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**INTELSAT EARTH STATION STANDARDS (IESS)**

**Document IESS–310 (Rev. 3)**

PERFORMANCE CHARACTERISTICS FOR INTERMEDIATE  
DATA RATE DIGITAL CARRIERS USING RATE 2/3 TCM/8PSK  
AND REED–SOLOMON OUTER CODING  
(TCM/IDR)

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

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TABLE OF CONTENTS

<u>SECTION</u>	<u>TITLE</u>	<u>PAGE</u>
1.	INTRODUCTION.....	1
1.1	Interim Operation of TCM/IDR on Intelsat VI.....	1
2.	TRELLIS–CODED MODULATION/INTERMEDIATE DATA RATE (TCM/IDR) DIGITAL CARRIER SYSTEM REQUIREMENTS, GENERAL .....	1
2.1	TCM/IDR Performance .....	2
2.2	Additional G/T Requirement For Ku–Band IDR Services Operating Under Adverse Local Weather Conditions .....	3
3.	EQUIVALENT ISOTROPICALLY RADIATED POWER (EIRP).....	4
3.1	EIRP Correction Factors .....	4
3.2	EIRP Adjustment .....	4
3.3	EIRP Stability .....	5
3.3.1	Clear Sky.....	5
3.3.2	Adverse Weather Conditions.....	5
3.4	Transponder Gain Step (Intelsat VII, VIIA, VIII and IX) .....	6
4.	EMISSION CONSTRAINTS .....	6
4.1	Spurious Emissions Within The Satellite Band (5,850 to 6,425 MHz and 14,000 to 14,500 MHz).....	6
4.1.1	Spurious Emissions (Except Intermodulation Products).....	6
4.1.2	Spurious Emissions – Intermodulation Products .....	7
4.1.3	RF Out–of–Band Emission (Carrier Spectral Sidelobes).....	7
4.2	Unwanted Emissions Outside The Satellite Band .....	7
4.2.1	Out–Of–Band (OOB) Emissions.....	8
4.2.2	Spurious Emissions in the Spurious Domain – For Earth Stations Brought Into Service After 1 January 2003.....	8
4.2.3	Spurious Emissions in the Spurious Domain – For All Earth Stations After 1 January 2012 .....	8
5.	FREQUENCY TOLERANCES AND SPECTRUM INVERSION .....	8
5.1	Carrier RF Tolerance.....	8
5.2	Satellite Transponder Frequency Tolerance .....	9
5.3	Spectrum Inversion .....	9
6.	AMPLITUDE AND GROUP DELAY EQUALIZATION .....	9
6.1	Earth Station.....	9

TABLE OF CONTENTS

<u>SECTION</u>	<u>TITLE</u>	<u>PAGE</u>
6.2	Satellite Channel .....	9
7.	PHASE NOISE .....	10
7.1	Earth Station (Transmit) .....	10
7.2	Earth Station (Receive) .....	10
8.	TRANSMISSION PARAMETERS .....	10
9.	CHANNEL UNIT CHARACTERISTICS .....	11
9.1	Modulator .....	12
9.1.1	Output Characteristics .....	12
9.1.2	Modulator Spectrum Output .....	12
9.2	Demodulator .....	13
9.2.1	Operating Conditions .....	13
9.2.2	Demodulator Filter Characteristics .....	14
9.3	Forward–Error Correction (FEC) .....	14
9.3.1	Rate 2/3 Pragmatic TCM Encoder .....	14
9.3.2	Rate 2/3 TCM Decoder .....	15
9.3.3	Reed–Solomon (RS) Outer Coding .....	15
9.4	Energy Dispersal (Scrambling) .....	15
9.5	Bit Error Rate Performance Characteristics .....	16
9.5.1	IF–to–IF Loopback .....	16
9.5.2	IF–to–RF Degradation .....	16
9.5.3	Modem Performance (Without RS Outer Coding) .....	17
9.6	Overhead Framing for ESC and Alarms .....	17
9.6.1	Overhead Frame Structure .....	17
9.6.2	Frame and Multiframe Alignment .....	19
9.6.3	Maintenance Alarm Concept for the TCM/IDR Channel Unit (With 96 kbit/s ESC Overhead) .....	19
9.6.4	Fault Conditions and Consequent Actions (For Carriers with 96 kbit/s ESC Overhead) .....	20
9.6.4.1	Definition of AIS (Alarm Indication Signal) .....	21
9.7	Timing Jitter .....	21
10.	BUFFERING, TIMING AND SLIP CONTROL .....	21
10.1	Transmission Delay Variation .....	21

TABLE OF CONTENTS

<u>SECTION</u>	<u>TITLE</u>	<u>PAGE</u>
10.2	Timing Accuracy .....	22
10.3	Buffer Capacity .....	22
10.4	Buffer Location .....	23
10.5	Slip Control .....	23
11.	BASEBAND CHARACTERISTICS .....	23
11.1	Digital Hierarchies and Information Rates .....	24
11.2	Single–Destinational (SD) Operation .....	24
11.3	Multi–Destinational (MD) Operation .....	24
11.3.1	Examples .....	24
11.3.2	Multiplex/Demultiplex Characteristics for Multi–Destinational Operation .....	25
11.3.2.1	1.544 Mbit/s Bit Streams .....	26
11.3.2.2	2.048 Mbit/s Bit Streams .....	26
11.3.2.3	6.312 Mbit/s Bit Streams .....	26
11.3.2.4	8.448 Mbit/s Bit Streams .....	26
11.3.2.5	34.368 Mbit/s Bit Streams .....	27
11.3.2.6	32.064 and 44.736 Mbit/s Bit Streams .....	27
11.3.2.7	Fault Conditions and Consequent Actions Related to Multiplex Equipment (Backward Alarm) .....	27
11.3.2.8	Circuit Supervision for Multi–Destinational 2.048 Mbit/s Streams not Using LRE/DSI .....	27
11.4	Signalling .....	28
11.5	Voice Channel Interfaces .....	28
11.5.1	PCM Encoding .....	28
11.5.2	Echo Protection .....	28
11.6	LRE/DSI Interface .....	29
12.	CARRIER LINE–UP AND IN–SERVICE MONITORING .....	29

	<u>LIST OF TABLES</u>	<u>PAGE</u>
Table 1	INTELSAT-RECOMMENDED TCM/IDR INFORMATION RATES and ASSOCIATED OVERHEAD [Rate 2/3 TCM/8PSK With Mandatory RS (219, 201) Outer Coding].....	30
Table 2	TCM/IDR PERFORMANCE [G.826 Plus Quality, Intelsat VII/VIA, VIII & IX] .....	31
Table 3	EARTH STATION EQUALIZATION REQUIRED FOR SATELLITE GROUP DELAY .....	32
Table 4	FAULT CONDITIONS AND CONSEQUENT ACTIONS.....	33
Table 5	INTELSAT SATELLITE DELAY PARAMETERS (For Nominal Satellite Stationkeeping Limits).....	34
Table 6	MINIMUM DOPPLER/PLESIOCHRONOUS BUFFER CAPACITY REQUIREMENTS .....	35
Table 7	ITU-T DIGITAL HIERARCHIES FOR USE WITH RECOMMENDED INTELSAT CARRIERS .....	36
Table 8	INTELSAT MULTIPLEX CHARACTERISTICS FOR MULTI- DESTINATIONAL OPERATION .....	37
Table 9	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.....	38

	<u>LIST OF FIGURES</u>	<u>PAGE</u>
Figure 1	ILLUSTRATION OF TCM/IDR CHANNEL UNIT (Small TCM/IDR Carriers < 1.544 Mbit/s, No Overhead Framing) .....	39
Figure 2	ILLUSTRATION OF TCM/IDR CHANNEL UNIT (Small TCM/IDR Carriers < 1.544 Mbit/s, With IBS Overhead Framing).....	40
Figure 3	ILLUSTRATION OF TCM/IDR CHANNEL UNIT (TCM/IDR Carriers $\geq$ 1.544 Mbit/s, With Optional 96 kbit/s ESC Overhead Framing) .....	41
Figure 4	EARTH STATION IF AND RF AMPLITUDE RESPONSE.....	42
Figure 5	EARTH STATION IF AND RF GROUP DELAY RESPONSE .....	43
Figure 6	CONTINUOUS SINGLE SIDEBAND PHASE NOISE REQUIREMENT (For Carriers With Information Rates Less Than Or Equal To 2.048 Mbit/s).....	44
Figure 7	MODULATOR FILTER AMPLITUDE RESPONSE .....	45
Figure 8	DEMODULATOR FILTER AMPLITUDE RESPONSE .....	46
Figure 9	MODULATOR AND DEMODULATOR FILTER GROUP DELAY RESPONSE .....	47
Figure 10	POWER SPECTRAL DENSITY MASK AT MODULATOR OUTPUT .....	48
Figure 11	RATE 2/3 PRAGMATIC TRELLIS-CODED MODULATION (TCM) ENCODING PROCESS BLOCK DIAGRAM.....	49
Figure 12	OVERHEAD STRUCTURE FOR 1544 AND 2048 kbit/s TCM/IDR CARRIERS .....	50
Figure 13	OVERHEAD STRUCTURE FOR 6312 kbit/s TCM/IDR CARRIERS.....	51
Figure 14	OVERHEAD STRUCTURE FOR 8448 kbit/s TCM/IDR CARRIERS.....	52
Figure 15	OVERHEAD STRUCTURE FOR 32.064, 34.368 and 44.736 Mbit/s TCM/IDR CARRIERS .....	53
Figure 16	TCM/IDR ALARM CONCEPT.....	54
Figure 17	CASE 1. EXAMPLE OF TIMING AND BUFFERING ARRANGEMENTS (Digital Network at Both Ends) .....	55
Figure 18	CASE 2. EXAMPLE OF TIMING AND BUFFERING ARRANGEMENTS (One End of the Link Remotely Timed From Other End).....	56
Figure 19	CASE 3. EXAMPLE OF TIMING AND BUFFERING ARRANGEMENTS (Recovered Timing From One Station is Used for Transmitting to Another Station) .....	57
Figure 20	CASE 4: EXAMPLE OF TIMING AND BUFFERING ARRANGEMENTS (No Synchronous Digital Network at Either End and No Buffer Requirements) .....	58
Figure 21	ILLUSTRATION OF MULTI-DESTINATIONAL TCM/IDR APPLICATION (Primary Order Carriers) .....	59

	<u>LIST OF FIGURES</u>	<u>PAGE</u>
Figure 22	ILLUSTRATION OF MULTI-DESTINATIONAL TCM/IDR APPLICATION (Primary and Secondary Order Carriers) .....	60
Figure 23	ILLUSTRATION OF MULTI-DESTINATIONAL TCM/IDR APPLICATION (Second and Third Order Carriers) .....	61
Figure 24	ILLUSTRATION OF MULTI-DESTINATIONAL TCM/IDR APPLICATION (Primary and Second Order Carriers Using the Interworking Hierarchy Bit Rates).....	62
Figure 25	SCRAMBLER/DESCRAMBLER LOGIC DIAGRAM.....	63
Figure 26	DIGITAL IMPULSE RESPONSE OF THE DESCRAMBLER.....	64

LIST OF APPENDICES

<u>APPENDIX</u>	<u>TITLE</u>
A	ITU REFERENCES
B	SMALL TCM/IDR CARRIER TRANSMISSION WITH CIRCUIT MULTIPLICATION (Information Rates < 1.544 Mbit/s)
C	TRANSMISSION PARAMETERS FOR INTELSAT VII, VIII and IX [Rate 2/3 TCM/8PSK IDR and RS (219, 201) Outer Coding]
D	PROPAGATION FADE MARGINS AND MAXIMUM EIRP TABLES FOR INTELSAT VII [Rate 2/3 TCM/8PSK IDR and RS (219, 201) Outer Coding]
E	PROPAGATION FADE MARGINS AND MAXIMUM EIRP* TABLES FOR INTELSAT VIIA [Rate 2/3 TCM/8PSK IDR and RS (219, 201) Outer Coding]
F	PROPAGATION FADE MARGINS AND MAXIMUM EIRP* TABLES FOR INTELSAT VIII [Rate 2/3 TCM/8PSK IDR and RS (219, 201) Outer Coding]
G	PROPAGATION FADE MARGINS AND MAXIMUM EIRP* TABLES FOR INTELSAT IX [Rate 2/3 TCM/8PSK IDR and RS (219, 201) Outer Coding]
H	REED-SOLOMON (RS) OUTER CODING FOR TCM/IDR
I	METHODOLOGY FOR CALCULATING EXCESS DOWNLINK DEGRATION (X FACTOR) AT Ku-BAND
J	REVISION HISTORY

INTELSAT EARTH STATION STANDARDS (IESS)

PERFORMANCE CHARACTERISTICS FOR INTERMEDIATE  
DATA RATE DIGITAL CARRIERS USING RATE 2/3 TCM / 8PSK  
AND REED-SOLOMON OUTER CODING  
(TCM/IDR)

1. INTRODUCTION

This document provides the performance characteristics of intermediate data rate digital carriers which use trellis-coded modulation (TCM) / 8PSK with mandatory Reed-Solomon outer coding (i.e., TCM/IDR) for operation with Standard A, B, C, E and F earth stations on Intelsat VII, VIII and IX. [The performance characteristics of IDR carriers which use the conventional convolutional encoding/Viterbi decoding and coherent QPSK modulation (i.e., QPSK/IDR) are provided in module IESS-308.]

1.1 Interim Operation of TCM/IDR on Intelsat VI

As indicated above, TCM/IDR is defined for operation only on Intelsat VII, VIIA, VIII and IX. As an interim measure, however, TCM/IDR operation will be utilized on Intelsat VI to facilitate the replacement of QPSK/IDR carriers in preparation for the transition to Intelsat IX. Intelsat VI TCM/IDR carriers will be assigned the identical space segment EIRP resources as those currently used for QPSK/IDR (refer to IESS-308, Section 2.1.1.1). 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. The resultant clear-sky BER performance of TCM/IDR on Intelsat VI, however, will be superior to that achieved today for QPSK/IDR.

2. TRELLIS-CODED MODULATION/INTERMEDIATE DATA RATE  
(TCM/IDR) DIGITAL CARRIER SYSTEM REQUIREMENTS, GENERAL

Trellis-coded modulation (TCM) intermediate data rate (TCM/IDR) digital carriers in the Intelsat system utilize coherent 8PSK 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). For TCM/IDR, the FEC comprises an inner Rate 2/3 Pragmatic TCM encoder/TCM decoder concatenated with a mandatory Reed-Solomon (219, 201) outer code. (See Section 9.3 for FEC requirements.)

Pragmatic TCM encoding is a patented technique (refer to U.S. Patent Nos. 2,233,630 and 5,469,452) which uses the standard  $k = 7$  convolutional code of

rate 1/2 in conjunction with supplementary circuitry to generate TCM-encoded information.

Any information rate from 64 kbit/s to 44.736 Mbit/s, inclusive, may be transmitted. Intelsat has defined, however, a set of recommended information rates which 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 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 TCM/IDR carriers is approximately equal to 0.333 times the transmission rate†. To provide a guardband between adjacent carriers, the nominal satellite bandwidth (i.e., allocated bandwidth) unit is approximately equal to 0.467 times the transmission rate. The actual carrier spacing will be determined by Intelsat, based on the particular transponder frequency plan.

