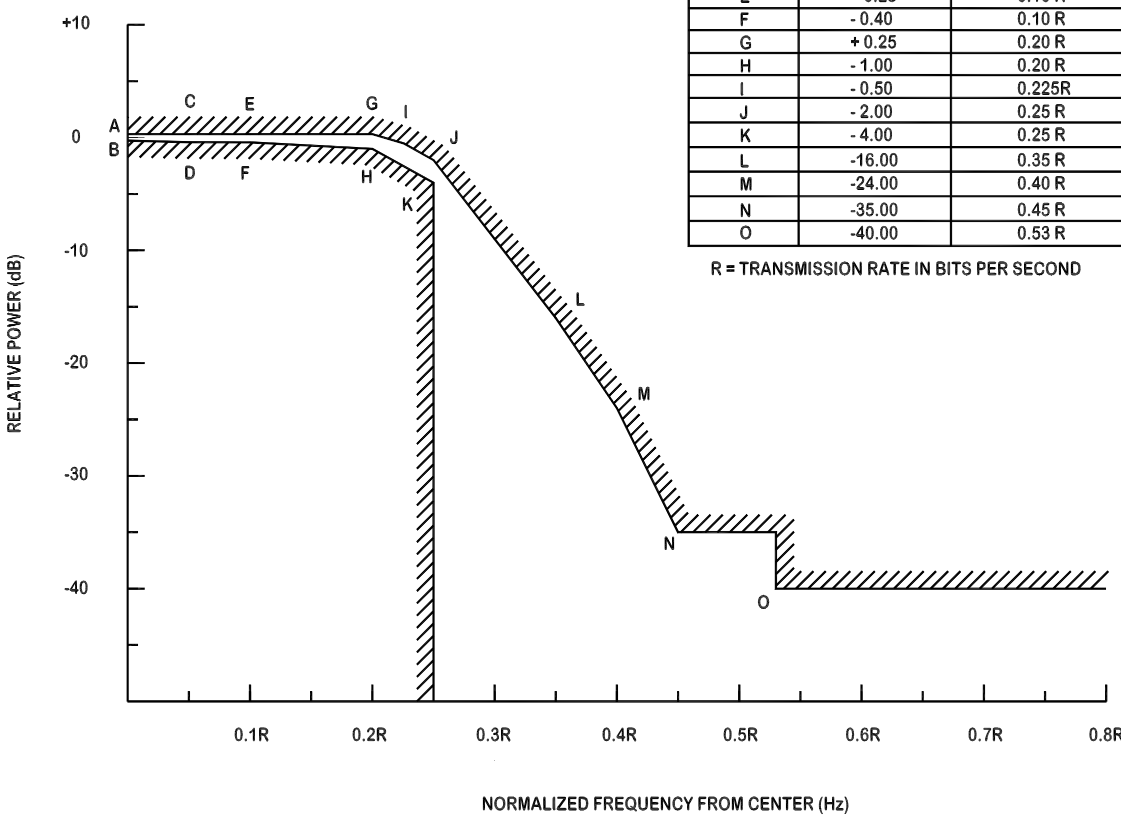
P:\CAD\IESS\308NEW\308-07.DWG
TITLE: MODULATOR AND DEMODULATOR FILTER GROUP DELAY RESPONSE

Figure 8
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	0.05 R
D	- 0.40	0.05 R
E	+ 0.25	0.10 R
F	- 0.40	0.10 R
G	+ 0.25	0.20 R
H	- 1.00	0.20 R
I	- 0.50	0.225R
J	- 2.00	0.25 R
K	- 4.00	0.25 R
L	-16.00	0.35 R
M	-24.00	0.40 R
N	-35.00	0.45 R
O	-40.00	0.53 R

R = TRANSMISSION RATE IN BITS PER SECOND

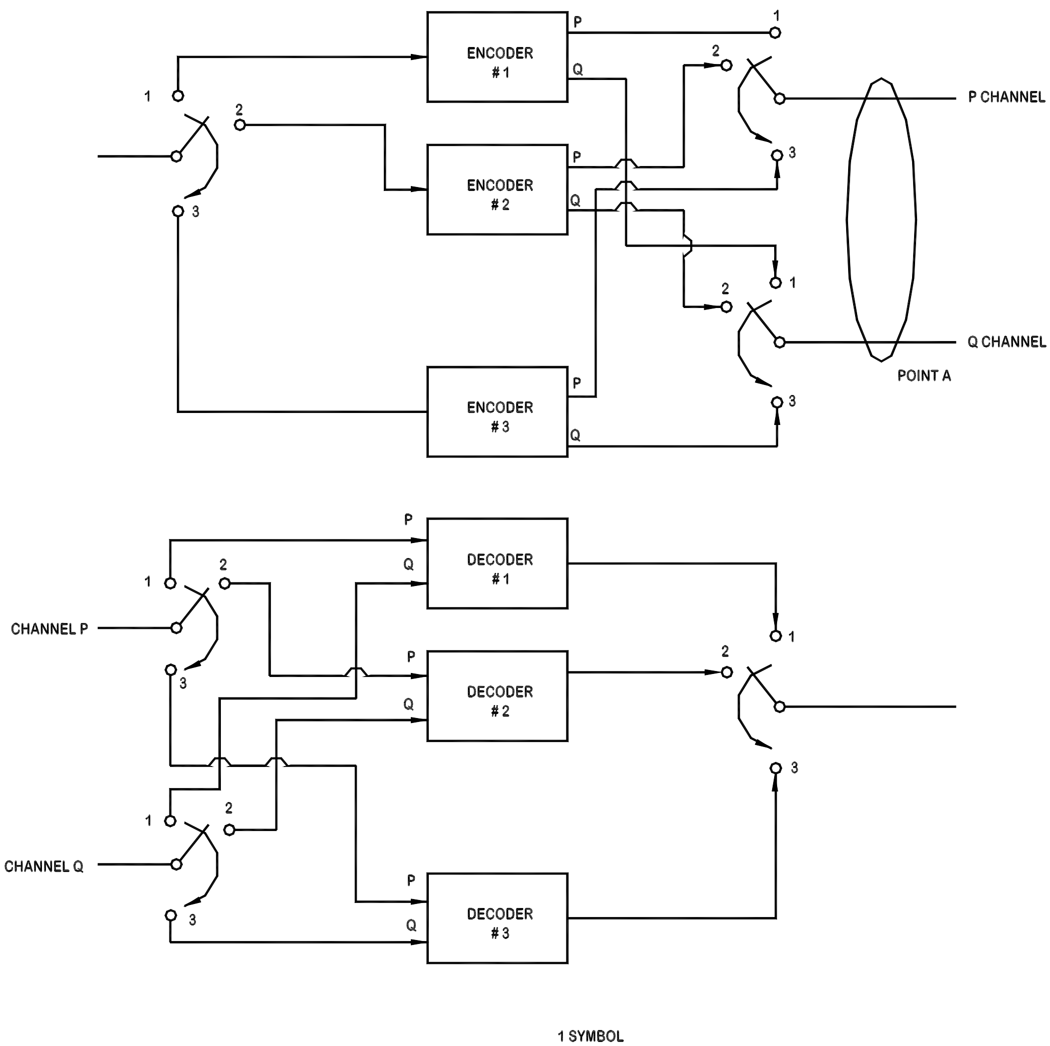


NOTES:

1. POINTS A THROUGH N CORRESPOND TO POINTS A THROUGH L IN FIGURE 5 MODULATOR FILTER AMPLITUDE RESPONSE
2. 0 dB RELATIVE POWER CORRESPONDS TO -10 LOG (R/2) dB/Hz RELATIVE TO THE UNMODULATED CARRIER POWER.

