Appendix A. Example Link Calculations

A.1 General

This appendix contains example link calculations for forward and return services. All link calculations are based on the TDRSS telecommunications services defined in Sections 5 (MA), 6 (SSA), 7 (KuSA), and 8 (KaSA).

NOTE

The calculations in this appendix are provided for example only, and no data should be extracted from them for specific use. For specifics on preparing necessary RF ICD's, contact the Mission Services Program Office.

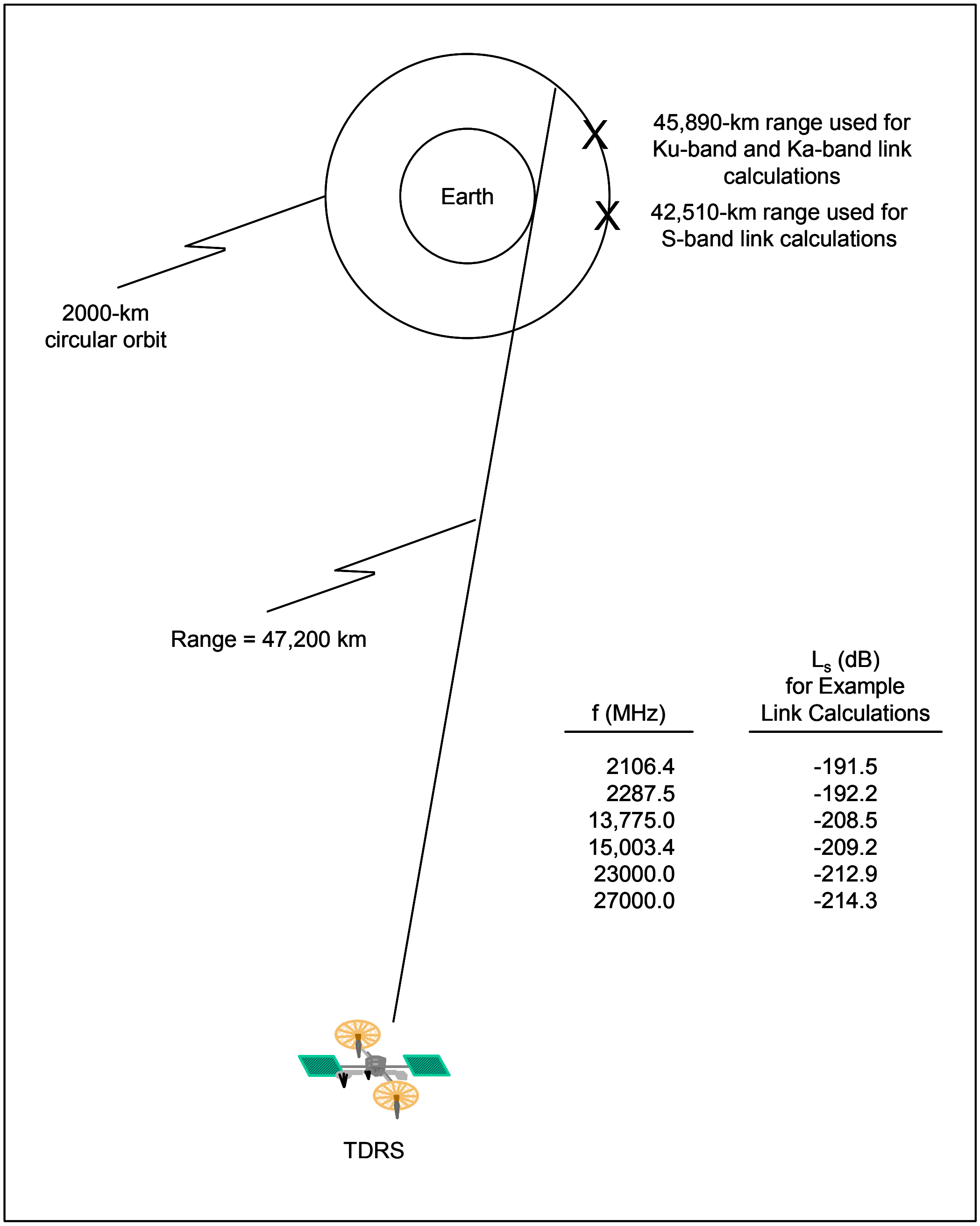
A.2 Customer Platform-to-TDRS-Range

All forward and return service link calculations are based upon example customer platform-to-TDRS ranges of 42,510 km for S-band and 45,890 km for K-band (Ku and Ka). Figure A-1 illustrates the example communications range positions for a 2000-km customer platform orbit. The maximum communications ranges for particular customer platform can differ from these values as a result of the actual orbit, Power Flux Density (PFD) constraints (refer to Appendix D), or other customer mission requirements and constraints.