IF equipment should be configured for maximum flexibility since changes in service patterns may require the relocation of carriers. Stations equipped with synthesizers should be capable of transmitting and receiving carriers whose frequency spacings are multiples of 22.5 kHz (for carriers with information rates up to and including 10 Mbit/s). Frequency spacings based on 125 kHz should be used for information rates above 10 Mbit/s, but can also be used for data rates as low as 2.048 Mbit/s. Actual operating carrier frequencies will be determined in consultation with Intelsat.

## 2.1 TCM/IDR Performance

TCM/IDR carriers have been designed to provide a service in accordance with Recommendations ITU-R S.522-4, ITU-R S.1062\* and ITU-R S.579-2. Intelsat has designed the transmission links to ensure that the BER performance of TCM/IDR carriers will meet the requirements of Note 2 of Recommends 3 of Rec. ITU-R S.1062 (see Table 2).

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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 TCM/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 8PSK modulator at the earth station (i.e., after the addition of any overhead or forward error correction (FEC) coding) and is equal to three times the symbol rate at the output of the 8PSK modulator. Figures 1 through 3 provide block diagrams of the TCM/IDR channel units and illustrate the definitions of information rate, transmission rate and symbol rate.
  - ‡ 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.

## 2.2 Additional G/T Requirement For Ku-Band 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 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 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 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 D 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:

$$\text{Standard C: } G/T \geq 37.0 + 20 \log_{10} f/11.2 + X \text{ dB, dB/K}$$

$$\text{Standard E-3: } G/T \geq 34.0 + 20 \log_{10} f/11.0 + X \text{ dB, dB/K}$$

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

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

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 D through G for the same percentage of time. (See Appendix I 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. For elevation angles other than 10° and earth station locations other than at satellite antenna beam edge, the correction factors  $K_1$  and  $K_2$  given in IESS–402 (EIRP Correction Factors) can be used.

Users should note that Intelsat may from time to time either change the location of a satellite or require an earth station to transfer operations from one satellite to another. In either case, the change may result in new correction factors such that the EIRP requirements will be increased, but within the limits of Appendices D 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 which 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  $\pm 0.5$  dB (for Standard A, B and C stations) and to within  $\pm 1.5$  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 a 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 D through G.

It is the user's responsibility to decide whether the above requirement is to be met by provision of diversity earth stations or by 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 transmitter power should be applied to restore the power flux density at the satellite to  $-1.5$  dB,  $\pm 1.5$  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 IX spacecraft in the 11 GHz frequency band and on the 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.

3.4 Transponder Gain Step (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 2 dB per step). Intelsat will use these gain adjustments to optimize transponder operation for various frequency plans as they may occur over the lifetime of the spacecraft.

4. EMISSION CONSTRAINTS

4.1 Spurious Emissions Within The Satellite Band (5,850 to 6,425 MHz 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 TCM/IDR carriers are not activated (carrier "off") shall not exceed 4 dBW/4 kHz anywhere within the following frequency ranges:

<u>Operating Satellite</u>	<u>Frequency Range</u>
Intelsat VII and VIIA	5,925 to 6,425 MHz 14,000 to 14,500 MHz

\* 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).

Intelsat 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 TCM/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 unit allocated for each carrier resulting 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 when 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 0.233 R to 0.333 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, 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 so as 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  $\pm 0.025 R$  Hz up to a maximum of  $\pm 3.5$  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  $\pm 3.5$  kHz.

## 5.2 Satellite Transponder Frequency Tolerance

The translation frequency tolerance due to the satellite should be assumed to be no worse than  $\pm 25$  kHz for the Intelsat VII, VIIA, VIII and IX satellites over their lifetime. The translation frequency tolerance over any one month is typically about  $\pm 2.5$  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 4 and Figure 5.

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 4 and Figure 5.

## 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. Transmit earth stations shall be equipped, however, for the limits shown in Table 3 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 TCM/IDR carriers with occupied bandwidths greater than 10 MHz.

Table 3 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 6. 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  $0.2 R$  Hz away from the center frequency, where  $R$  is the transmission rate in bits per second, shall not exceed 2.0 degrees RMS. (The total phase noise due to both sidebands shall not exceed 2.8 degrees RMS).

The option of satisfying either of two limits has been given to recognize the possibility that the phase noise spectrum can have various distributions which, when integrated, will have the same overall effect.

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

### 7.2 Earth Station (Receive)

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

## 8. TRANSMISSION PARAMETERS

The transmission parameters for Intelsat's recommended TCM/IDR information rates are provided in Appendix C.

9. CHANNEL UNIT CHARACTERISTICS

The channel unit consists of the following:

- (1) Modulator/demodulator (modem)
- (2) Pragmatic\* TCM encoder/TCM decoder
- (3) Scrambler/descrambler
- (4) Overhead framing unit
- (5) Reed-Solomon encoder/decoder.
- (6) Interleaver/de-interleaver
- (7) Switchability to QPSK/IDR mode of operation (optional)

The channel unit shall utilize coherent 8PSK modulation together with Rate 2/3 pragmatic TCM encoding/TCM decoding and Reed-Solomon (219, 201) outer coding (see Section 9.3 regarding the use of TCM and the Reed-Solomon outer coding).

For TCM/IDR carriers which have information rates ( $n \times 64$  kbit/s) less than 1.544 Mbit/s (i.e., small TCM/IDR carriers), either no overhead framing or IBS overhead framing (refer to Appendix B) can be utilized. For small TCM/IDR carriers using the IBS overhead framing, in order to maintain frame alignment, only the following values of  $n$  will be applicable:  $n = 1, 2, 4, 6, 8, 12, 16$  and  $24$ . The only Intelsat-recommended small TCM/IDR information rates are 512 kbit/s ( $n = 8$ ) and 1024 kbit/s ( $n = 12$ ).

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).

Switchability between the TCM/IDR and the QPSK/IDR mode of operation is an optional requirement which allows users to maintain backward compatibility with existing QPSK/IDR channel unit designs in operational situations where this

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\* Pragmatic TCM encoding is a patented technique (U.S. Patent Nos. 2,233,630 and 5,469,452) which uses the standard  $k = 7$  convolutional code of rate  $1/2$  together with supplementary circuitry to generate TCM-encoded information.

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

might be necessary. If provided, the technical characteristics for QPSK/IDR operation, which are specified in IESS-308, shall be met. Because of a fundamental difference in the channel unit's FEC architecture for TCM/IDR and QPSK/IDR for information rates above 10 Mbit/s, however, backward compatibility will not be achievable at these higher information rates.

9.1 Modulator

For reference purposes, it is assumed that the modulator accepts three parallel data streams from the Rate 2/3 Pragmatic TCM encoder, designated the P channel, the Q channel and the R 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:

TRANSMITTED BITS			RESULTANT PHASE
P CHANNEL	Q CHANNEL	R CHANNEL	
0	0	0	22.5°
0	0	1	+ 67.5°
0	1	1	+ 112.5°
0	1	0	+ 157.5°
1	0	0	+ 202.5°
1	0	1	+ 247.5°
1	1	1	+ 292.5°
1	1	0	+ 337.5°

The phase accuracy at the modulator output shall be equal to or better than  $\pm 2^\circ$ . The amplitude accuracy at the modulator output shall be equal to or better than  $\pm 0.2$  dB.

The above specification has been written in terms of absolute phase encoding rather than differential encoding.

9.1.2 Modulator Spectrum Output

The transmitted IF spectrum within the frequency range  $\pm 0.233 R$  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 8PSK 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 7;

- (c) The filter has group delay characteristics given in Figure 9 or a phase response with less than  $\pm 4.0$  degrees departure from a linear phase shift over the frequency range  $\pm 0.167 R$  about the nominal center frequency.

Within the bandwidth  $0.233 R$  to  $0.5 R$  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  $\pm 0.5 R$  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  $\pm 0.233 R$  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  $\text{sinc}^{-1}$  compensation (the overall  $BT_s$  of cascaded elements is equal to 1.5), where:

$$\text{sinc}^{-1} = \frac{\pi \Delta f T_s}{\sin(\pi \Delta f T_s)}$$

- and:  $B = 3$  dB double–sided bandwidth of filter  
 $T_s =$  Symbol period =  $3/R$  baud  
 $\Delta f =$  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 10.

## 9.2 Demodulator

A coherent 8PSK demodulator shall be used and it shall provide an output which is compatible with the TCM decoder.

### 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  $\pm 25$  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 may be assumed to operate at the same transmission rate as the desired carrier, at nominal center frequencies of  $\pm 0.467 R$  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 8. The group delay characteristics have been assumed as given in Figure 9.

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 (FEC)

Rate 2/3 pragmatic trellis–coded modulation (TCM) encoding/TCM decoding and Reed–Solomon (219, 201) outer coding shall be employed by all TCM/IDR carriers.

The function of the data codecs is threefold:

- (1) to generate appropriate coding bits and to interface with the 8PSK modulator;
- (2) to accept the demodulated signal and to recover correct code synchronization and correct carrier phase; and
- (3) in conjunction with the 8PSK demodulator, to make use of the code for reliable decisions about the transmitted sequence of data bits.

Since Rate 2/3 TCM encoding is used with 8PSK modulation, the received phase may be rotated from the transmitted phase by  $n \times 45^\circ$ , where  $n = 0$  to 7. These phase ambiguities must be resolved before the received data can be properly decoded.

#### 9.3.1 Rate 2/3 Pragmatic TCM Encoder

The Rate 2/3 pragmatic TCM encoder shown in the functional diagram of Figure 11 shall be employed. For every two information data bits entering the TCM encoder, three encoded data bits are generated at the encoder's output. The three output TCM–encoded bits (P, Q and R) are used to determine the phase mapping for 8PSK modulation (see Section 9.1.1).

The pragmatic TCM encoder shall consist of:

1. A binary differential encoder followed by a conventional rate 1/2 convolutional encoder whose code generator polynomials are 133 and 171 (in octal notation) and whose constraint length,  $k$ , is equal to 7.

The two output bits (“Q” and “R”) of the rate 1/2 convolutional encoder shall be the least significant bits (LSBs) of the transmitted 8PSK carrier phase (see Section 9.1.1).

2. A phase ambiguity resolution encoder. The output bit (“P”) of the phase ambiguity resolution encoder shall be the most significant bit (MSB) of the transmitted 8PSK carrier phase (see Section 9.1.1 and Figure 11). The information bit entering the phase ambiguity encoder shall be the first information bit which was transmitted in time from the data source. This time sequence relationship shall be preserved between the two input information bits during the serial-to-parallel conversion performed on the input information stream to the TCM encoder.

### 9.3.2 Rate 2/3 TCM Decoder

TCM decoding shall be performed by a maximum likelihood decoder in conjunction with a mechanism for resolving phase ambiguity.

The TCM decoder shall have the following characteristics:

- (a) Its coding gain shall be sufficient to ensure the required  $E_b/N_0$  performance specified in Section 9.5.1 is satisfied.
- (b) Internal resolution for 45° carrier phase ambiguity shall be provided.
- (c) Binary differential decoding of the serial output data stream shall be provided.
- (d) It is recommended that an estimate of the channel bit error rate (BER) be provided for monitoring the performance of the carrier.

### 9.3.3 Reed–Solomon (RS) Outer Coding

To improve the power efficiency of TCM/IDR links, Reed–Solomon outer coding shall be concatenated with the inner Rate 2/3 TCM code. The (219, 201) Reed–Solomon codeword shall be used for all TCM information rates ranging from 64 kbit/s to 44,736 kbit/s. An interleaving depth of four (4) RS codewords shall be used for small TCM/IDR carriers which have information rates less than 1.544 Mbit/s (with and without IBS–specified overhead framing).

For information rates between 1.544 Mbit/s and 44.736 Mbit/s, an interleaving depth of eight (8) RS codewords shall be used.

The performance characteristics and operational requirements for the considered Reed–Solomon outer code 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 at the transmit earth station in conjunction with the application of the Reed-Solomon outer coding, as described in Appendix H.

For those instances when the Reed-Solomon outer coding, and hence the synchronous scrambler, must be disabled for testing purposes (for example, SSOG lineups), the need for scrambling must still be satisfied. To accomplish this, a self-synchronizing data scrambler shall be employed for TCM/IDR carriers with information rates greater than or equal to 1.544 Mbit/s. The self-synchronizing scrambler shall have a logic diagram equivalent to that shown in Figure 25 and the descrambler shall have the impulse response shown in Figure 26. It should be noted that, for the self-synchronizing scrambler, a single error in the received data stream can produce 3 errors over an interval of 20 bits. For this reason, the TCM encoder shall follow the self-synchronizing scrambler at the transmit earth station and, at the receive earth station, the descrambler shall follow the TCM decoder.

9.5 Bit Error Rate Performance Characteristics

9.5.1 IF-to-IF Loopback

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 (Rate 2/3 TCM and Reed-Solomon (219, 201) outer coding), and under the conditions outlined in Section 9.2.1:

<u>BER better than:</u>	<u>Composite Data Rate <math>E_b/N_o</math> (dB)</u> [Rate 2/3 TCM & RS (219, 201)]
$10^{-4}$	6.1
$10^{-6}$	6.5
$10^{-7}$	6.7
$10^{-8}$	6.9
$10^{-10}$	7.3

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

9.5.2 IF-to-RF Degradation

For transmission over the satellite, an IF-to-RF link degradation of 0.4 dB for  $10^{-4}$ ,  $10^{-6}$ ,  $10^{-7}$  and  $10^{-8}$ , relative to the modem's IF loopback performance, is assumed to account for possible degradation due to phase noise, imperfect amplitude/group delay equalization, adjacent channel interference (ACI) and transponder nonlinearities. At a BER of  $10^{-10}$ , an IF-to-RF link degradation of 0.6 dB is assumed.

9.5.3 Modem Performance (Without RS Outer Coding)

Due to the steepness of the BER versus  $E_b/N_o$  response curve when using the Reed-Solomon outer coding, an inordinately long period of time is necessary to detect a sufficient number of errors to determine the BER performance with a reasonable degree of confidence at even moderate  $E_b/N_o$  values. Assuming that the Reed-Solomon outer codec is functioning, determining the BER performance of the TCM codec without the Reed-Solomon outer coding, i.e., the performance of the inner code only, would enable users to quickly determine whether or not the modem is functioning correctly. As a guideline, the following BER versus  $E_b/N_o$  performance (IF loopback) is suggested:

<u>BER better than:</u>	<u>Composite Data Rate <math>E_b/N_o</math> (dB)</u> [IF Loop, Rate 2/3 TCM/8PSK, No RS Outer Coding]
$10^{-3}$	6.3
$10^{-4}$	7.3
$10^{-5}$	8.2
$10^{-6}$	9.0
$10^{-7}$	9.8
$10^{-8}$	10.4

9.6 Overhead Framing for ESC and Alarms (Optional)

An overhead framing structure has been defined for certain TCM/IDR carrier sizes (1.544, 2.048, 6.312, 8.448, 32.064, 34.368, and 44.736 Mbit/s) to optionally provide engineering service channels (ESC) 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 TCM/IDR carriers having information rates of 1.544, 2.048, 6.312, 8.448, 32.064, 34.368 and 44.736 Mbit/s. Other TCM/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 96 kbit/s ESC overhead framing is employed, the mandatory requirements detailed in this Section shall apply to ensure that equipment provided by different manufacturers will be compatible.