P:\CAD\IESS\308NEW\308-08.DWG
TITLE: POWER SPECTRAL DENSITY MASK AT MODULATOR OUTPUT

Figure 9
Configuration of Encoder and Decoder For
QPSK/IDR Carriers Greater Than 10 Mbit/s



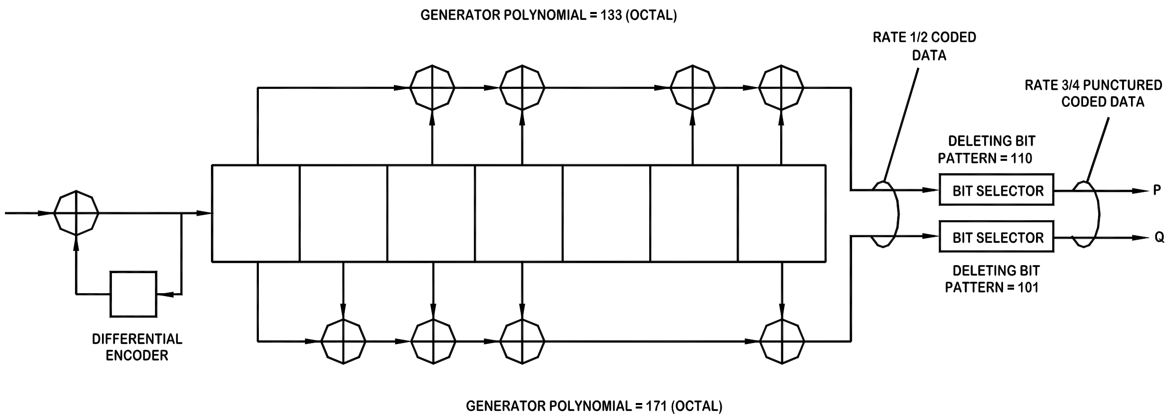
CHANNEL P	FROM ENCODER # 1	FROM ENCODER # 2	FROM ENCODER # 3	FROM ENCODER # 1	FROM ENCODER # 2
CHANNEL Q	FROM ENCODER # 1	FROM ENCODER # 2	FROM ENCODER # 3	FROM ENCODER # 1	FROM ENCODER # 2

SIGNAL FORMAT AT POINT A

P:\CAD\IESS\308NEW\308-09.DWG
TITLE: CONF. OF ENCODER AND DECODER FOR IDR CARRIERS GREATER THAN 10 Mbit/s

Figure 10

Convolutional Encoding Process Block Diagrams
For Use With Rate 3/4 FEC With Viterbi Decoding



RATE 3/4 FEC

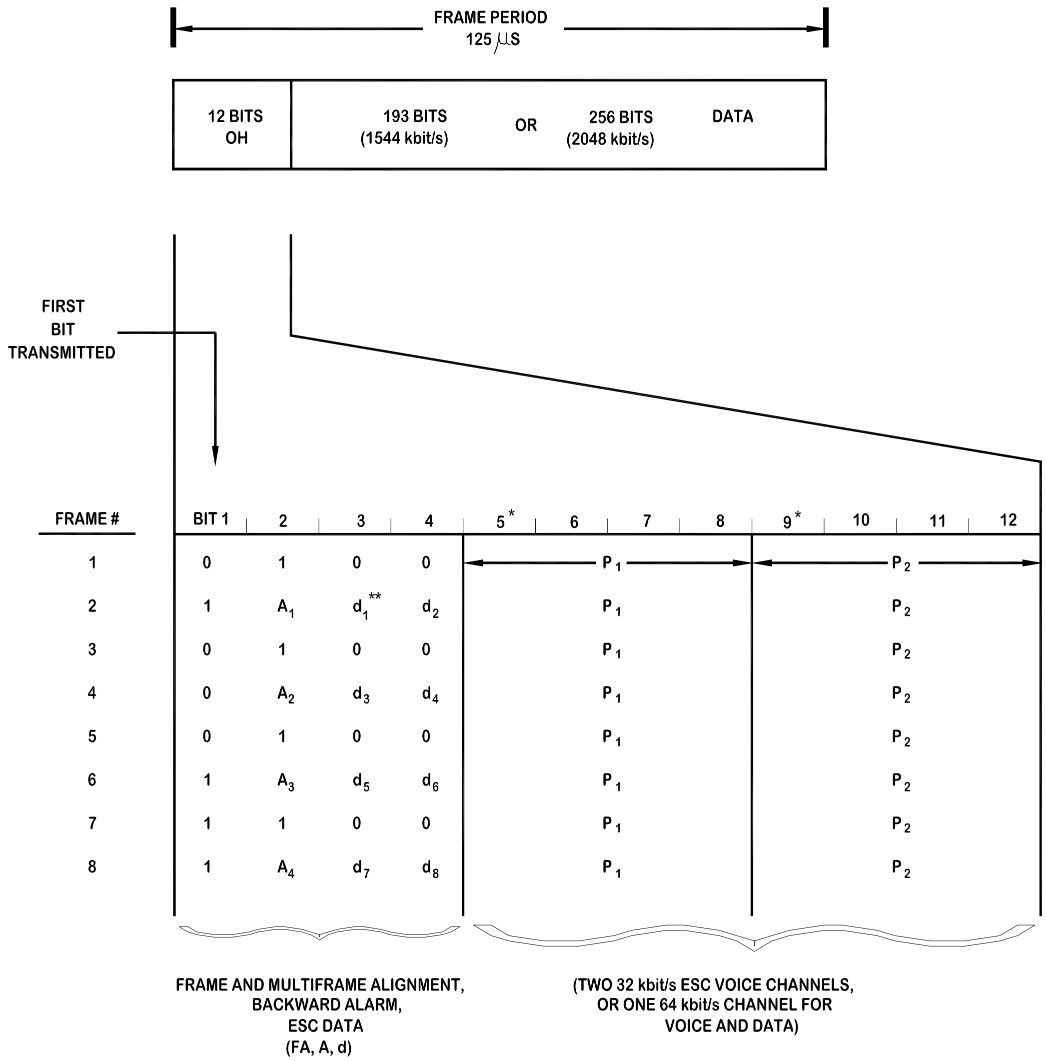
NOTES:

1. THE SYMBOL ⊕ DENOTES A MODULO-2 ADDER.
2. IN THE DELETING BIT PATTERN, 1 DENOTES TRANSMITTING AND 0 DENOTES DELETING.
3. THE RIGHT-MOST SHIFT REGISTER STAGE CORRESPONDS TO THE LEAST SIGNIFICANT BIT IN THE GENERATOR POLYNOMIAL.

P:\CAD\IESS\308NEW\308-10-R2.DWG
TITLE: CONVOLUTIONAL ENCODING PROCESS BLOCK DIAGRAMS FOR USE WITH VITERBI DECODING (3/4 FEC)

Figure 11

Overhead Structure for 1544 and 2048 kbit/s QPSK/IDR Carriers



P_i† = ESC VOICE CHANNEL i BITS (i = 1, 2); (SET TO 1 IF NOT USED)

A_i = BACKWARD ALARM TO DESTINATION i (i = 1, 2, 3, 4); NO ALARM = 0; ALARM = 1

d_i = ESC DIGITAL DATA (i = 1 TO 8); (SET TO 1 IF NOT USED)