A.3 Forward Service Link Calculations

A.3.1

Forward service performance is expressed in terms of having a sufficient data Bit Energy to Noise Spectral Density Ratio (E_b/N_o) at the customer platform receiving system for the desired link operating point (e.g., command data channel BER of 10^{-5}). Forward service performance is determined by calculating a predicted (E_b/N_o) and comparing it against the required (E_b/N_o).



f (MHz)	L_s (dB) for Example Link Calculations
2106.4	-191.5
2287.5	-192.2
13,775.0	-208.5
15,003.4	-209.2
23000.0	-212.9
27000.0	-214.3

Figure A-1. Geometry Depicting Nominal Ranges Used for Example Link Calculations

A.3.2

Forward service link calculations are based on the TDRS EIRP's and the transmitting antenna axial ratios shown in Tables 5-2 (MA), 6-3 (SSA), 7-2 (KuSA), and 8-2 (KaSA), the customer platform receiving system characteristics, the link operating frequency, and the customer platform-to-TDRS range. The following procedure may be used to determine the performance of the forward service command channel:

Equation A-1

$$\frac{P_{rec}}{N_o} = EIRP + L_s + L_p + L_\theta + (G/T) - 10\log(k)$$

where:

EIRP = The total TDRS EIRP in the direction of the customer platform (fixed by TDRS performance specification). The EIRP in the data channel is a function of the modulation type and the modulation index. The EIRP in the data channel is:

$EIRP_{data}$ (dBW) = EIRP – 0.4 (UQPSK when the baud rate ≤ 300 kbps)

$EIRP_{data}$ (dBW) = EIRP (BPSK and when baud rate > 300 kbps)

$EIRP_{data}$ (dBW) = EIRP $-20\log_{10}(\sin(mi))$ (SSA direct PM)

$EIRP_{data}$ (dBW) = EIRP $-20\log_{10}(2*J1(mi))$ (SSA PSK subcarrier PM)

$EIRP_{carrier}$ (dBW) = EIRP $-20\log_{10}(\cos(mi))$ (SSA direct PM)

$EIRP_{carrier}$ (dBW) = EIRP $-20\log_{10}(J0(mi))$ (SSA PSK subcarrier PM)

where mi is the modulation index, J1 is the first order Bessel function, J0 is the zero order Bessel function.

L_s = space loss (in dB) = $-[32.45 + 20\log_{10}(R) + 20\log_{10}(f)]$, ($L_s < 0$ dB).

R = maximum range (in km) between the TDRS and the customer platform over which communications will occur.

f = TDRS transmission frequency (in MHz).

L_p = polarization loss (in dB) due to the mismatch of the TDRS radiated polarization and that of the customer platform receiving antenna ($L_p \leq 0$ dB).

L_θ = pointing loss (in dB) in the customer platform received signal due to inability of the customer platform to point its receiving antenna directly at the TDRS ($L_\theta \leq 0$ dB).

G/T = customer platform receiving antenna gain to system thermal noise temperature ratio (in dB/K).

10 log (k) = -228.6 dBW/Hz-K (k is Boltzmann's constant).

Equation A-2

$$(E_b/N_o)_{predicted} = P_{rec}/N_o - 10 \log R_d + \gamma$$

where:

R_d = data rate in bps

γ = sum of customer platform receiving system and TDRSS forward service degradation factors (in dB), accounting for non-ideal degradations such as PN loss, demodulator degradation, bit sync loss, interference and multipath degradations, and distortion losses ($\gamma \leq 0$ dB).

Equation A-3

$$M = (E_b/N_o)_{predicted} - (E_b/N_o)_{required}$$

where:

M = customer performance margin (in dB) to allow for customer platform performance degradation throughout its operational lifetime ($M \geq 0$ dB).