9.6.1 Overhead Frame Structure

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

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

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 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 a single 64 kbit/s data channel.
- 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 12 (for 1.544 and 2.048 Mbit/s information rates), Figure 13 (for the 6.312 Mbit/s information rate), Figure 14 (for the 8.448 Mbit/s information rate) and Figure 15 (for the 32.064, 34.368 and 44.736 Mbit/s information rates). It is not mandatory that a single unit provide overhead for all information rates. The structure, however, has been designed 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 Reed-Solomon encoder. No knowledge of the 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 voice/data channel\*.

The 8 kbit/s data channel bits shall be set to one 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 12, Figure 13, Figure 14 and Figure 15. 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 TCM/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 3 and as illustrated in Figure 16.

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.

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\* See Figure 12.

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

Table 4 shows the actions to be taken after 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 4 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 over any 1 minute period.

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

The actions shown in Table 4 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 which have been assigned to that particular earth station.

#### 9.6.4.1 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, for disparity between clocks at 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 depends 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 TCM/IDR voice circuits are to be connected to an analog terrestrial network. However, buffering will be required to connect TCM/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 as shown in Table 5. 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) which 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 17 and Figure 18, as described in Section 10.3. Particular configurations should be determined by bilateral agreement.

## 10.3 Buffer Capacity

Three examples of circuit configuration and applicable buffer sizes are shown in Figure 17 through Figure 19. Other configurations are possible, but these examples are expected to represent the majority of cases. Table 6 can be used to determine the approximate buffer capacity in each. Figure 20 is an example of a situation where there is no need for buffering.

Case 1: 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 17.

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 which originated the timing signal. This is illustrated in Figure 18.

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 which is different from the one which originated the timing signal. This is illustrated in Figure 19.

Under the conditions of 1 part in  $10^{11}$  clock accuracy and the buffer capacities given in Table 6, 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 which convert between the analog and digital modes. The receive timing is derived from the recovered clock from the demodulator. This is illustrated in Figure 20.

#### 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 TCM/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 which form part of an international plesiochronous digital network, slips shall consist of integer multiples of one complete multiframe, to avoid loss of synchronization of the multiplex equipment and in order not to disturb 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 6).

### 11. BASEBAND CHARACTERISTICS

The performance characteristics for TCM/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 without and with circuit

multiplication (e.g., LRE/DSI), digital data, digital video, or a multiplexed combination of these. Transmission is carried out in a manner which is transparent to the digitally-encoded information being conveyed.

TCM/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, inclusive, may be transmitted. However, to limit the possible sets of equipment configurations, performance requirements for a finite set of Intelsat-recommended carrier sizes have been developed. It is not necessary to restrict operation to the recommended carrier sizes. In such cases, however, appropriate performance characteristics must be agreed to among the 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 7. Performance characteristics for MD TCM/IDR carriers have been developed for the information bit rates listed in Table 7.

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 7 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 TCM/IDR applications are depicted in Figure 21 through Figure 24 for each level of the digital hierarchy.

In the example shown in Figure 21, 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 TCM/IDR channel unit interface) and 64 kbit/s channels cross interfaces "a" and "d" (the terrestrial interface).

In Figure 22, primary order bit streams at 2.048 Mbit/s data rates are derived from 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 23, second order 8.448 Mbit/s bit streams are derived from 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 24 shows an example of MD TCM/IDR application using the Primary and Second order interworking hierarchy bit rates.

These examples are provided to illustrate the various possibilities which are available with MD TCM/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 which 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 21, 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 22, 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-Destinal Operation

Characteristics for MD TCM/IDR carrier bit streams have been defined at the TCM/IDR channel unit, i.e., at interfaces "b" and "c" in Figure 21 through Figure 24, 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 8, which also

indicates 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 TCM/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 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 21 through Figure 24.

#### 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 allowed for input to the TCM/IDR channel unit. A 24–frame multiframe, as defined in Rec. ITU–T G.704, Para. 3.1.1.3A, 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 TCM/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 TCM/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 TCM/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 TCM/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 TCM/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 TCM/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 TCM/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 TCM/IDR channel unit described in Section 9.6.3, the multiplex equipment will normally have a set of fault conditions and consequent actions which 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 9. 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 22, 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 give 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 9.

These detections and actions should be undertaken in an 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 responsibility of the users. 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  $\mu$ -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  $\mu$ -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 TCM/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 TCM/IDR equipment. This means that the multi-clique and MD capability of the LRE/DSI equipment will operate independently of the TCM/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 a provision for measuring the EIRP of the transmitted carrier, the  $E_b/N_o$  of the received carrier (either with a spectrum analyzer or through a filter of known noise bandwidth) and by the ability to perform bit-error-rate measurements using a pseudo-random test pattern.

The minimum requirement for in-service monitoring may be satisfied by providing a transmission rate BER indication through a facility built into the channel unit (e.g., an indication of the rate of error correction or a pseudo-error measurement technique). Alternatively, either a composite rate or information rate BER indication can be based upon observation of a low rate multiplexed channel containing a test pattern (e.g., the frame alignment signal in the overhead unit), or upon detection of pattern violations of the digital multiplex framing information.

Table 1

INTELSAT-RECOMMENDED TCM/IDR INFORMATION RATES and ASSOCIATED OVERHEAD  
[Rate 2/3 TCM/8PSK With Mandatory RS (219, 201) Outer Coding]

Number of 64 kbit/s Bearer Channels (n)	Info. Rate (n x 64 kbit/s)	TYPE OF OVERHEAD		
		No Overhead (1)	With Optional 96 kbit/s IDR Overhead	With 6.7% IBS Overhead (2)
8	512	X		X
16	1024	X		X
24	1544 (3)		X	
30 (31)	2048 (3)		X	
90 (93)	6312 (3)		X	
120 (124)	8448 (3)		X	
480	32064 (3)		X	
480 (496)	34368 (3)		X	
630 (651) or 672	44736 (3)		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 512 and 1024 kbit/s.
- (2) The carriers in this column are small TCM/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).] The approach described in Appendix B may also be used for other n x 64 kbit/s information rates, but the only Intelsat-recommended rates are 512 and 1024 kbit/s.
- (3) 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

TCM/IDR PERFORMANCE  
[G.826 Plus Quality, Intelsat VII/VIIA, VIII & IX]

<u>Weather Condition</u>	<u>Minimum BER Performance (4)</u> (% of year)	<u>Typical BER Performance (5)</u> (% of year)
Clear Sky	$\leq 10^{-9}$ for $\geq 95.90\%$	$\ll 10^{-10}$ for $\geq 95.90\%$
Degraded	$\leq 10^{-8}$ for $\geq 99.36\%$	$\ll 10^{-10}$ for $\geq 99.36\%$
Degraded	$\leq 10^{-6}$ for $\geq 99.96\%$	$\leq 10^{-10}$ for $\geq 99.96\%$
Degraded	(6)	$\leq 10^{-5}$ for $\geq 99.98\%$

Notes:

- (1) 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.
- (2) 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.
- (3) 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).
- (4) 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 2 applies to all TCM/IDR carrier sizes of 45 Mbit/s or less, where the value of  $\alpha$  (average number of errors per burst) is equal to 10. The typical TCM/IDR performance will either meet or exceed the minimum BER performance recommended in Note 2.
- (5) The typical clear–sky performance values shown are based on specified modem performance characteristics and the minimum IESS specified 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.
- (6) Not specified in Recommendation ITU–R S.1062.

Table 3

EARTH STATION EQUALIZATION REQUIRED FOR  
SATELLITE GROUP DELAY

<u>Equalized Bandwidth</u> (MHz)				<u>Linear Equalization</u> (nsec/MHz)	<u>Parabolic Equalization</u> (nsec/MHz <sup>2</sup> )*
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
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 supplied upon request for transponder bandwidth units greater than 72 MHz.

Table 4

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†	AS1	–	AD1
	FS2†	AS1	AH1	AD2
FROM TERRESTRIAL LINK (ACROSS INTERFACE A)	FA1	AS1	–	AD1
FROM SATELLITE (ACROSS INTERFACE E)	FE1	AS1	AH1	AD2
	FE2	AS1	AH1	AD2
	FE3	AS1	–	AD2
	FE4	AS2	–	–

\* Actions to be taken to the terrestrial link (i.e., AH1) are not mandatory. See Figure 16 for location of interfaces.

† This function is to be performed only if practicable.

Table 5

INTELSAT SATELLITE DELAY PARAMETERS  
(For Nominal Satellite Stationkeeping Limits)

<u>Satellite</u>	<u>Maximum Variations</u> (msec)	<u>Maximum Rate of Variations</u> (nsec/sec)
VII, VIIA, VIII & IX	0.43	15.4

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 :

<u>Satellite</u>	<u>Nominal Stationkeeping</u>	
	<u>North-South</u> (degrees)	<u>East-West</u> (degrees)
VII, VIIA, VIII & IX	± 0.05	± 0.05

Table 6

## MINIMUM DOPPLER/PLESIOCHRONOUS BUFFER CAPACITY REQUIREMENTS

SATELLITE ORBIT INCLINATION (degrees)	BUFFER CAPACITY (ms) FOR VARIOUS CIRCUIT CONFIGURATIONS			
	CASE 1 Figure 17	CASE 2 Figure 18	CASE 3 Figure 19	CASE 4 Figure 20
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 which 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 7

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

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\* 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 8

INTELSAT MULTIPLEX CHARACTERISTICS FOR  
MULTI-DESTINATIONAL OPERATION

<u>TRANSMITTED BIT RATE (Mbit/s)</u>	<u>NUMBER OF 64 kbit/s CHANNELS (Note 3)</u>	<u>NUMBER AND BIT RATE OF LOWER ORDER TRIBUTARIES</u>	<u>ITU-T MULTIPLEX RECOMMENDATION</u>	<u>NOTES</u>
1.544	24	–	G.733	(1)
2.048	30 (31)	–	G.732	(4)
6.312	96	4 x 1.544	G.743	(2)
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	

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 TS0 is reserved for frame alignment and alarms and TS16 can be used for signalling or to transport traffic. The number in parentheses includes the number of channels available when TS16 is used to transport traffic.

It is recommended that bit 1 of the 2.048 Mbit/s frame be used for a cyclic redundancy check (CRC) procedure, as specified in Rec. ITU-T G.704, Para.2.3.3.

Table 9

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)					Yes	
	Failure of incoming stream		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)

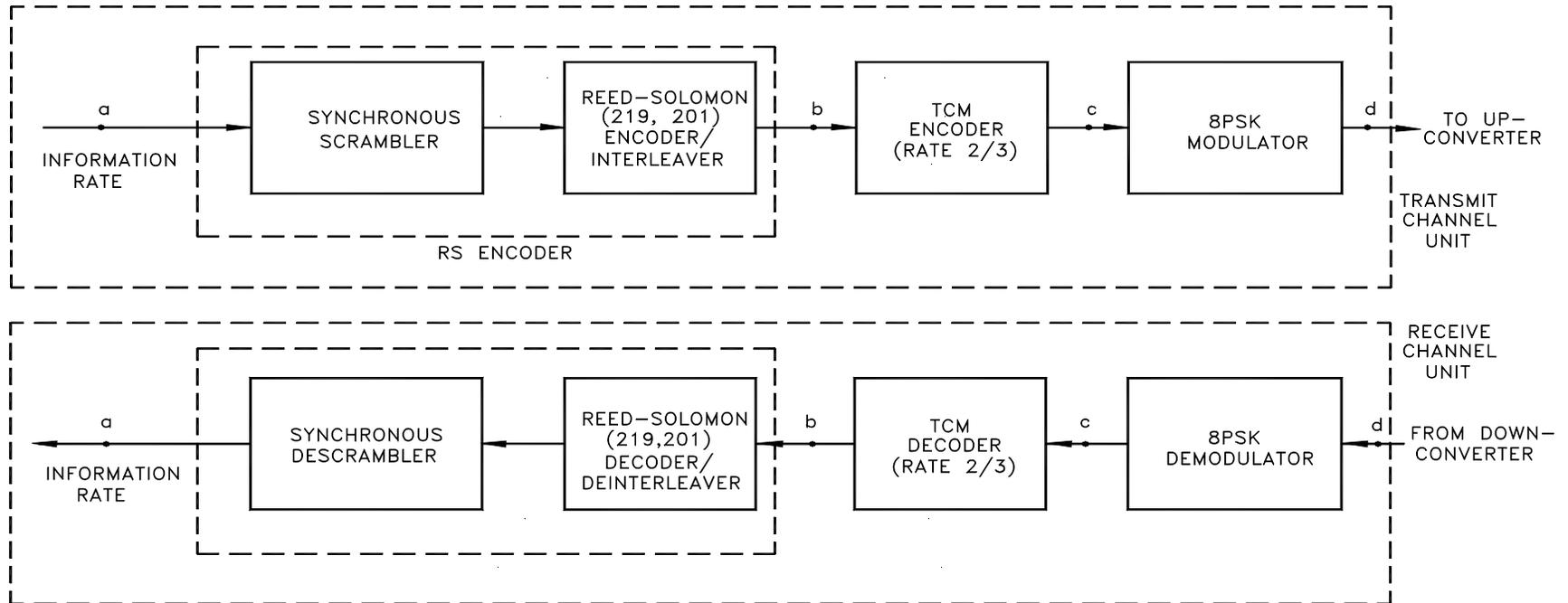
DACS = Digital Access and Cross Connect

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, Paragraph 3.3.3.2.2.