8 FRAMES = 1 MULTI-FRAME (PERIOD = 1 ms)

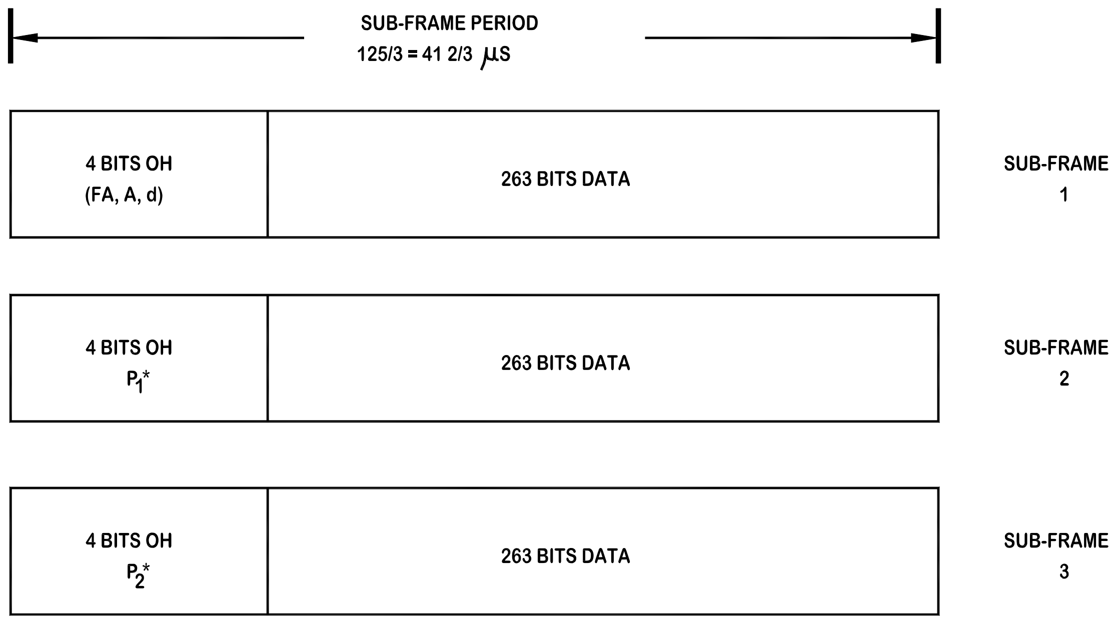
OH RATE = 12 BITS/125 μS = 96 kbit/s

* BITS 5 AND 9 IN THE OVERHEAD FRAME CORRESPOND TO THE FIRST BITS TRANSMITTED IN THE ESC VOICE CHANNELS.
** d_1 CORRESPONDS TO THE FIRST BIT TRANSMITTED IN THE ESC DATA CHANNEL.
† P_i WAS FORMERLY DESIGNATED BY V_i.

P:\CAD\IESS\308NEW\308-11-R2.DWG
TITLE: OVERHEAD STRUCTURE FOR 1544 AND 2048 kbit/s IDR CARRIERS

Figure 12

Overhead Structure for 6312 kbit/s QPSK/IDR Carriers



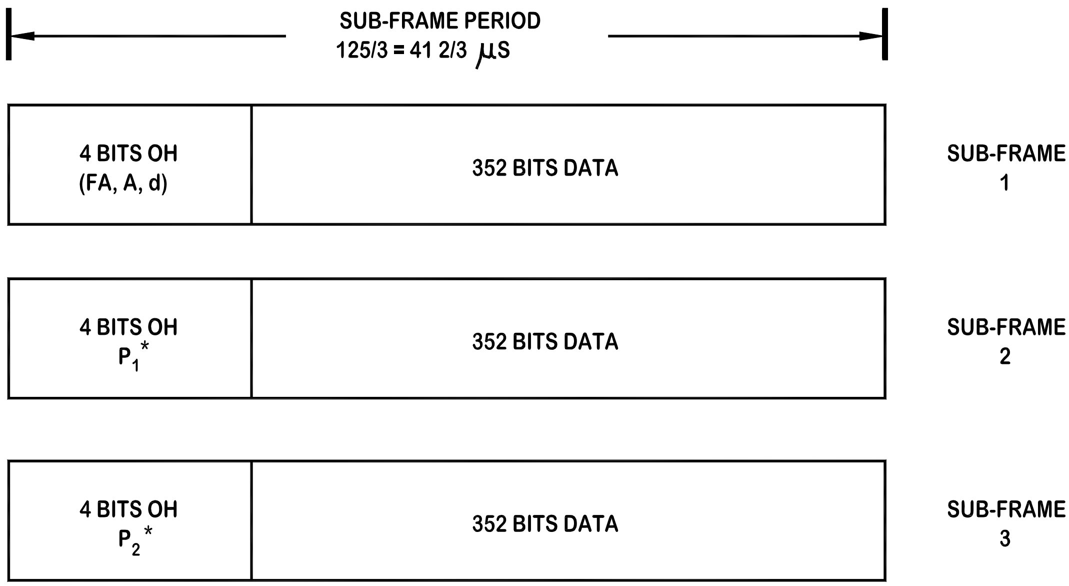
- 3 SUB-FRAMES = 1 FRAME (PERIOD = 125 µS)
- ALLOCATION OF OH BITS IS SAME AS 1544 AND 2048 kbit/s CASE.
- 8 FRAMES = 1 MULTI-FRAME (PERIOD = 1 ms)
- OH RATE = 12 BITS/125 µS = 96 kbit/s

* P_1 AND P_2 WERE FORMERLY DESIGNATED BY V_1 AND V_2 RESPECTIVELY.

P:\CAD\IESS\308NEW\308-12-R2.DWG
TITLE: OVERHEAD STRUCTURE FOR 6312 kbit/s IDR CARRIERS

Figure 13

Overhead Structure For 8448 kbit/s QPSK/IDR Carriers



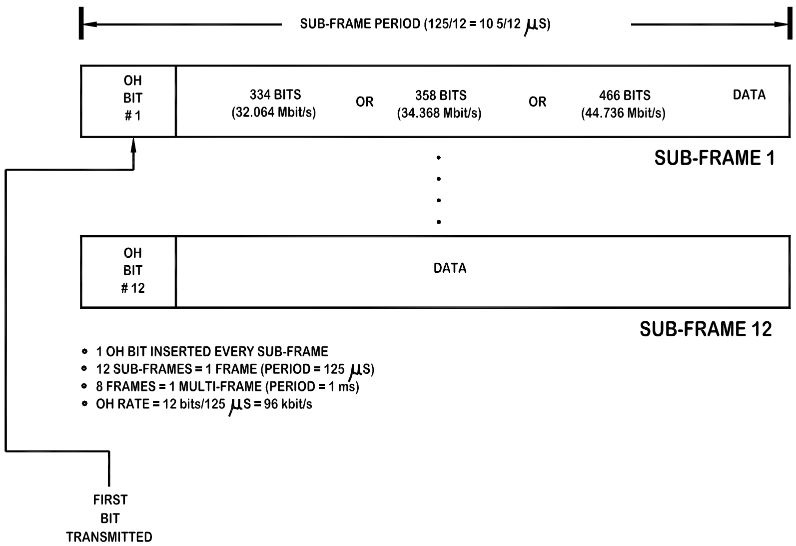
- 3 SUB-FRAMES = 1 FRAME (PERIOD = 125 μS)
- ALLOCATION OF OH BITS IS SAME AS 1544 AND 2048 kbit/s.
- 8 FRAMES = 1 MULTI-FRAME (PERIOD = 1 ms)
- OH RATE = 12 BITS/125 μS = 96 kbit/s

* P_1 AND P_2 WERE FORMERLY DESIGNATED BY V_1 AND V_2 RESPECTIVELY.

P:\CAD\IESS\308NEW\308-13-R2.DWG
TITLE: OVERHEAD STRUCTURE FOR 8448 kbit/s IDR CARRIERS

Figure 14

Overhead Structure For 32.064, 34.368 and 44.763 Mbit/s QPSK/IDR Carriers



ALLOCATION OF OH BITS

OH BIT # (SUB-FRAME #)

FRAME #	1	2	3	4	5*	6	7	8	9*	10	11	12
1	0	1	0	0	P_1				P_2			
2	1	A_1	d_1**	d_2	P_1				P_2			
3	0	1	0	0	P_1				P_2			
4	0	A_2	d_3	d_4	P_1				P_2			
5	0	1	0	0	P_1				P_2			
6	1	A_3	d_5	d_6	P_1				P_2			
7	1	1	0	0	P_1				P_2			
8	1	A_4	d_7	d_8	P_1				P_2			

P_i† = ESC VOICE CHANNEL i BITS (i = 1, 2); (SET TO 1 IF NOT USED)

A_i = BACKWARD ALARM TO DESTINATION i (i = 1, 2, 3, 4); NO ALARM = 0; ALARM = 1

d_i = ESC DIGITAL DATA (i = 1 TO 8); (SET TO 1 IF NOT USED)

8 FRAMES = 1 MULTI-FRAME (PERIOD = 1 ms)

OH RATE = 12 BITS/125 µS = 96 kbit/s

* BITS 5 AND 9 IN THE OVERHEAD FRAME CORRESPOND TO THE FIRST BITS TRANSMITTED IN THE ESC VOICE CHANNELS.