$(E_b/N_o)_{required}$ = the bit energy to noise spectral density ratio in (dB) theoretically required for the command data BER (e.g., 9.9 dB for a 10^{-5} BER with coherent differential PSK).

The forward service performance curves in Figure A-2 through Figure A-11 are for example only and show Achievable Data Rate (ADR) versus customer platform G/T for the command data channel. The ADR equation is derived by solving Equation A-1, Equation A-2 and Equation A-3 for 10 log R_d and using the values of the equation parameters defined in the appropriate figure, and the following assumptions:

a. The margin (M) is assumed constant at 3 dB – the amount of margin is a customer decision that should be coordinated with the Mission Services Program Office and should consider long-term degradations in the customer platform.

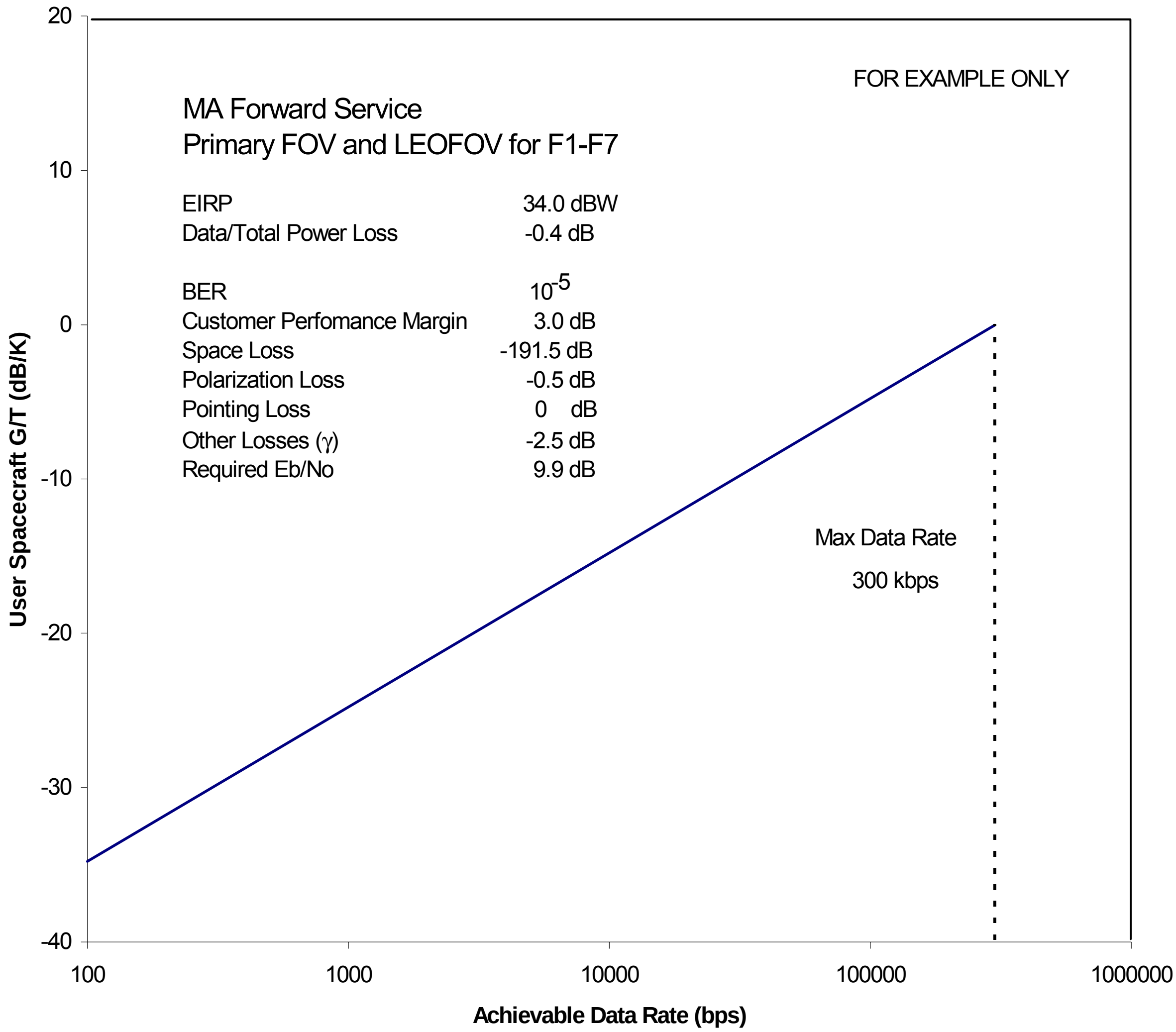


Figure A-2. MA Forward ADR versus G/T (Primary FOV and LEOFOV for F1-F7)