Figure 1

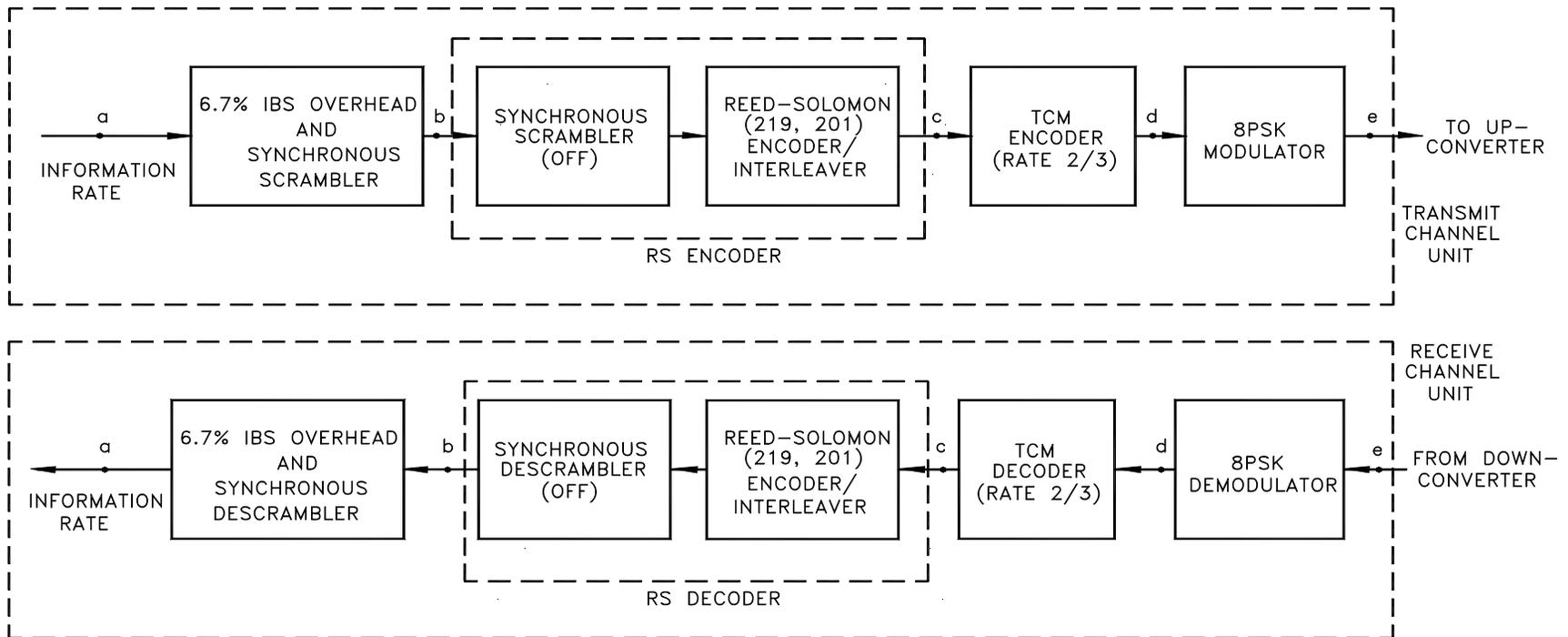
ILLUSTRATION OF TCM/IDR CHANNEL UNIT  
(Small TCM/IDR Carriers < 1.544 Mbit/s, No Overhead Framing)



- a INFORMATION RATE, IR
- b  $IR \times (219/201)$
- c TRANSMISSION RATE,  $R = [IR \times (219/201)]/C$  (C = CODE RATE = 2/3)
- d SYMBOL RATE,  $SR = R/3$

Figure 2

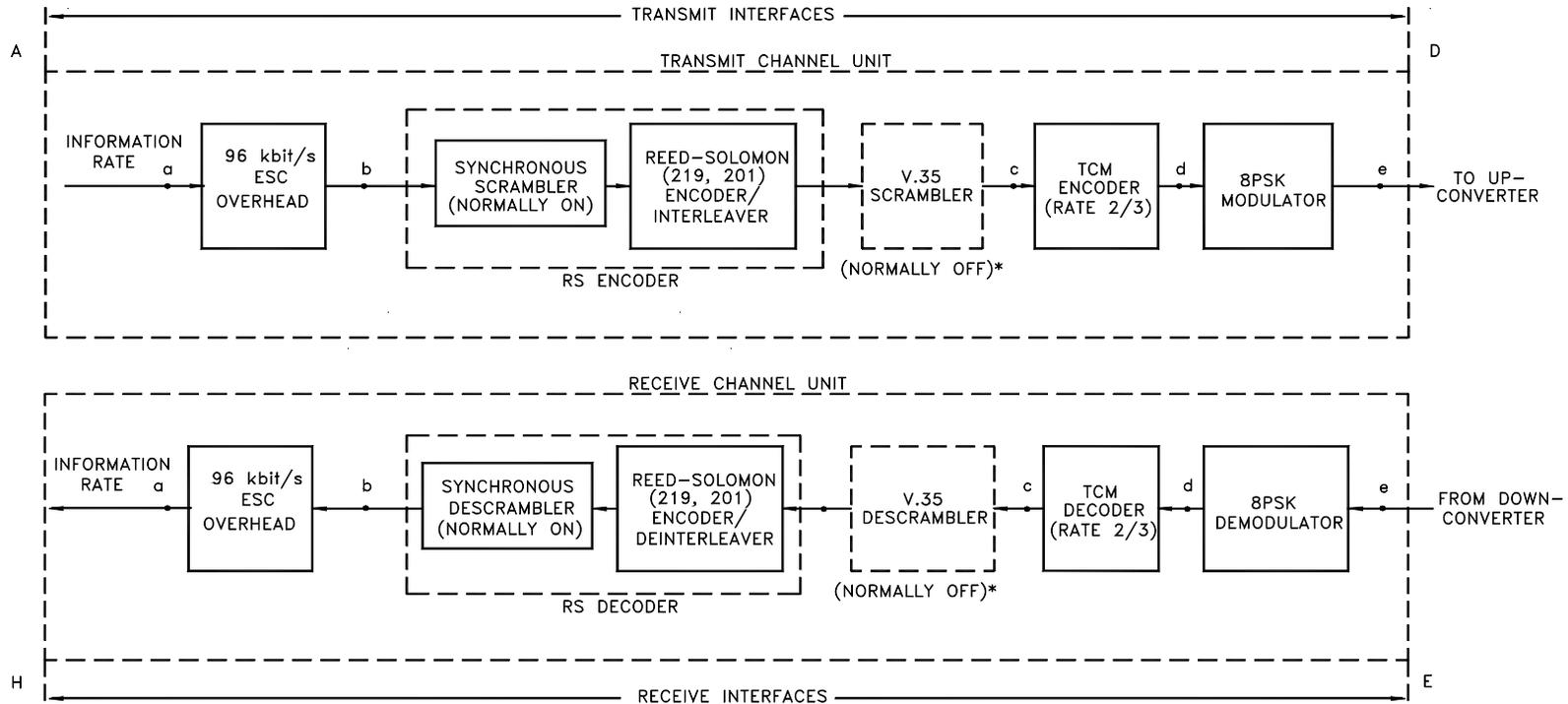
ILLUSTRATION OF TCM/IDR CHANNEL UNIT  
(Small TCM/IDR Carriers < 1.544 Mbit/s, With IBS Overhead Framing)



- a INFORMATION RATE, IR
- b COMPOSITE RATE, CR = IR PLUS OVERHEAD
- c  $CR \times (219/201)$
- d TRANSMISSION RATE,  $R = [CR \times (219/201)]/C$  (C = CODE RATE = 2/3)
- e SYMBOL RATE,  $SR = R/3$

Figure 3

ILLUSTRATION OF TCM/IDR CHANNEL UNIT  
(TCM/IDR Carriers  $\geq 1.544$  Mbit/s, With Optional 96 kbit/s ESC Overhead Framing)



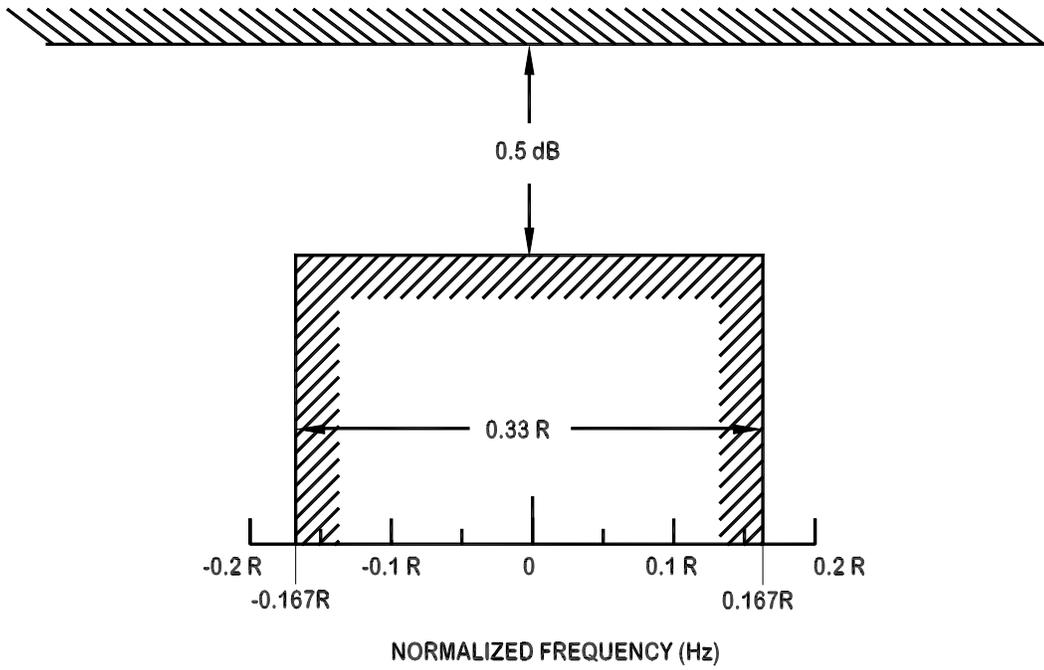
\* THE IDR V.35 SELF-SYNCHRONIZING SCRAMBLER/DESCRAMBLER IS NORMALLY DEACTIVATED (SWITCHED "OFF") WHENEVER THE REED-SOLOMON OUTER CODEC IS BEING USED. WHEN THE REED-SOLOMON OUTER ENCODER/DECODER IS NOT BEING USED (E.G., DURING SSOG LINEUP), THE IDR SCRAMBLER MUST BE ACTIVATED (SWITCHED "ON").

- a INFORMATION RATE, IR
- b COMPOSITE RATE, CR = IR PLUS OVERHEAD
- c  $C = CR \times (219/201)$
- d TRANSMISSION RATE,  $R = [CR \times (219/201)]/C$  (C = CODE RATE = 2/3)
- e SYMBOL RATE, SR = R/3

Figure 4

EARTH STATION IF AND RF AMPLITUDE RESPONSE

\*



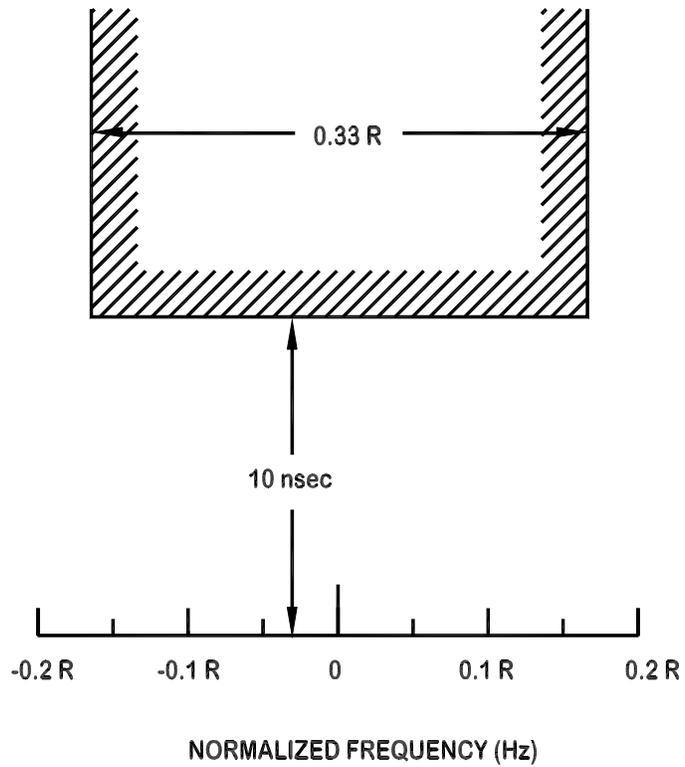
R = TRANSMISSION RATE IN BITS PER SECOND