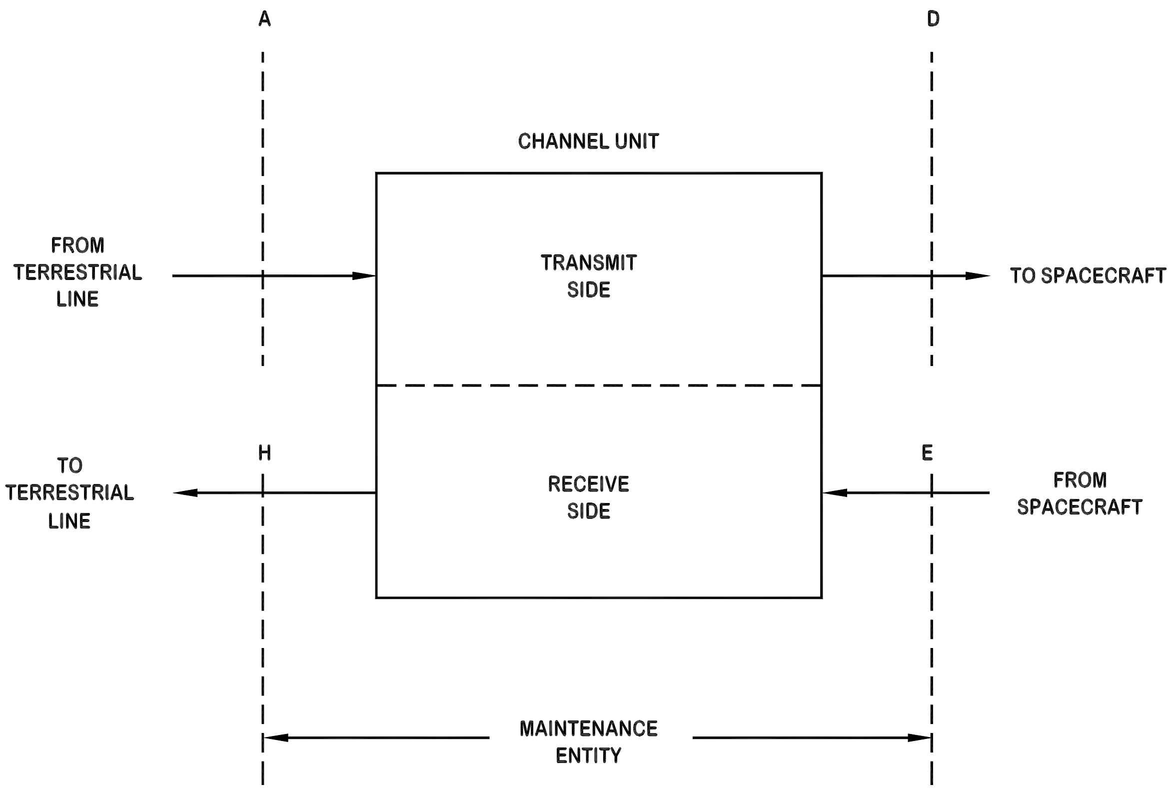
** d_1 CORRESPONDS TO THE FIRST BIT TRANSMITTED IN THE ESC DATA CHANNEL.

† P_i WAS FORMERLY DESIGNATED BY V_i.

P:\CAD\IESS\308NEW\308-14.DWG
TITLE: OVERHEAD STRUCTURE FOR 32.064, 34.368 AND 44.736 Mbit/s IDR CARRIERS

Figure 15

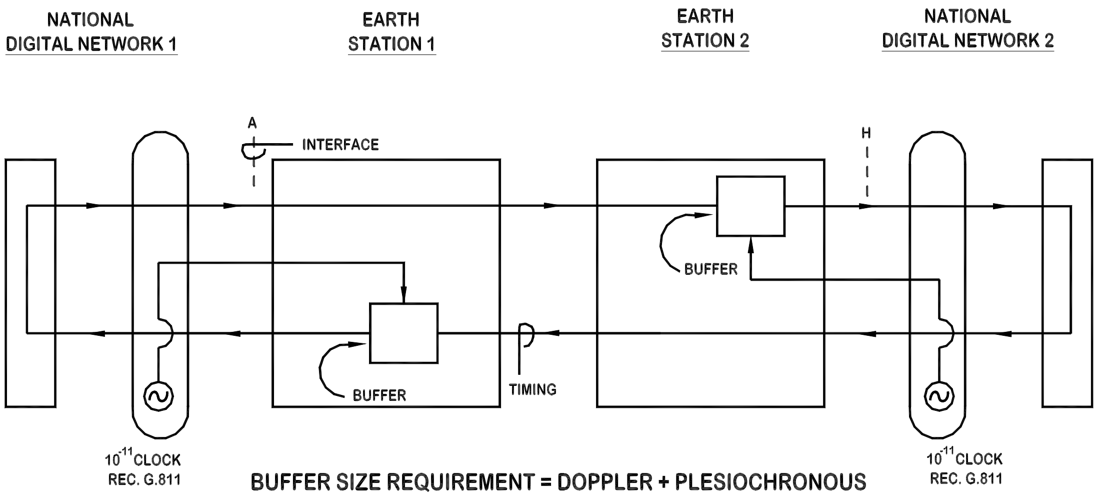
QPSK/IDR Alarm Concept



P:\CAD\IESS\308NEW\308-15.DWG
TITLE: IDR ALARM CONCEPT

Figure 16

Case 1. Example of Timing and Buffering Arrangements
(Digital Networks at Both Ends)

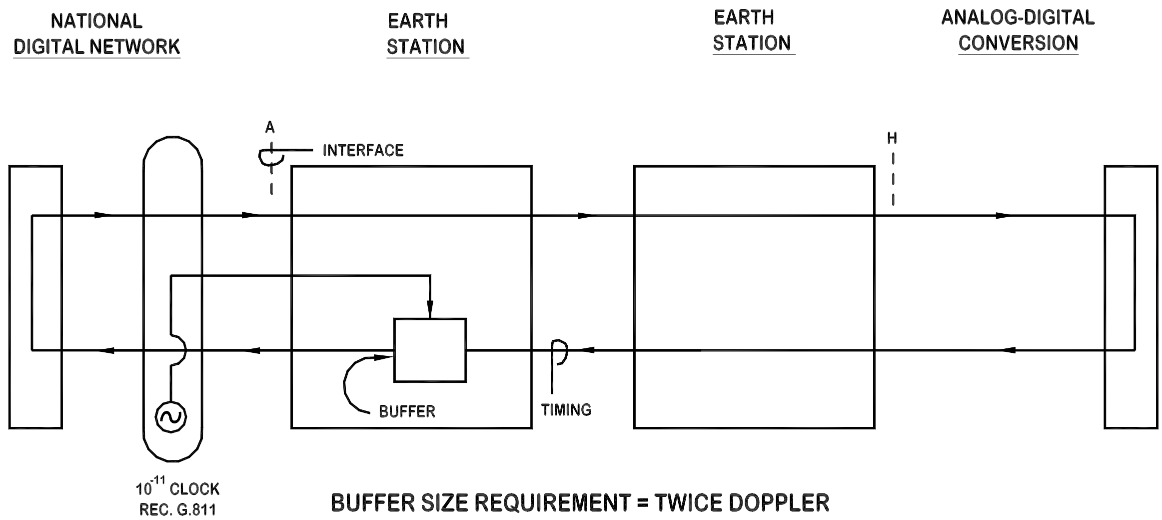


NOTE: THE BUFFER MAY OR MAY NOT BE LOCATED AT THE EARTH STATION

P:\CAD\IESS\308NEW\308-16.DWG
TITLE: CASE 1. EXAMPLE OF TIMING AND BUFFERING ARRANGEMENTS
(Digital Network at Both Ends)

Figure 17

Case 2. Example of Timing and Buffering Arrangements
(One End of the Link Remotely Timed From Other End)