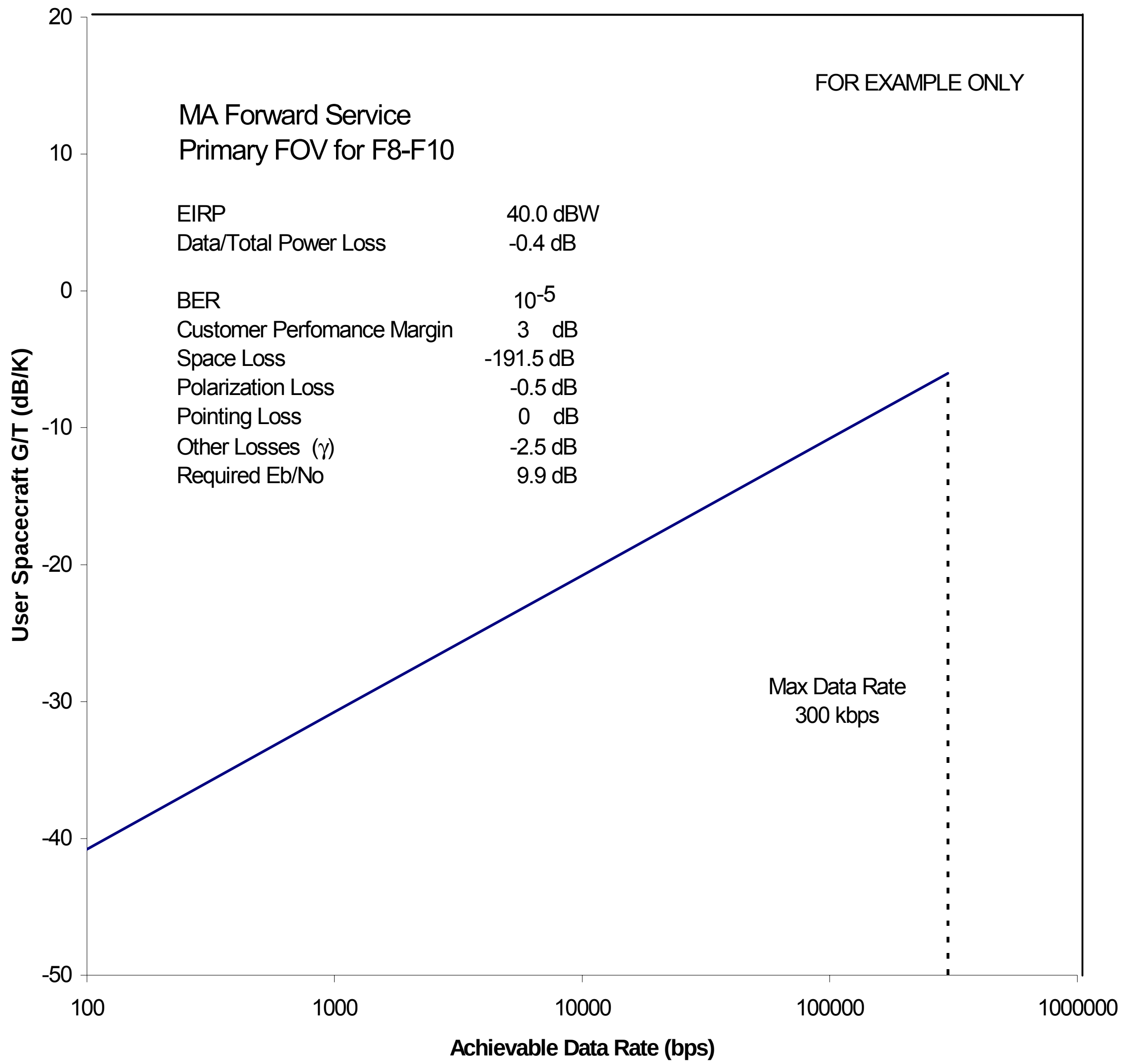


Figure A-3. MA Forward ADR versus G/T (Primary FOV for F8-F10)