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

Figure 5

EARTH STATION IF AND RF GROUP DELAY RESPONSE

\*

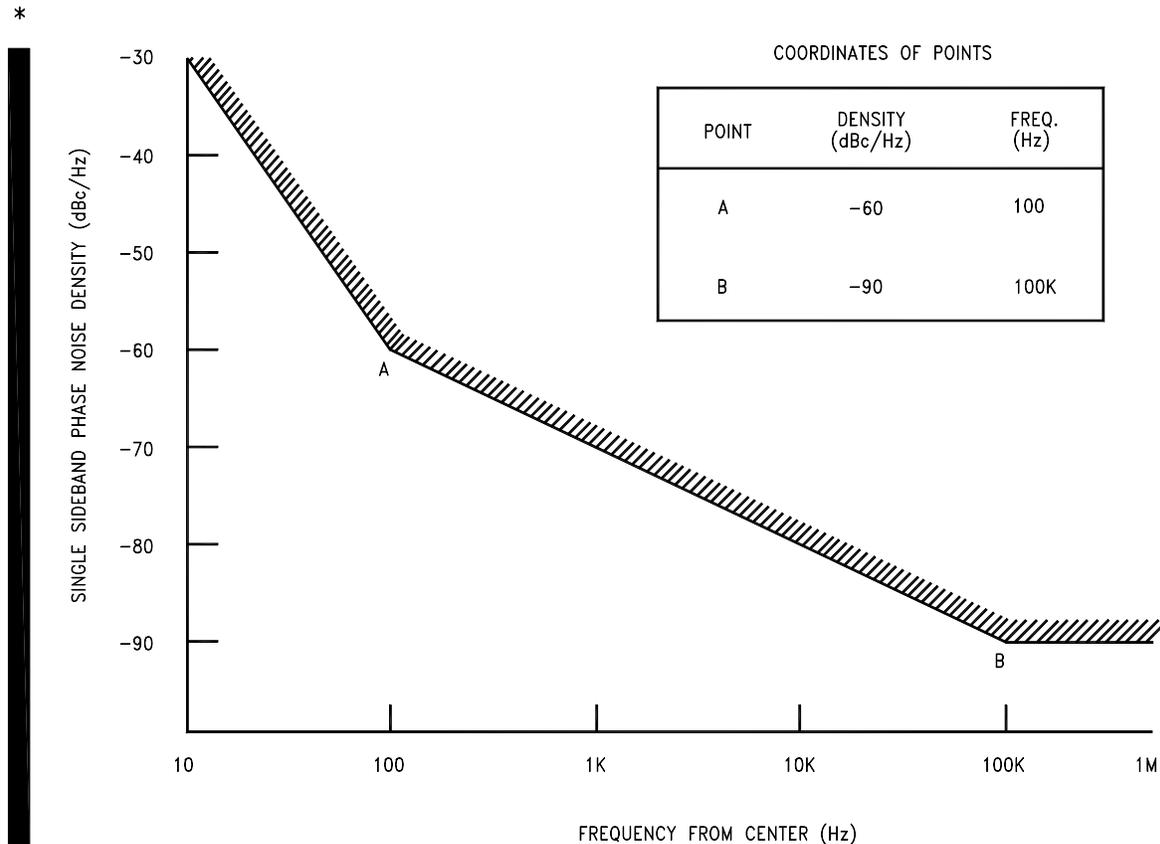


R = TRANSMISSION RATE IN BITS PER SECOND

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

Figure 6

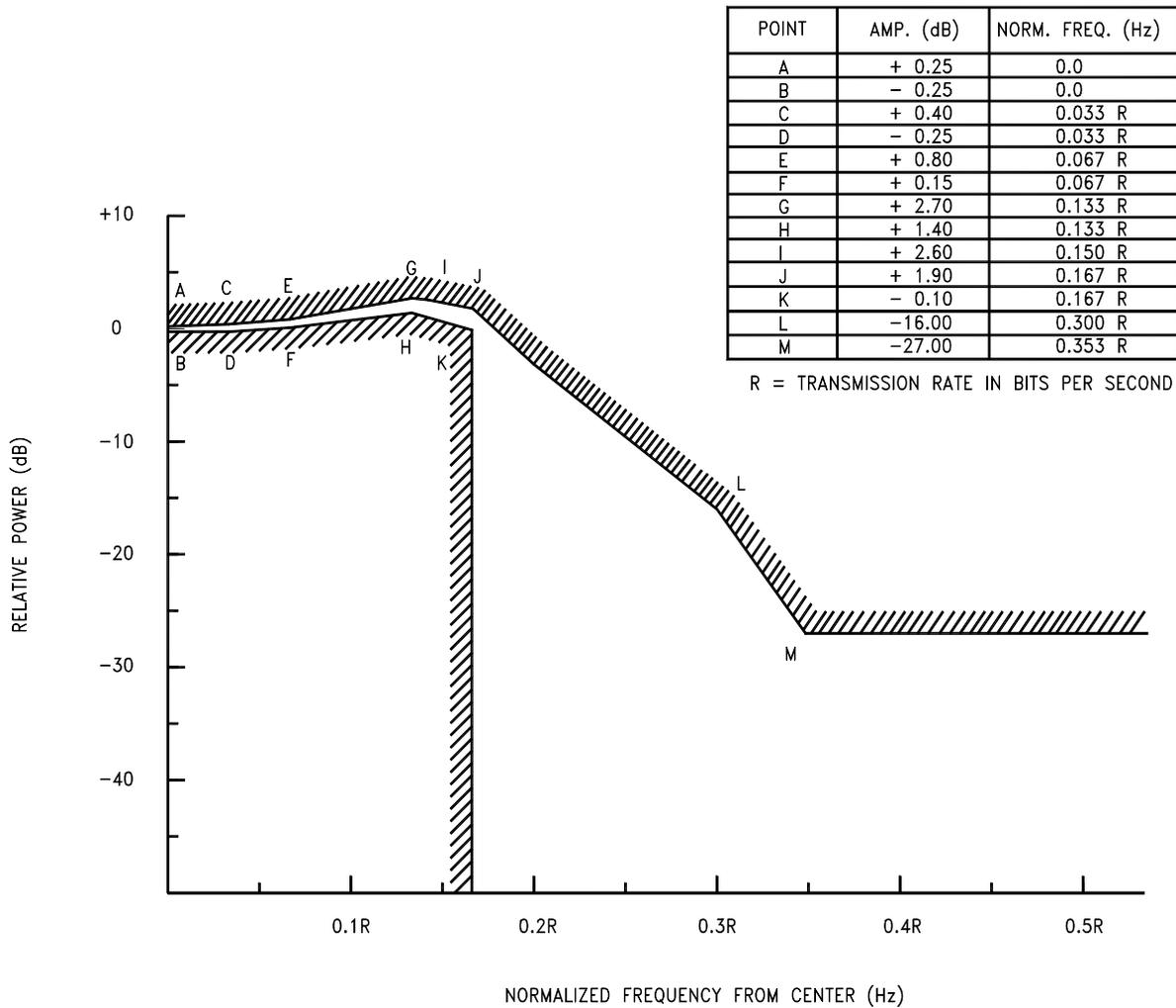
CONTINUOUS SINGLE SIDEBAND PHASE NOISE REQUIREMENT  
 (For Carriers With Information Rates Less Than Or Equal To 2.048 Mbit/s)



\* 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.

Figure 7

MODULATOR FILTER AMPLITUDE RESPONSE



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

Figure 8

DEMODULATOR FILTER AMPLITUDE RESPONSE

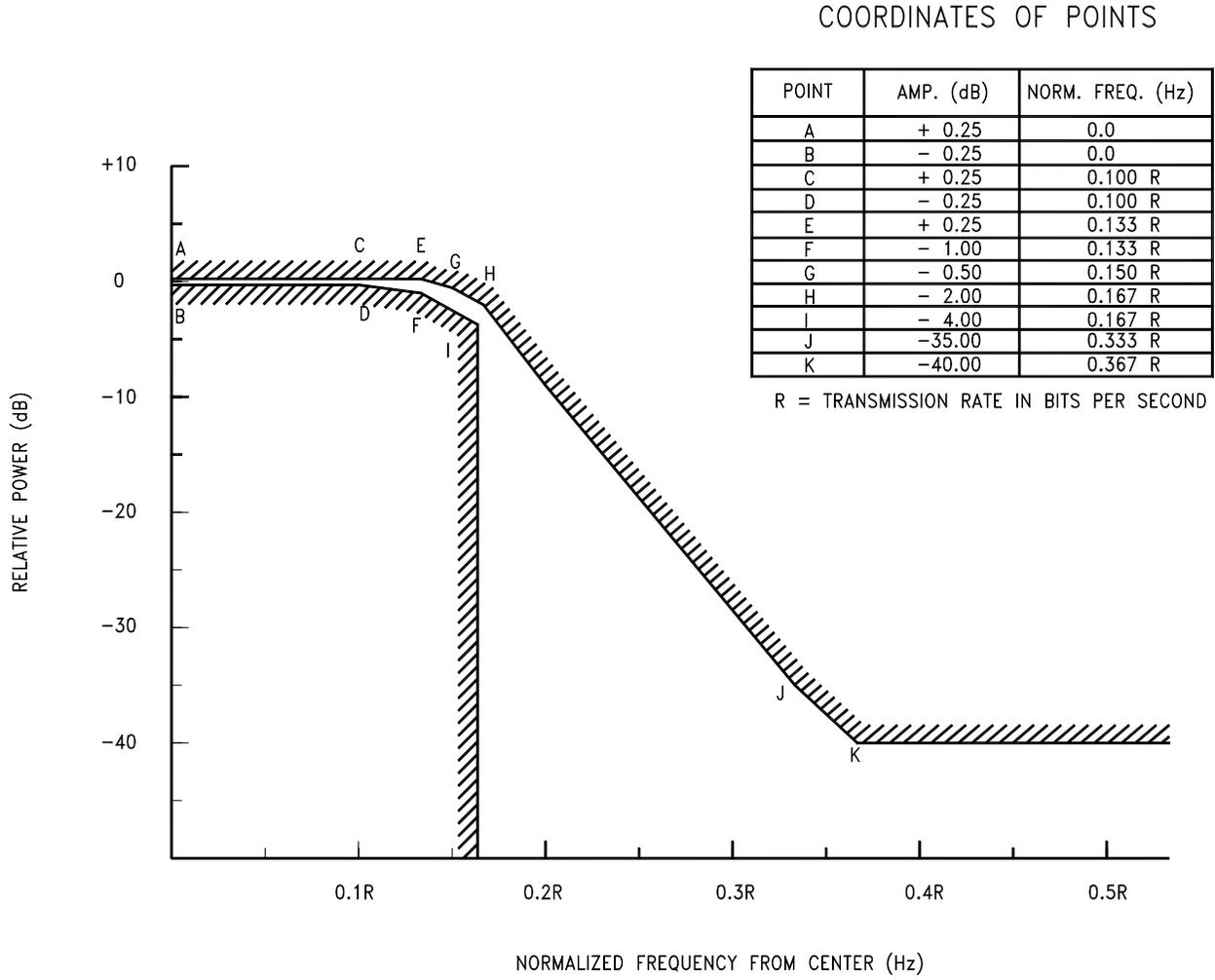
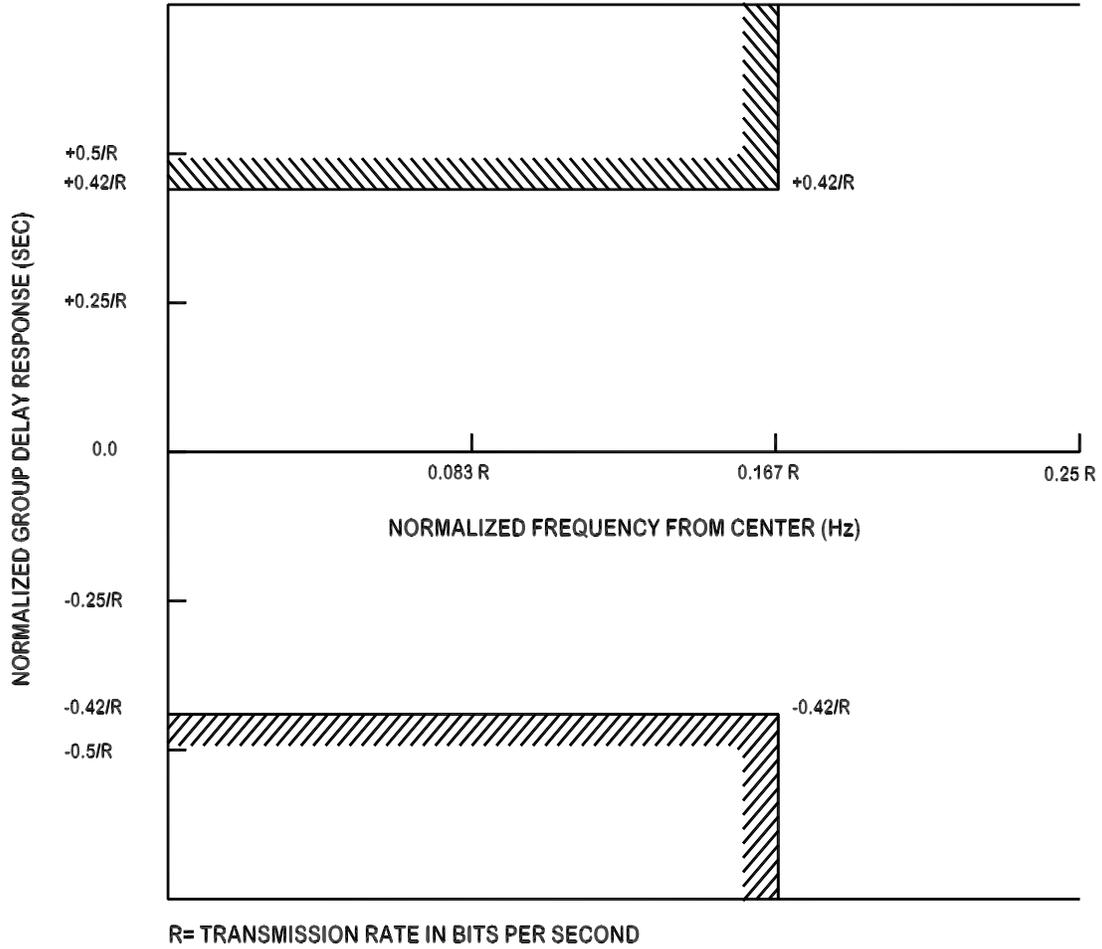


Figure 9

MODULATOR AND DEMODULATOR FILTER GROUP DELAY RESPONSE

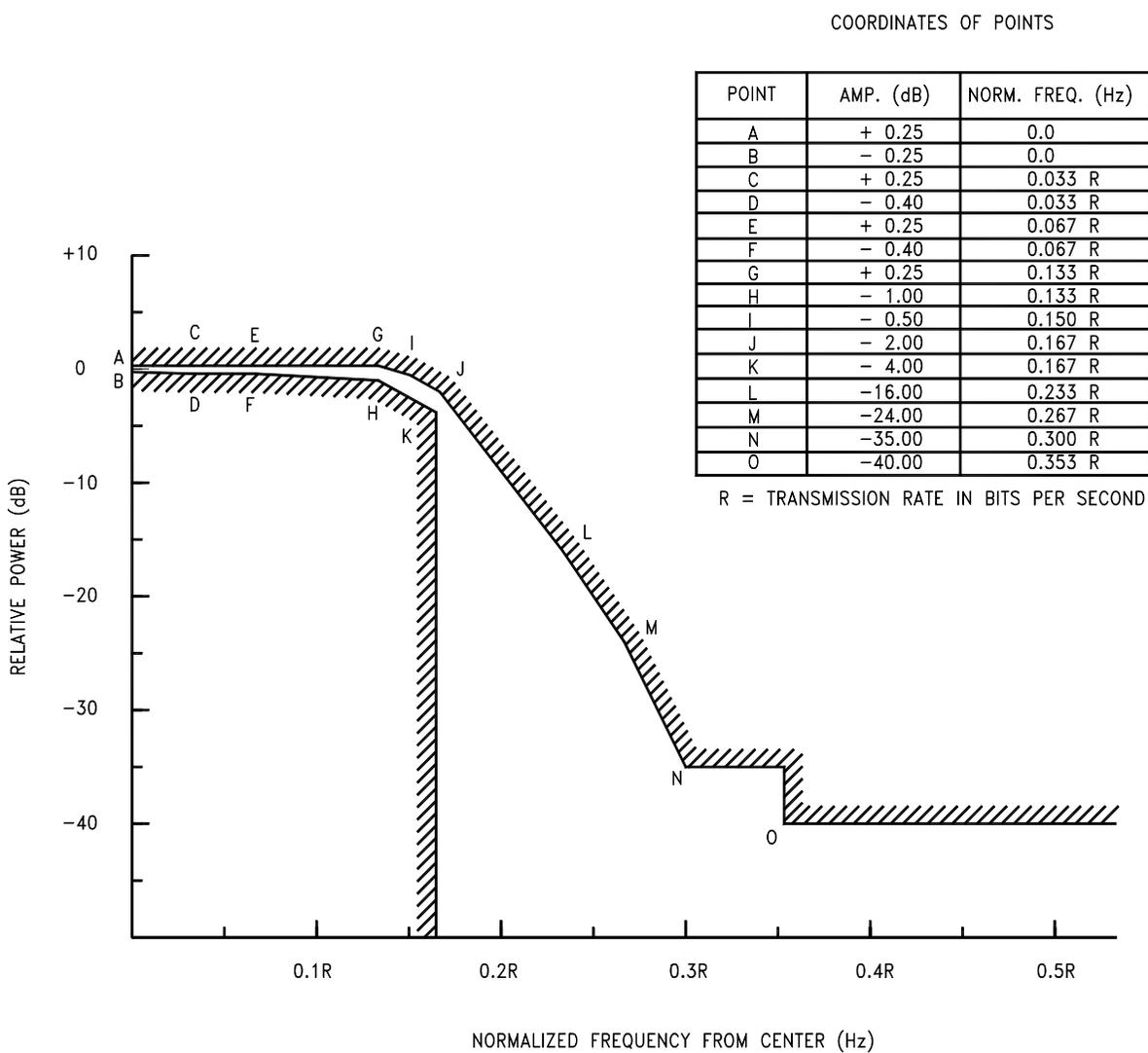


NOTES:

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  $\pm 4$  DEGREES DEPARTURE FROM A LINEAR PHASE SHIFT (OVER THE FREQUENCY RANGE  $\pm R/6$  Hz ABOUT THE CENTER FREQUENCY) MAY BE USED.