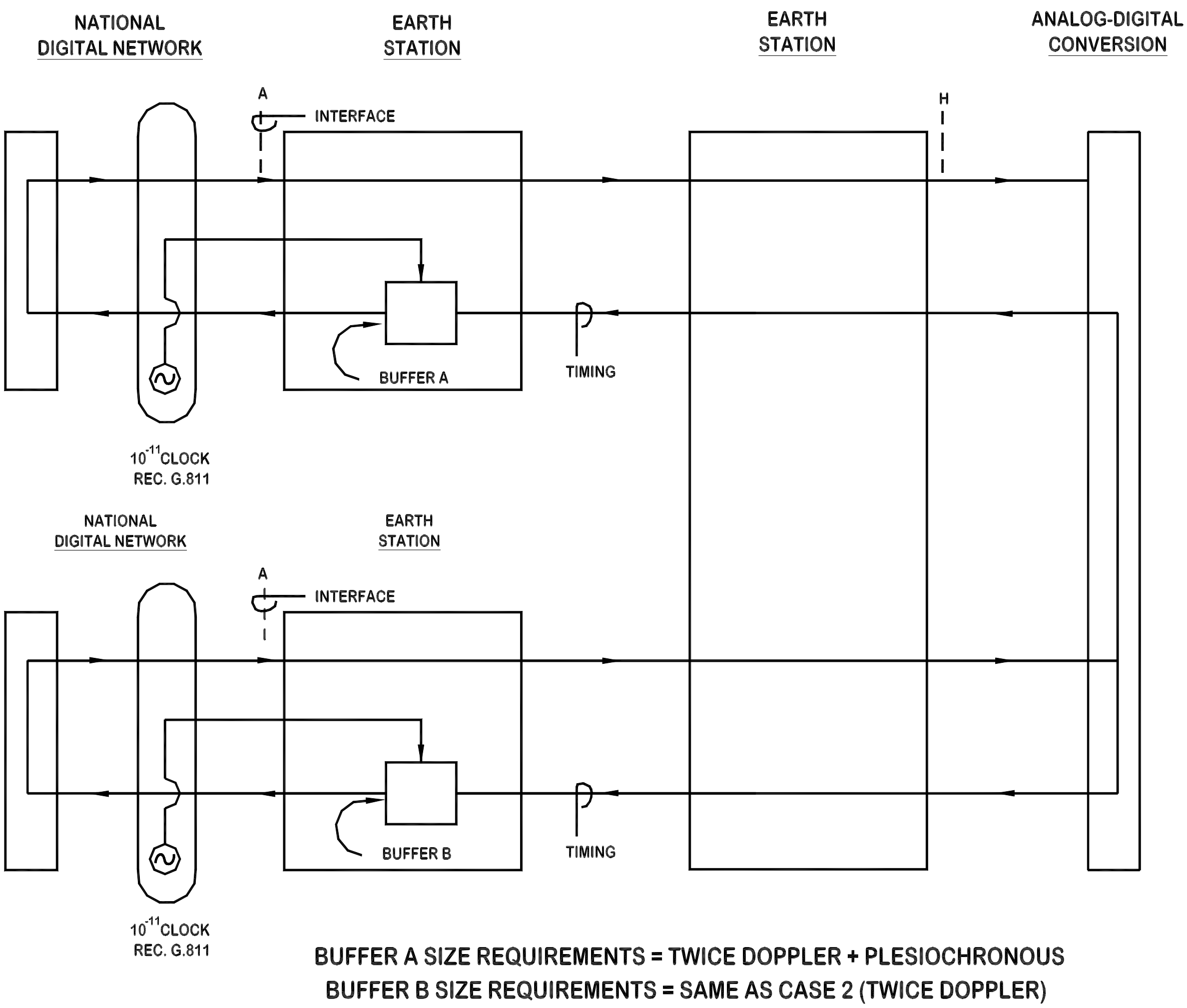


NOTE: THE BUFFER MAY OR MAY NOT BE LOCATED AT THE EARTH STATION

P:\CAD\IESS\308NEW\308-17.DWG
TITLE: CASE 2. EXAMPLE OF TIMING AND BUFFERING ARRANGEMENTS
(One End of the Link Remotely Timed From Other End)

Figure 18

Case 3. Example of Timing and Buffering Arrangements
(No Synchronous Digital Network at Either End and No Buffer Requirements)

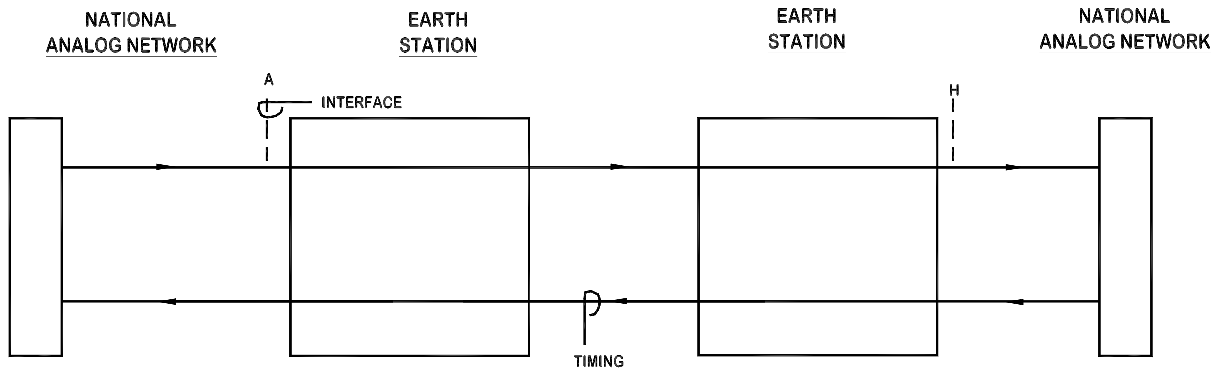


NOTE: THE BUFFER MAY OR MAY NOT BE LOCATED AT THE EARTH STATION

P:\CAD\IESS\308NEW\308-18.DWG
TITLE: CASE 3. EXAMPLE OF TIMING AND BUFFERING ARRANGEMENTS
(Recovered Timing From One Station is Used for Transmitting to Another Station)