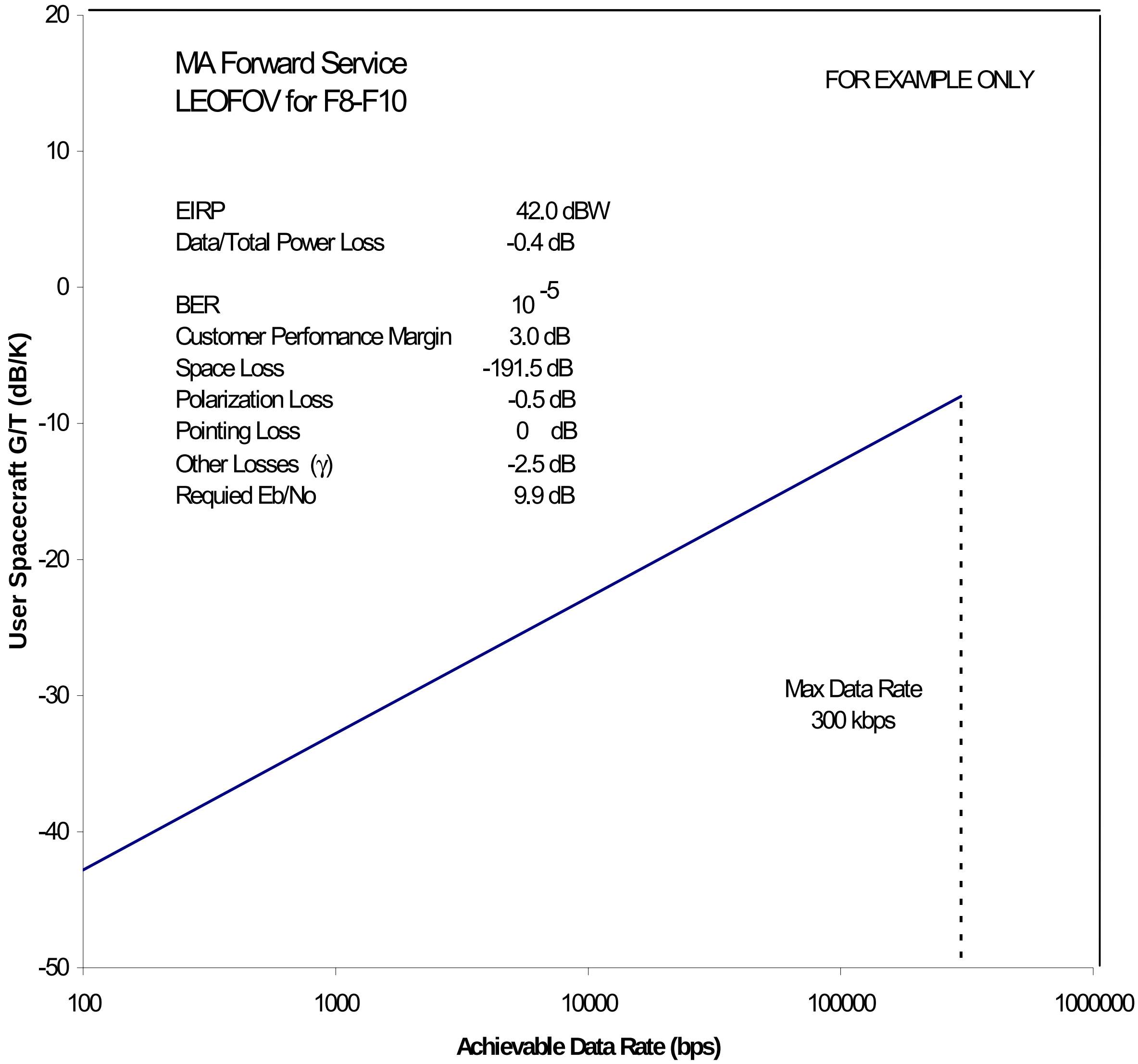


Figure A-4. MA Forward ADR versus G/T (LEOFOV for F8-F10)