Figure 10

POWER SPECTRAL DENSITY MASK AT MODULATOR OUTPUT

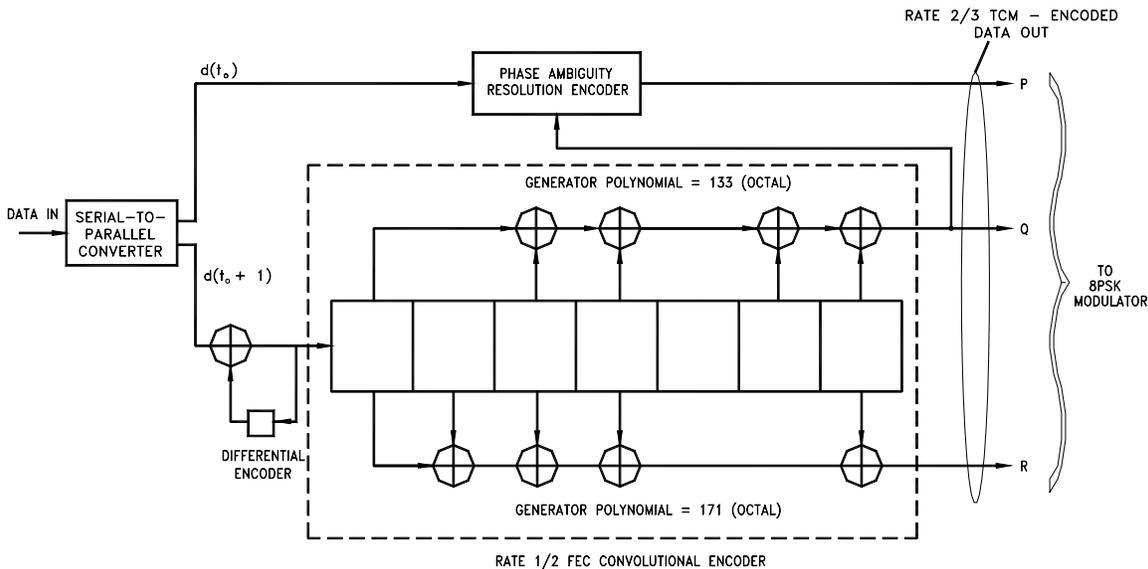


NOTES:

1. POINTS A THROUGH N CORRESPOND TO POINTS A THROUGH L IN FIGURE 7 MODULATOR FILTER AMPLITUDE RESPONSE
2. 0 dB RELATIVE POWER CORRESPONDS TO  $-10 \log (R/3)$  dB/Hz RELATIVE TO THE UNMODULATED CARRIER POWER.

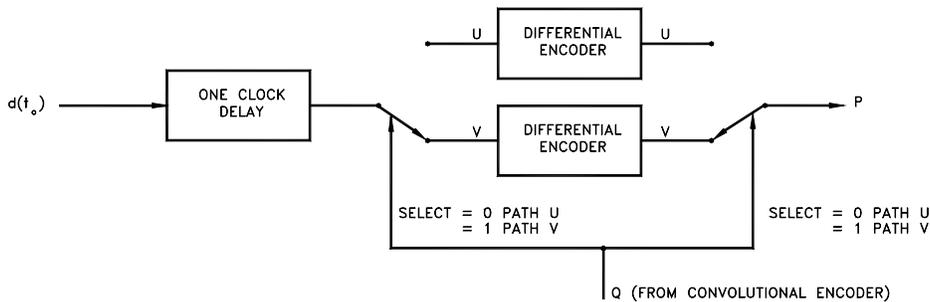
Figure 11

RATE 2/3 PRAGMATIC TRELLIS-CODED MODULATION (TCM)  
ENCODING PROCESS BLOCK DIAGRAM



$d(t_o)$  = DATA BIT AT TIME  $t_o$   
 $d(t_o + 1)$  = DATA BIT AT TIME  $(t_o + 1)$

(a) TRELLIS ENCODER

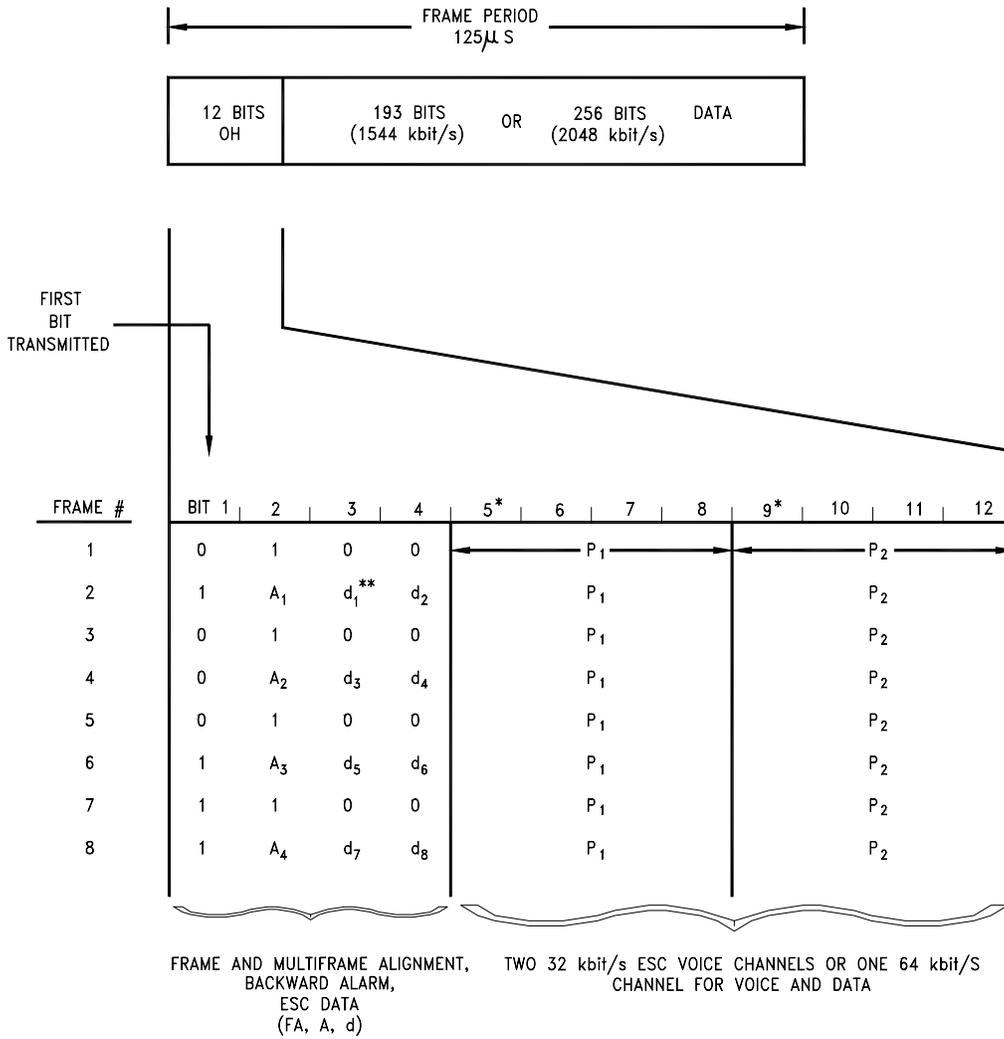


(b) PHASE AMBIGUITY RESOLUTION ENCODER

\* REFER TO U.S. PATENT NOS. 5,233,630 AND 5,469,452.

Figure 12

OVERHEAD STRUCTURE FOR 1544 AND 2048 kbit/s TCM/IDR CARRIERS



P<sub>i</sub> = ESC VOICE CHANNEL i BITS (i = 1, 2); (SET TO 1 IF NOT USED)

A<sub>i</sub> = BACKWARD ALARM TO DESTINATION i (i = 1, 2, 3, 4); NO ALARM = 0; ALARM = 1

d<sub>i</sub> = ESC DIGITAL DATA (i = 1 TO 8); (SET TO 1 IF NOT USED)

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

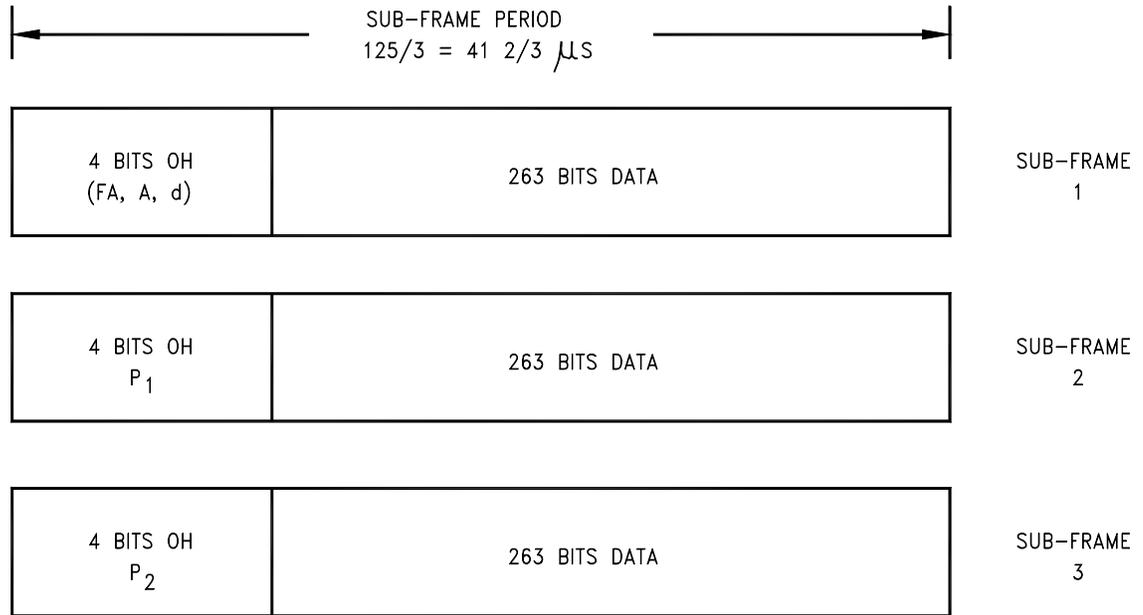
OH RATE = 12 BITS/125 μs = 96 kbit/s

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

\*\* d<sub>1</sub> CORRESPONDS TO THE FIRST BIT TRANSMITTED IN THE ESC DATA CHANNEL.

Figure 13

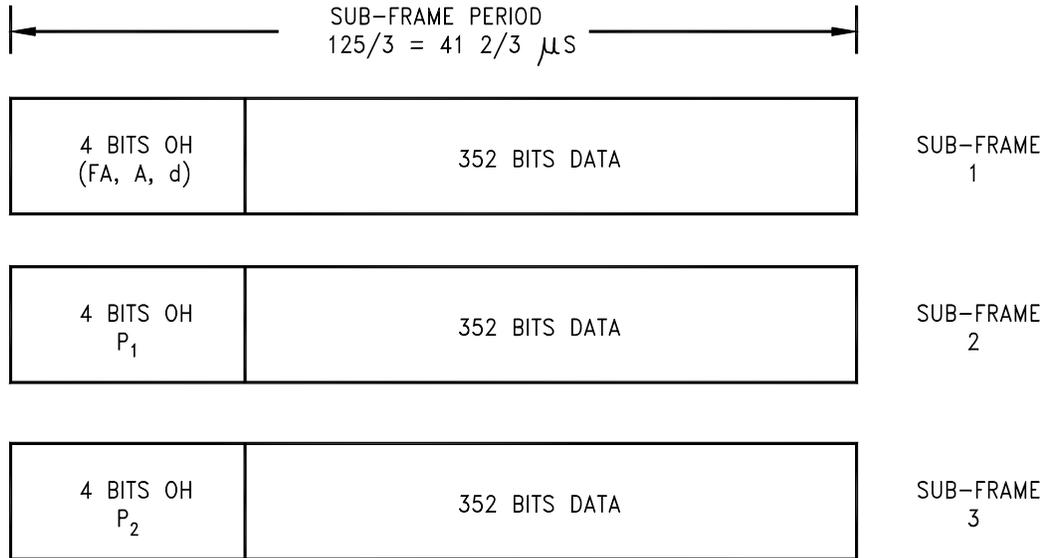
OVERHEAD STRUCTURE FOR 6312 kbit/s TCM/IDR CARRIERS



- 3 SUB-FRAMES = 1 FRAME (PERIOD = 125  $\mu\text{s}$ )
- 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  $\mu\text{s}$  = 96 kbit/s

Figure 14

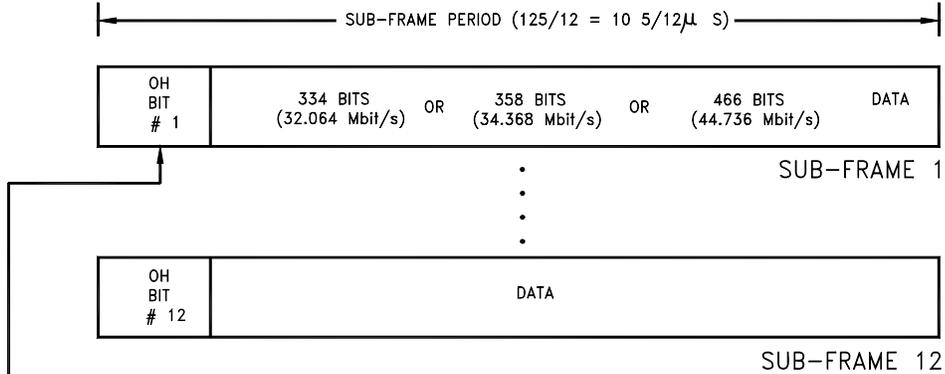
OVERHEAD STRUCTURE FOR 8448 kbit/s TCM/IDR CARRIERS



- 3 SUB-FRAMES = 1 FRAME (PERIOD = 125  $\mu\text{s}$ )
- 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  $\mu\text{s}$  = 96 kbit/s

Figure 15

OVERHEAD STRUCTURE FOR 32.064, 34.368 and 44.736 Mbit/s TCM/IDR CARRIERS



- 1 OH BIT INSERTED EVERY SUB-FRAME
- 12 SUB-FRAMES = 1 FRAME (PERIOD =  $125 \mu s$ )
- 8 FRAMES = 1 MULTI-FRAME (PERIOD = 1 ms)
- OH RATE = 12 bits/ $125 \mu s$  = 96 kbit/s

FIRST  
BIT  
TRANSMITTED

ALLOCATION OF OH BITS

FRAME #	OH BIT # (SUB-FRAME #)											
	1	2	3	4	5*	6	7	8	9*	10	11	12
1	0	1	0	0	← P <sub>1</sub> →				← P <sub>2</sub> →			
2	1	A <sub>1</sub>	d <sub>1</sub> **	d <sub>2</sub>	P <sub>1</sub>				P <sub>2</sub>			
3	0	1	0	0	P <sub>1</sub>				P <sub>2</sub>			
4	0	A <sub>2</sub>	d <sub>3</sub>	d <sub>4</sub>	P <sub>1</sub>				P <sub>2</sub>			
5	0	1	0	0	P <sub>1</sub>				P <sub>2</sub>			
6	1	A <sub>3</sub>	d <sub>5</sub>	d <sub>6</sub>	P <sub>1</sub>				P <sub>2</sub>			
7	1	1	0	0	P <sub>1</sub>				P <sub>2</sub>			
8	1	A <sub>4</sub>	d <sub>7</sub>	d <sub>8</sub>	P <sub>1</sub>				P <sub>2</sub>			

P<sub>i</sub> = ESC VOICE CHANNEL i BITS (i = 1, 2); (SET TO 1 IF NOT USED)

A<sub>i</sub> = BACKWARD ALARM TO DESTINATION i (i = 1, 2, 3, 4); NO ALARM = 0; ALARM = 1

d<sub>i</sub> = 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/ $125 \mu s$  = 96 kbit/s

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

\*\* d<sub>1</sub> CORRESPONDS TO THE FIRST BIT TRANSMITTED IN THE ESC DATA CHANNEL.