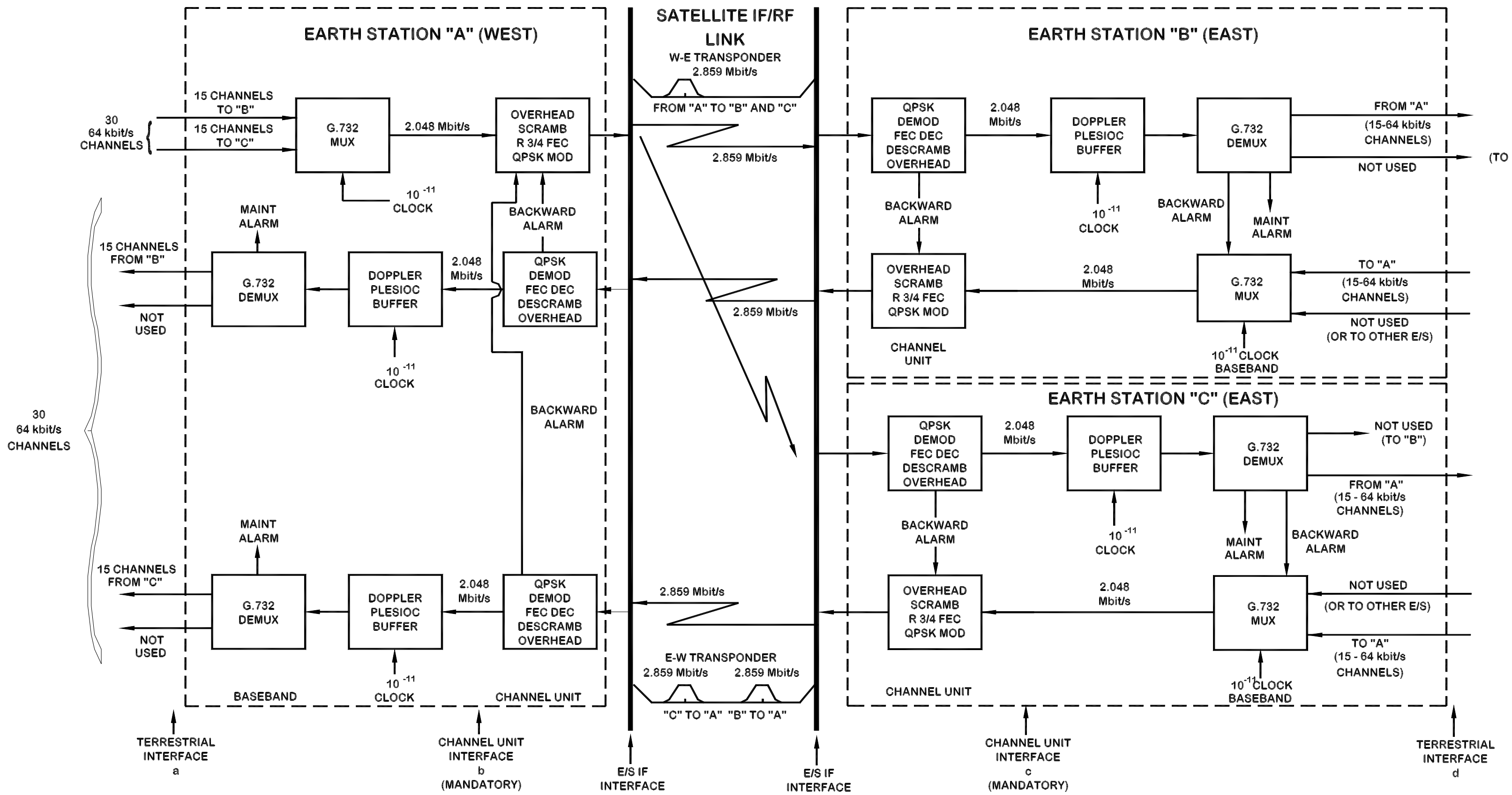
Figure 19

Case 4: No Buffering Required



P:\CAD\IESS\308NEW\308-19.DWG
TITLE: CASE 4. EXAMPLE OF TIMING AND BUFFERING ARRANGEMENTS
(No Synchronous Digital Network at Either End and No Buffer Requirements)

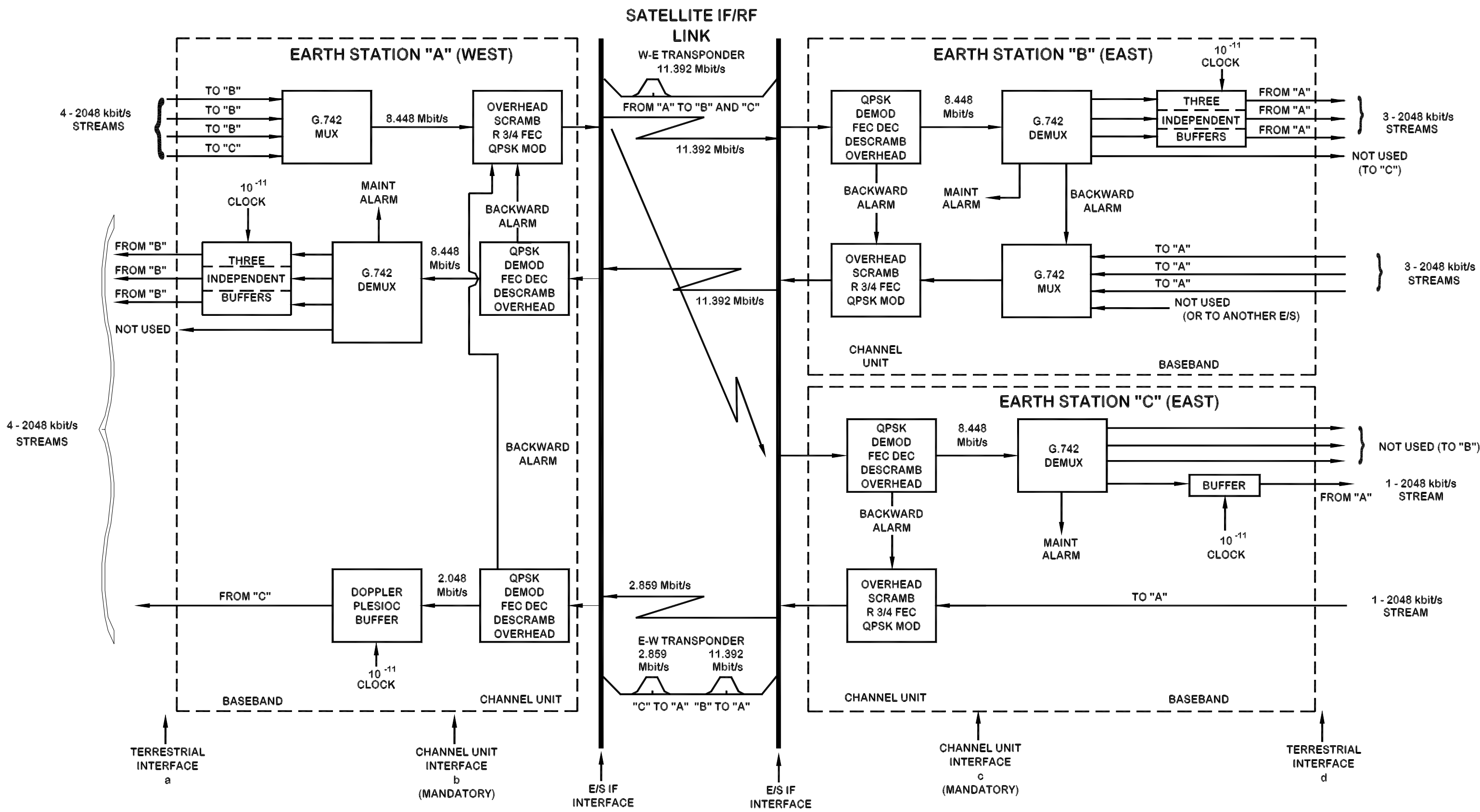
Figure 20
Illustration of Multi–Destinational QPSK/IDR Application
(Primary Order Carriers)



NOTE: THIS FUNCTIONAL BLOCK DIAGRAM IS INTENDED FOR ILLUSTRATION PURPOSES ONLY, AND IS NOT INTENDED TO PORTRAY ANY PARTICULAR PHYSICAL EQUIPMENT ARRANGEMENT OR THE TYPE OF TERRESTRIAL INTERFACE. FOR EXAMPLE, THE BUFFER COULD BE PART OF THE CHANNEL UNIT. THE MULTI-TIPLEX EQUIPMENT COULD ALSO BE ON THE TERRESTRIAL SIDE OF INTERFACES a AND d.

P:\CAD\IESS\308NEW\308-20.DWG
TITLE: ILLUSTRATION OF MULTI-DESTINATIONAL IDR APPLICATION
(Primary Order Carriers)

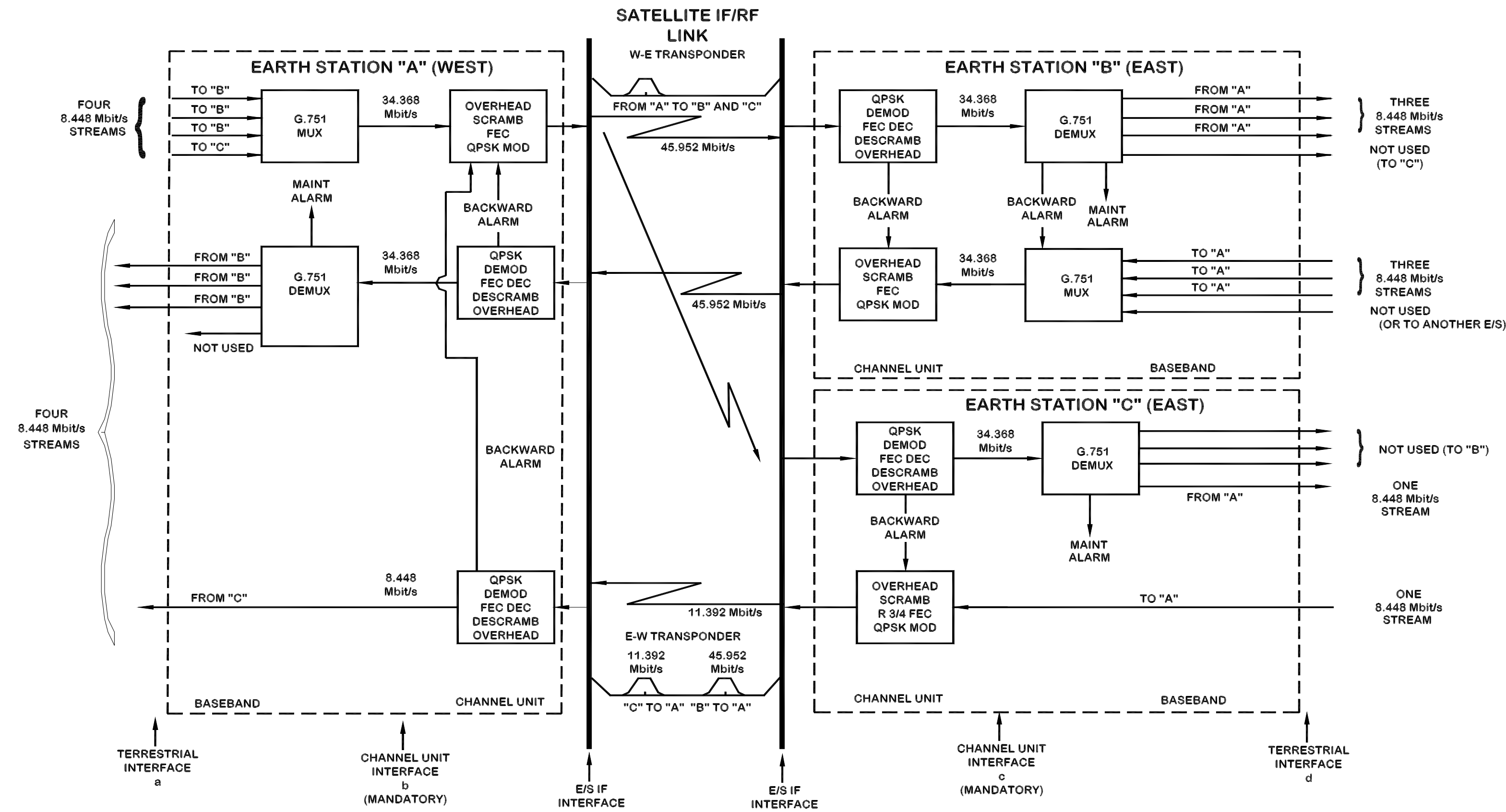
Figure 21
Illustration of Multi–Destinational QPSK/IDR Application
(Primary and Secondary Order Carriers)



NOTE: THIS FUNCTIONAL BLOCK DIAGRAM IS INTENDED FOR ILLUSTRATION PURPOSES ONLY, AND IS NOT INTENDED TO PORTRAY ANY PARTICULAR PHYSICAL EQUIPMENT ARRANGEMENT OR TYPE OF TERRESTRIAL INTERFACE. FOR EXAMPLE, THE HIGHER ORDER MULTIPLEXERS COULD BE TIMED FROM A CLOCK WITH 10^{-11} ACCURACY, IN WHICH CASE THE BUFFER COULD BE PART OF THE CHANNEL UNIT. THE MULTIPLEX EQUIPMENT COULD ALSO BE ON THE TERRESTRIAL SIDE OF INTERFACES a AND d.

P:\CAD\IESS\308NEW\308-21.DWG
TITLE: ILLUSTRATION OF MULTI-DESTINATIONAL IDR APPLICATION
(Primary and Second Order Carriers)

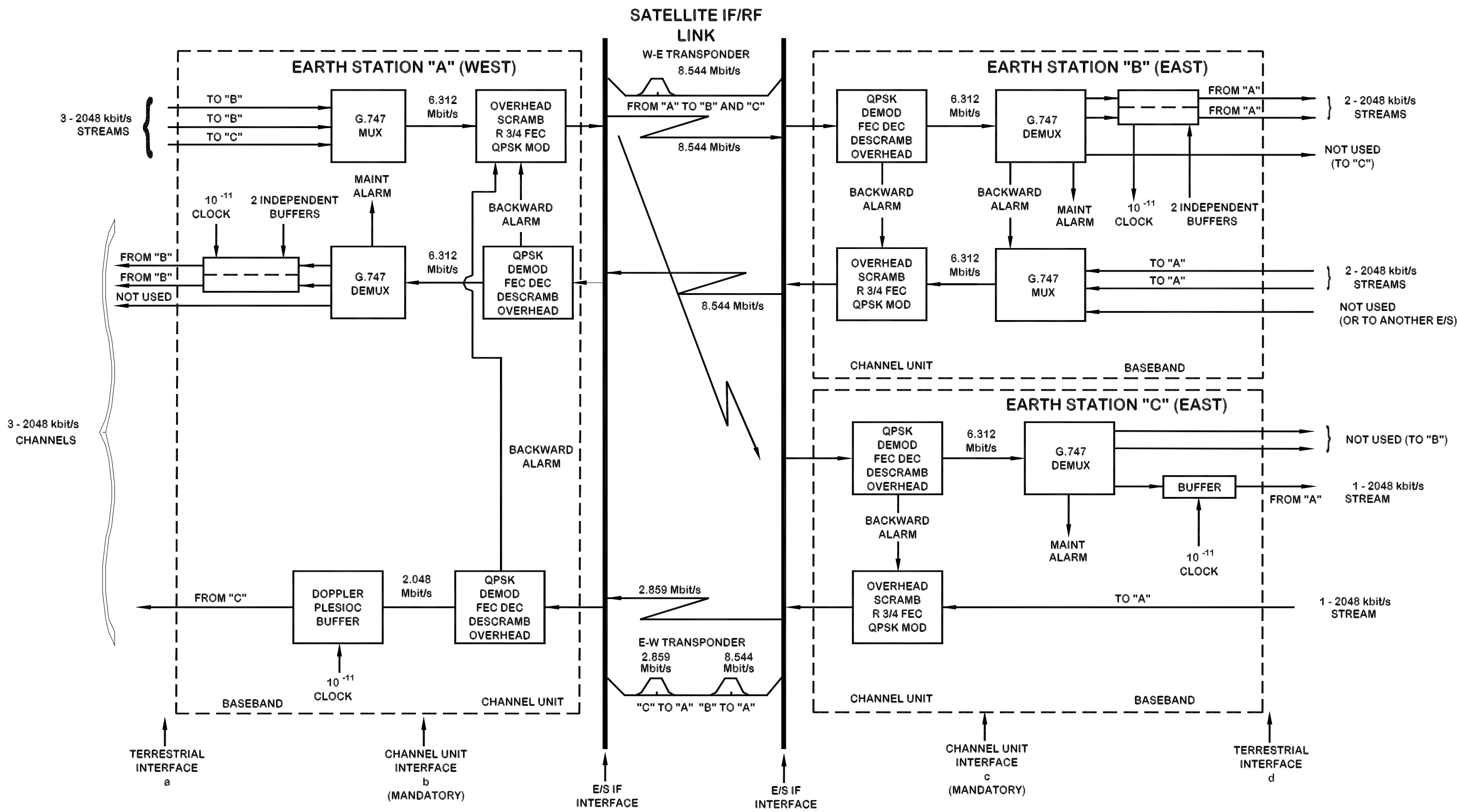
Figure 22
Illustration of Multi–Destinational QPSK/IDR Application
(Second and Third Order Carriers)



NOTE: THIS FUNCTIONAL BLOCK DIAGRAM IS INTENDED FOR ILLUSTRATION PURPOSES ONLY, AND IS NOT INTENDED TO PORTRAY ANY PARTICULAR PHYSICAL EQUIPMENT ARRANGEMENT OR TYPE OF TERRESTRIAL INTERFACE. FOR EXAMPLE, THE HIGHER ORDER MULTIPLEXERS COULD BE TIMED FOR A CLOCK WITH 10^{-11} ACCURACY, IN WHICH CASE THE BUFFER COULD BE PART OF THE CHANNEL UNIT. THE MULTIPLEX EQUIPMENT COULD ALSO BE ON THE TERRESTRIAL SIDE OF INTERFACES a AND d.