Figure 16  
TCM/IDR ALARM CONCEPT

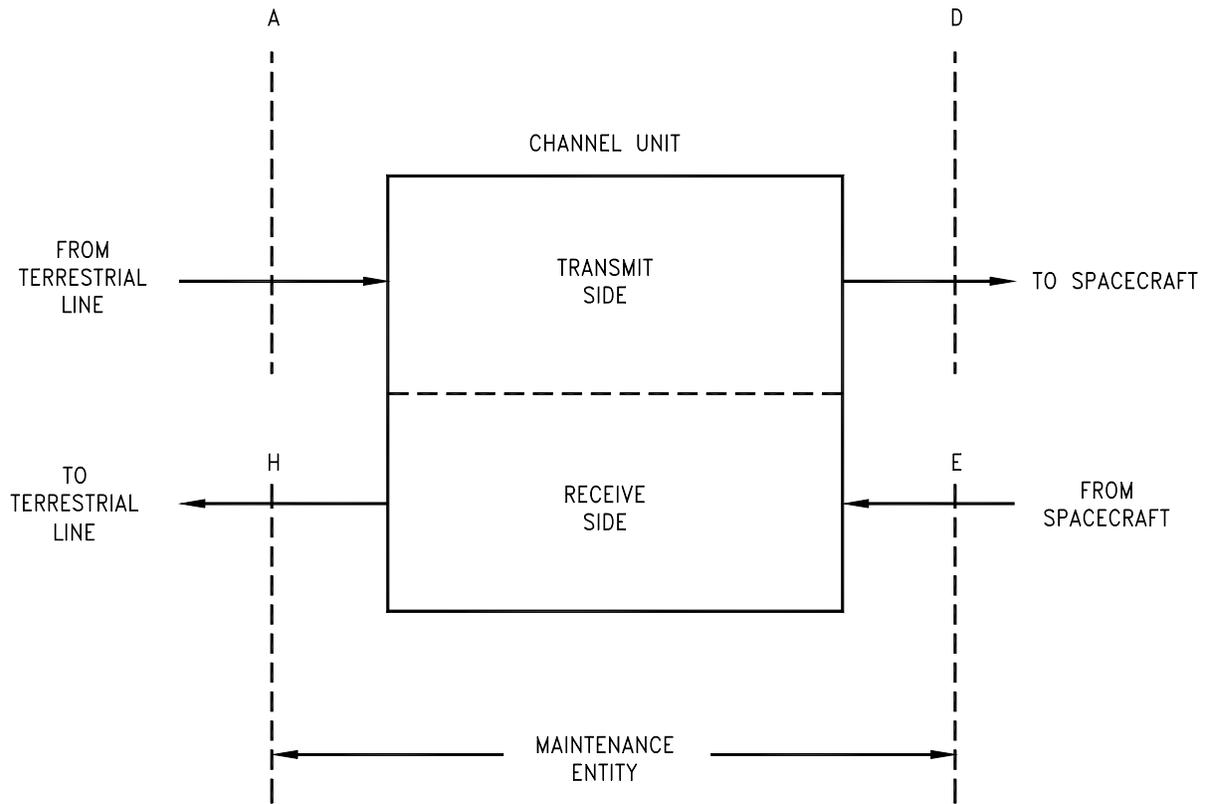
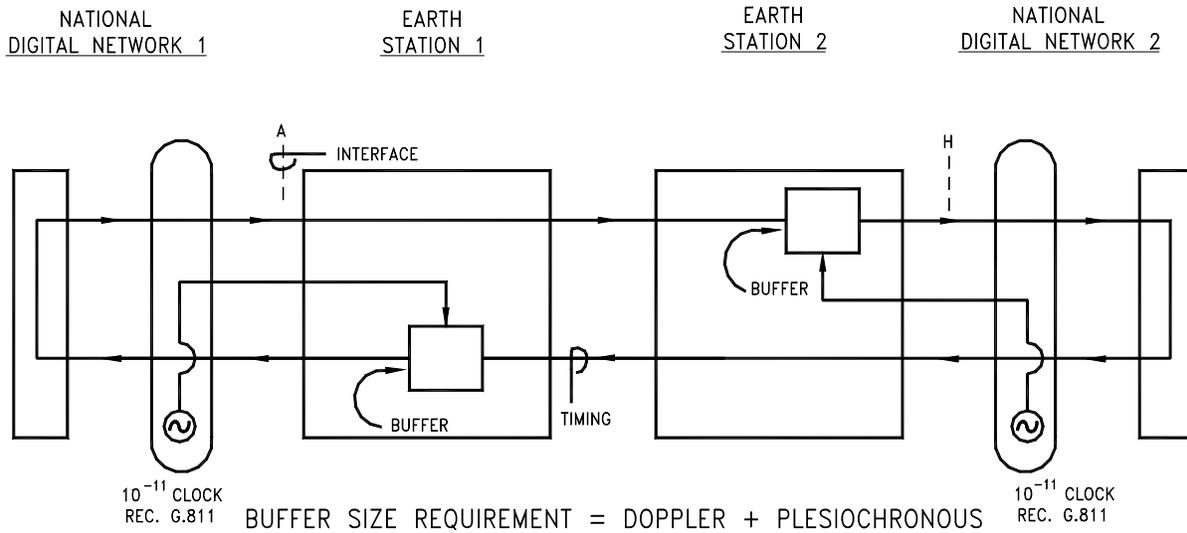


Figure 17

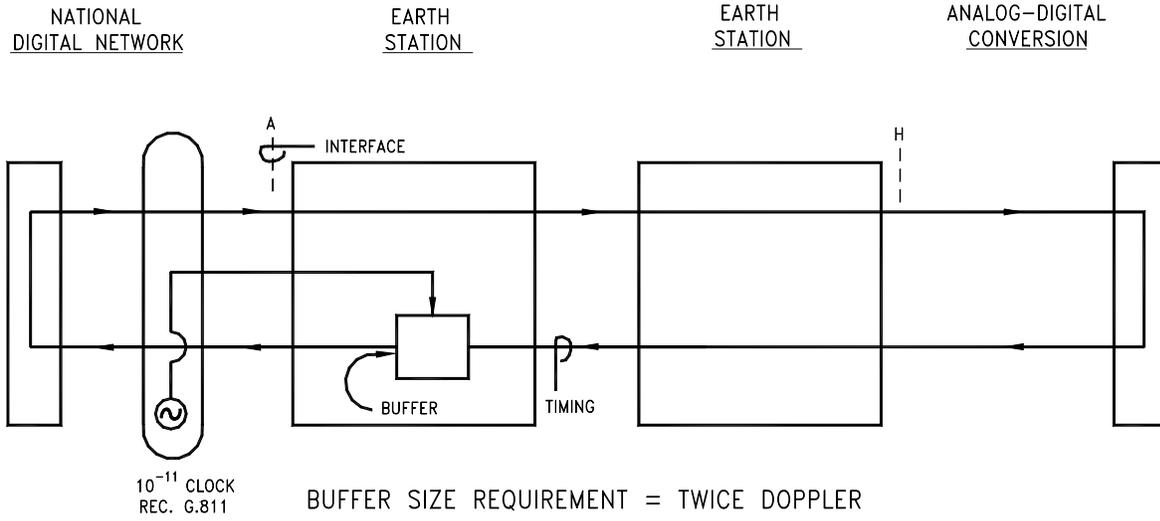
CASE 1. EXAMPLE OF TIMING AND BUFFERING ARRANGEMENTS  
(Digital Network at Both Ends)



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

Figure 18

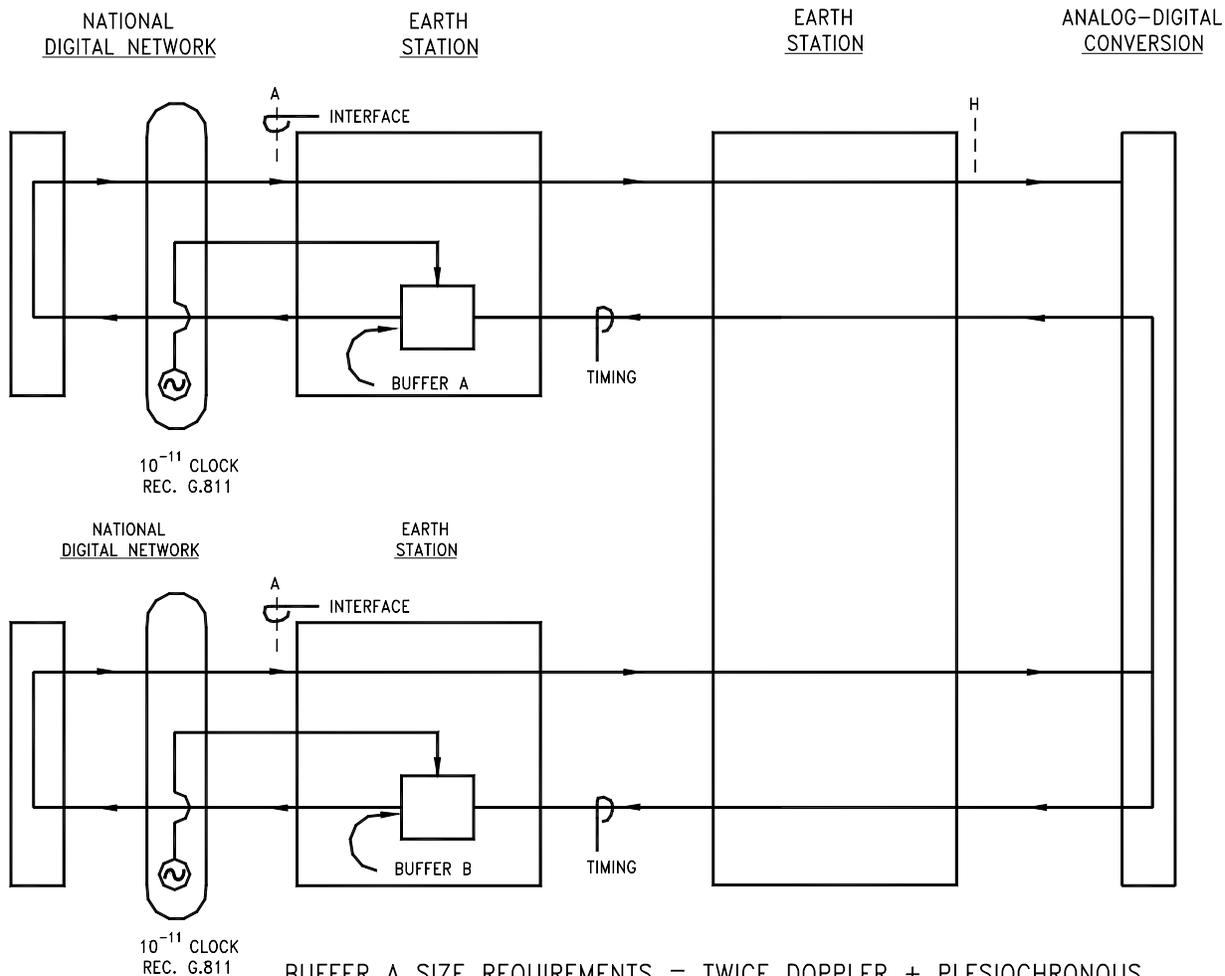
CASE 2. EXAMPLE OF TIMING AND BUFFERING ARRANGEMENTS  
(One End of the Link Remotely Timed From Other End)



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

Figure 19

CASE 3. EXAMPLE OF TIMING AND BUFFERING ARRANGEMENTS  
 (Recovered Timing From One Station is Used for Transmitting to Another Station)

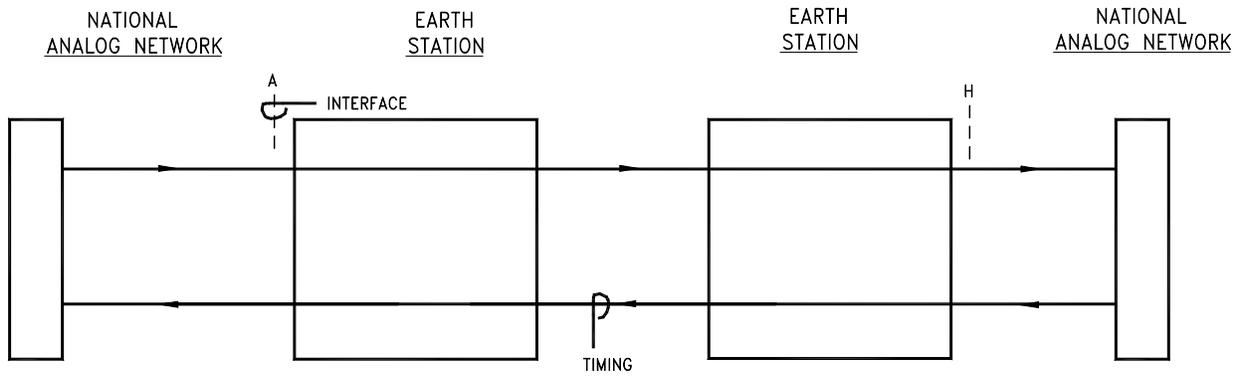


BUFFER A SIZE REQUIREMENTS = TWICE DOPPLER + PLESIOCHRONOUS  
 BUFFER B SIZE REQUIREMENTS = SAME AS CASE 2 (TWICE DOPPLER)

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

Figure 20

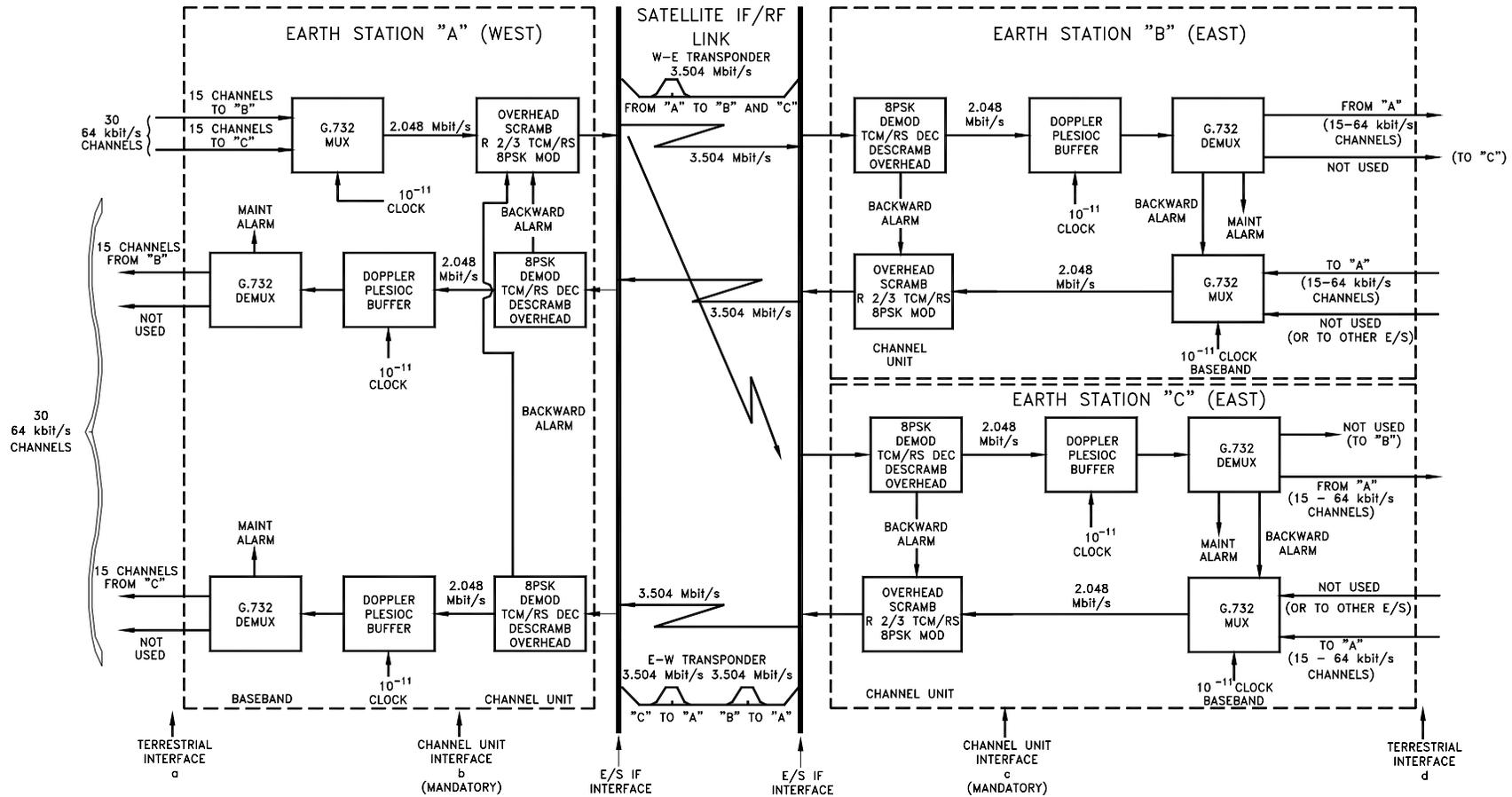
CASE 4: EXAMPLE OF TIMING AND BUFFERING ARRANGEMENTS  
(No Synchronous Digital Network at Either End and No Buffer Requirements)