P:\CAD\IESS\308NEW\308-22.DWG
TITLE: ILLUSTRATION OF MULTI-DESTINATIONAL IDR APPLICATION
(Second and Third Order Carriers)

Figure 23
Illustration of Multi–Destinational QPSK/IDR Application
(Primary and Second Order Carriers Using the Interworking Hierarchy Bit Rates)



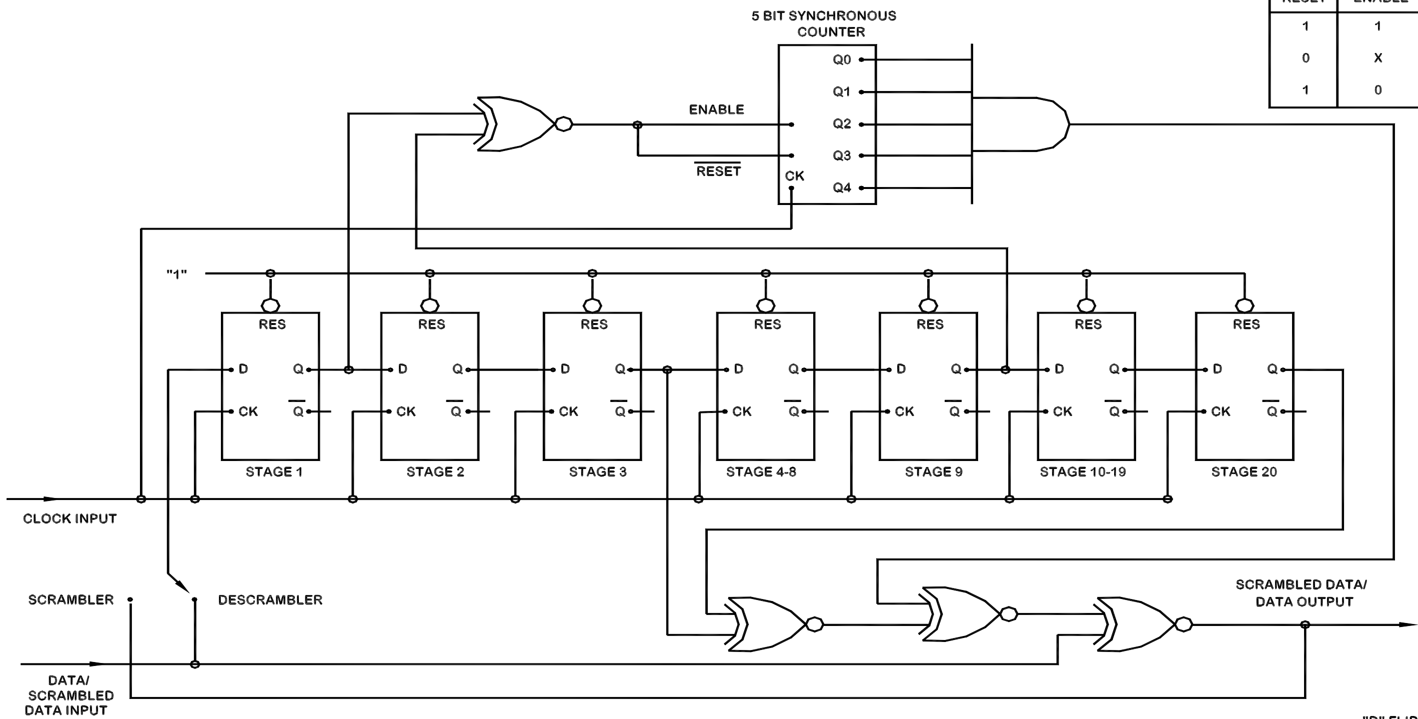
NOTE: THIS FUNCTIONAL BLOCK DIAGRAM IS INTENDED FOR ILLUSTRATION PURPOSES ONLY, AND IS NOT INTENDED TO PORTRAY ANY PARTICULAR PHYSICAL EQUIPMENT ARRANGEMENT OR TYPE OF TERRESTRIAL INTERFACE. FOR EXAMPLE, THE HIGHER ORDER MULTIPLEXERS COULD BE TIMED FROM A CLOCK WITH 10^{-11} ACCURACY, IN WHICH CASE THE BUFFER COULD BE PART OF THE CHANNEL UNIT. THE MULTIPLEX EQUIPMENT COULD ALSO BE ON THE TERRESTRIAL SIDE OF INTERFACES a AND d.

P:\CAD\IESS\308NEW\308-23.DWG
TITLE: ILLUSTRATION OF MULTI-DESTINATIONAL IDR APPLICATION
(Primary and Second Order Carriers Using the Interworking Hierarchy Bit Rates)

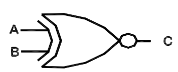
Figure 24
Scrambler / Descrambler Logic Diagram

5 BIT SYNCHRONOUS COUNTER

$\overline{RESET}$	ENABLE	CK	Qn
1	1	↑	COUNT
0	X	↑	0
1	0	↑	Qn

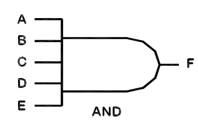


A	B	C
0	0	1
0	1	0
1	0	0
1	1	1



EXCLUSIVE NOR

A	B	C	D	E	F
1	1	1	1	1	1
0	X	X	X	X	0
X	0	X	X	X	0
X	X	0	X	X	0
X	X	X	0	X	0
X	X	X	X	0	0



AND

"D" FLIP-FLOP

RES	D	CK	Q	$\overline{Q}$
1	0	↑	0	1
1	1	↑	1	0
0	X	↑	0	1
X	X	↓	Q	$\overline{Q}$

P:\CAD\IESS\308NEW\308-24.DWG
TITLE: SCRAMBLER/DESCRAMBLER LOGIC DIAGRAM

Figure 25
Digital Impulse Response of the Descrambler

```
CLOCK               −25       −20       −15       −10       −5        0         +5        +10
PERIOD        . . . . + . . . . + . . . . + . . . . + . . . . + . . . . + . . . . + . . . . +

SCRAMBLED
DATA IN       X X X 1 00 0 0 0 00 0 0 0 00 0 0 0 00 0 0 0 00 0 0 0 10 0 0 0 00 0 0 0 0

DATA OUT      X X X X XX X X X XX X X X XX X X X XX X X X XX X X X 01 1 0 1 1 1 1 1 1 1

CLOCK               +15       +20       +25       +30       +35       +40       +45       +50
PERIOD        . . . . + . . . . + . . . . + . . . . + . . . . + . . . . + . . . . + . . . . +

SCRAMBLED
DATA IN       0 0 0 0 00 0 0 0 00 0 0 0 00 0 0 0 00 0 0 0 0 0 0 0 0 0 00 0 0 0 00 0 0 0 0

DATA OUT      1 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1

CLOCK               +55       +60       +65       +70       +75       +80       +85       +90
PERIOD        . . . . + . . . . + . . . . + . . . . + . . . . + . . . . + . . . . + . . . . +

SCRAMBLED
DATA IN       0 0 0 0 00 0 0 0 00 0 0 0 00 0 0 0 00 0 0 0 0 0 0 0 0 0 00 0 0 0 00 0 0 0 0

DATA OUT      1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
```

REPEATS EVERY 32ND BIT
THEREAFTER

NOTES:
1. X = EITHER 1 OR 0 (DON'T CARE)
2. THE PURPOSE OF THE DIGITAL "ONE" FOLLOWED BY 25 "ZEROES" BEGINNING AT CLOCK PERIOD -26
IS TO RESET THE 5-BIT COUNTER AND "FLUSH-OUT" THE 20-STAGE SHIFT REGISTER.

P:\CAD\IESS\308NEW\308-25.DWG
TITLE: DIGITAL IMPULSE RESPONSE OF THE DESCRAMBLER