P:\CAD\IESS\310NEW\310-20.DWG

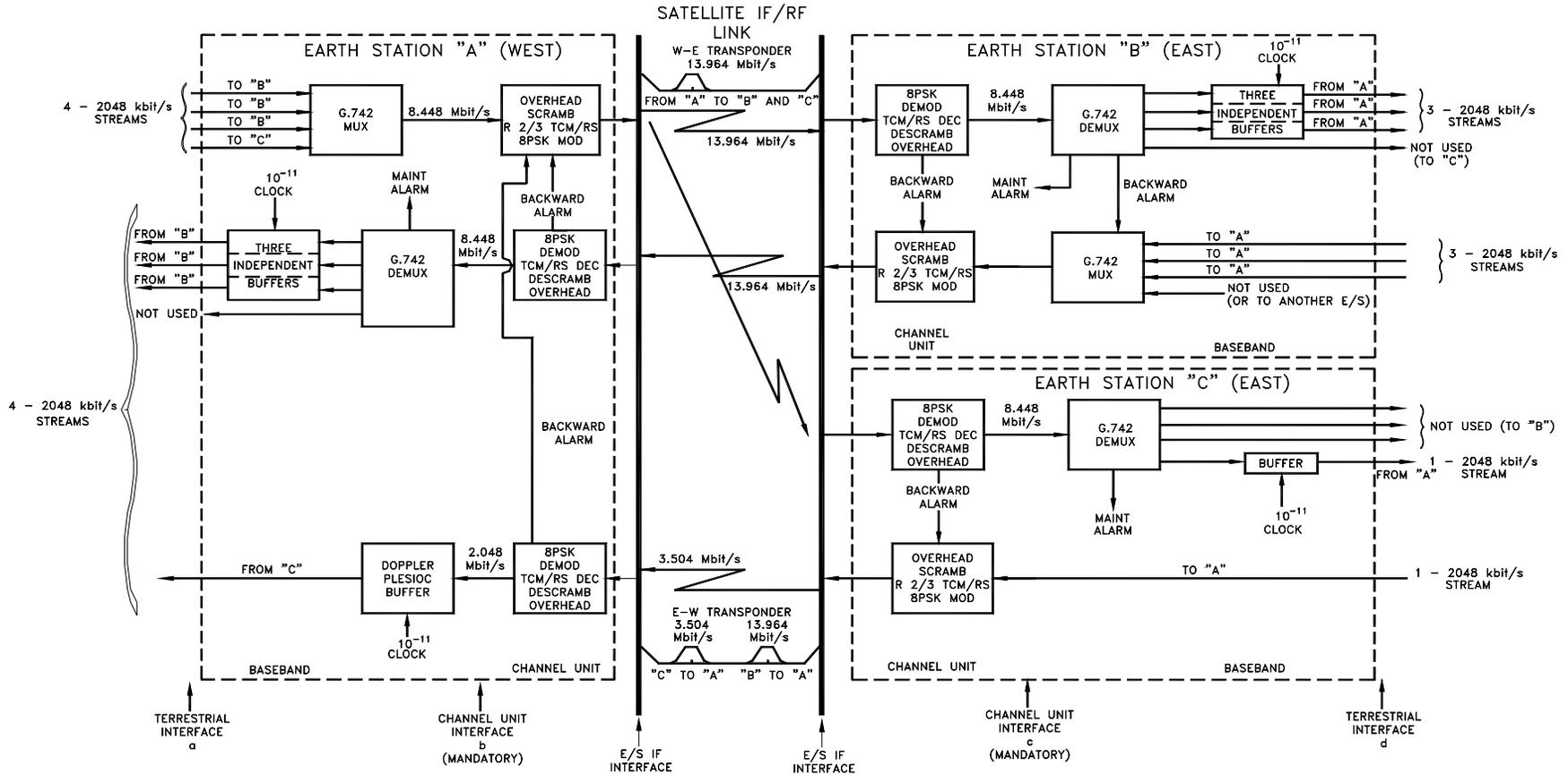
Figure 21

ILLUSTRATION OF MULTI-DESTINATIONAL TCM/IDR APPLICATION  
(Primary Order Carriers)



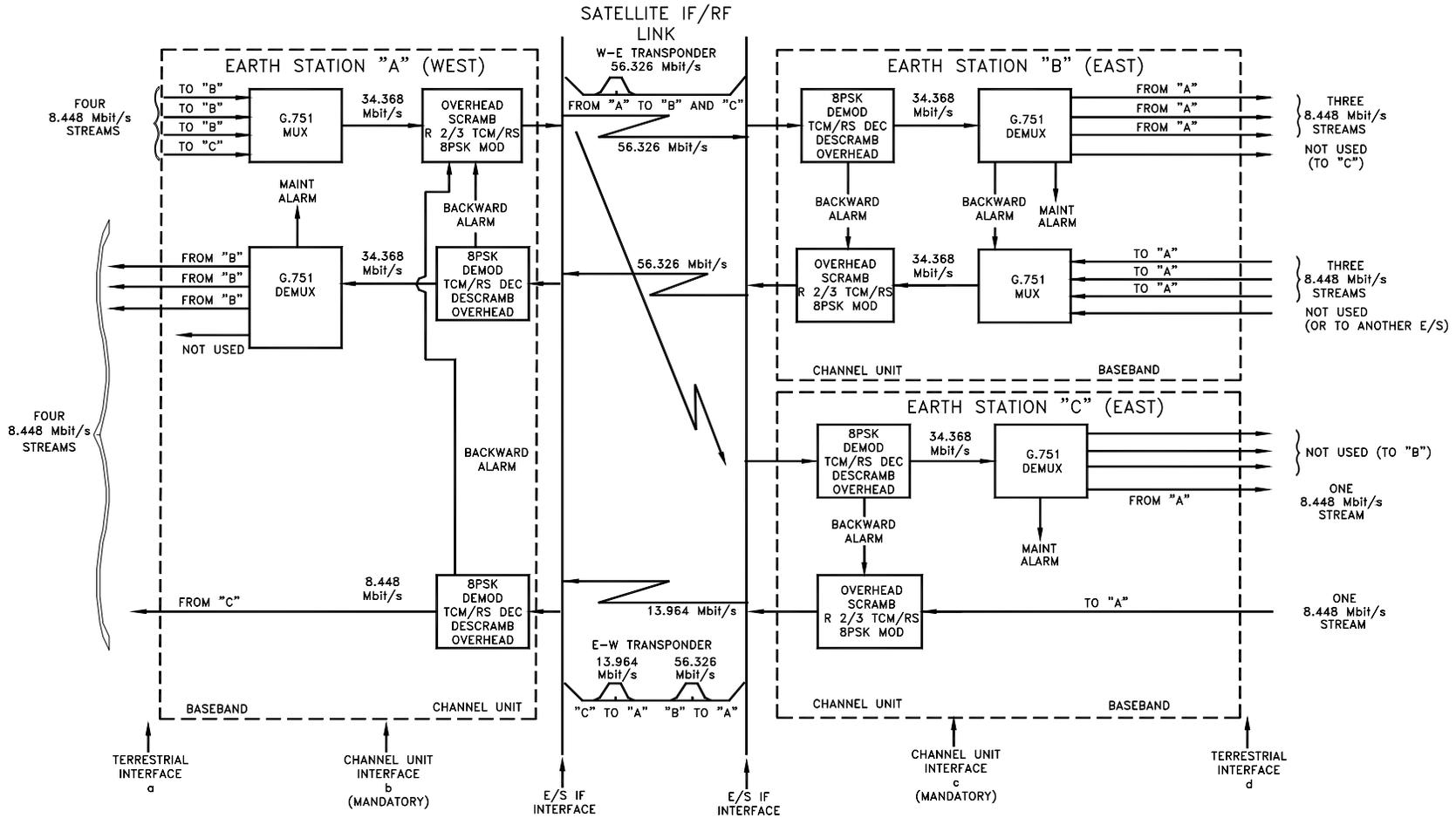
NOTE: THIS FUNCTIONAL BLOCK DIAGRAM IS INTENDED FOR ILLUSTRATION PURPOSES ONLY, AND IS NOT INTENDED TO PORTRAY ANY PARTICULAR PHYSICAL EQUIPMENT ARRANGEMENT OR THE TYPE OF TERRESTRIAL INTERFACE. FOR EXAMPLE, THE BUFFER COULD BE PART OF THE CHANNEL UNIT. THE MULTI-MULTIPLEX EQUIPMENT COULD ALSO BE ON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

Figure 22  
ILLUSTRATION OF MULTI-DESTINATIONAL TCM/IDR APPLICATION  
(Primary and Secondary Order Carriers)



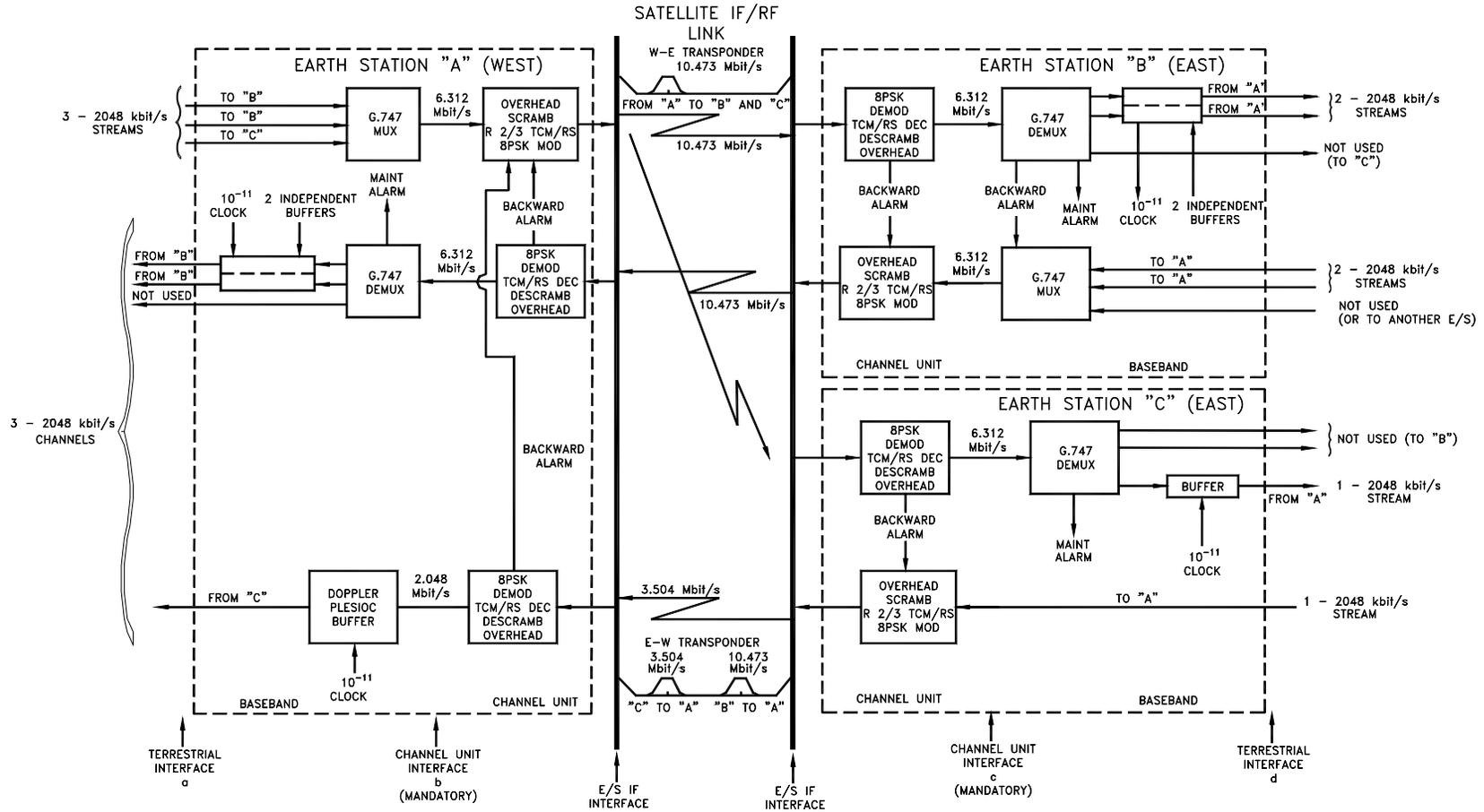
NOTE: THIS FUNCTIONAL BLOCK DIAGRAM IS INTENDED FOR ILLUSTRATION PURPOSES ONLY, AND IS NOT INTENDED TO PORTRAY ANY PARTICULAR PHYSICAL EQUIPMENT ARRANGEMENT OR TYPE OF TERRESTRIAL INTERFACE. FOR EXAMPLE, THE HIGHER ORDER MULTIPLEXERS COULD BE TIMED FROM A CLOCK WITH 10<sup>-11</sup> ACCURACY, IN WHICH 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.

Figure 23  
ILLUSTRATION OF MULTI-DESTINATIONAL TCM/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 MULTIPLEXER EQUIPMENT COULD ALSO BE ON THE TERRESTRIAL SIDE OF INTERFACES a AND d.

Figure 24  
ILLUSTRATION OF MULTI-DESTINATIONAL TCM/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<sup>-11</sup> ACCURACY, IN WHICH CASE THE BUFFER COULD BE PART OF THE CHANNEL UNIT. THE MULTIPLEXER EQUIPMENT COULD ALSO BE ON THE TERRESTRIAL SIDE OF INTERFACES 'a' AND 'd'.

Figure 25  
SCRAMBLER / DESCRAMBLER LOGIC DIAGRAM