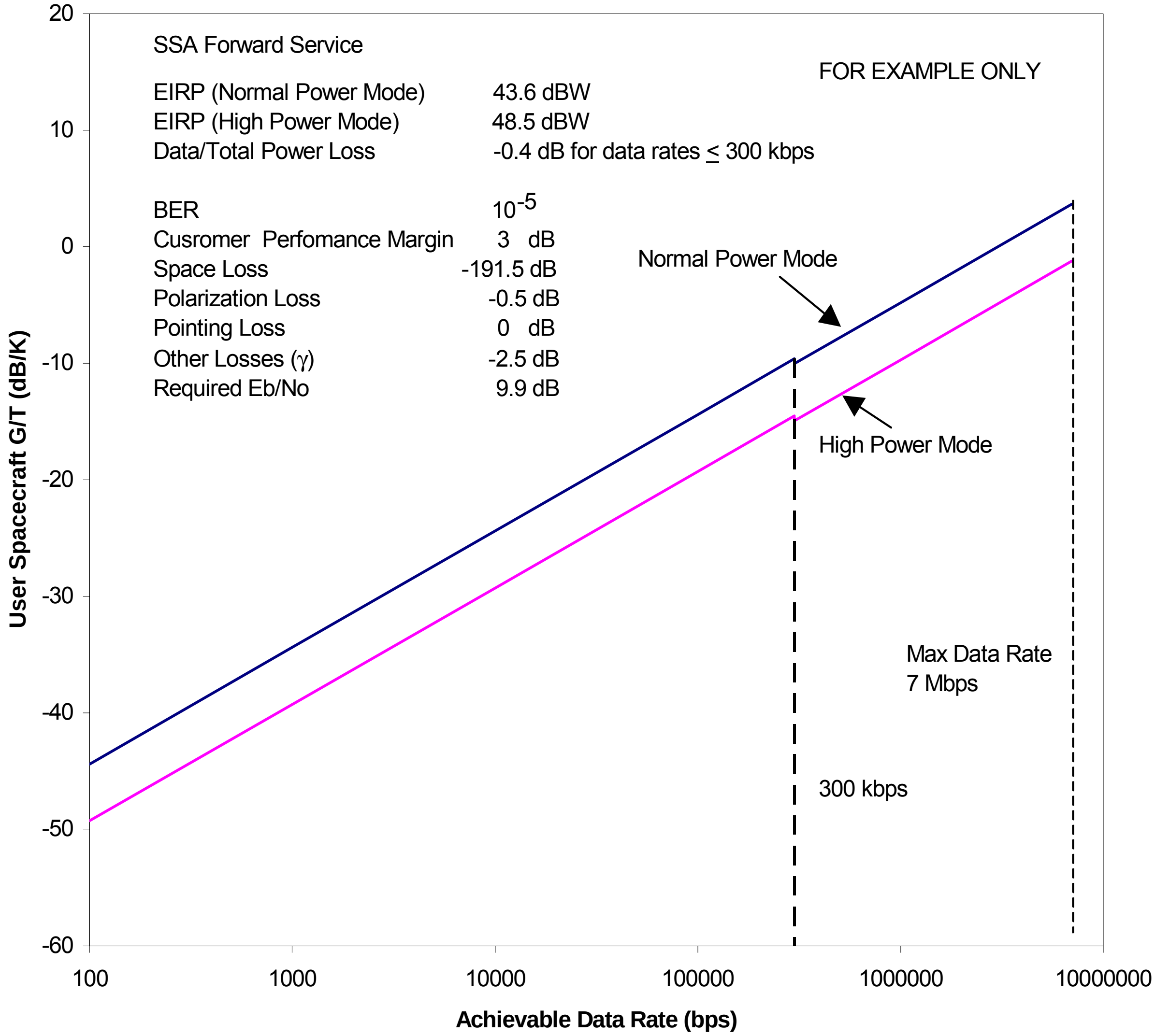


Figure A-5. SSA Forward ADR versus G/T for F1-F10

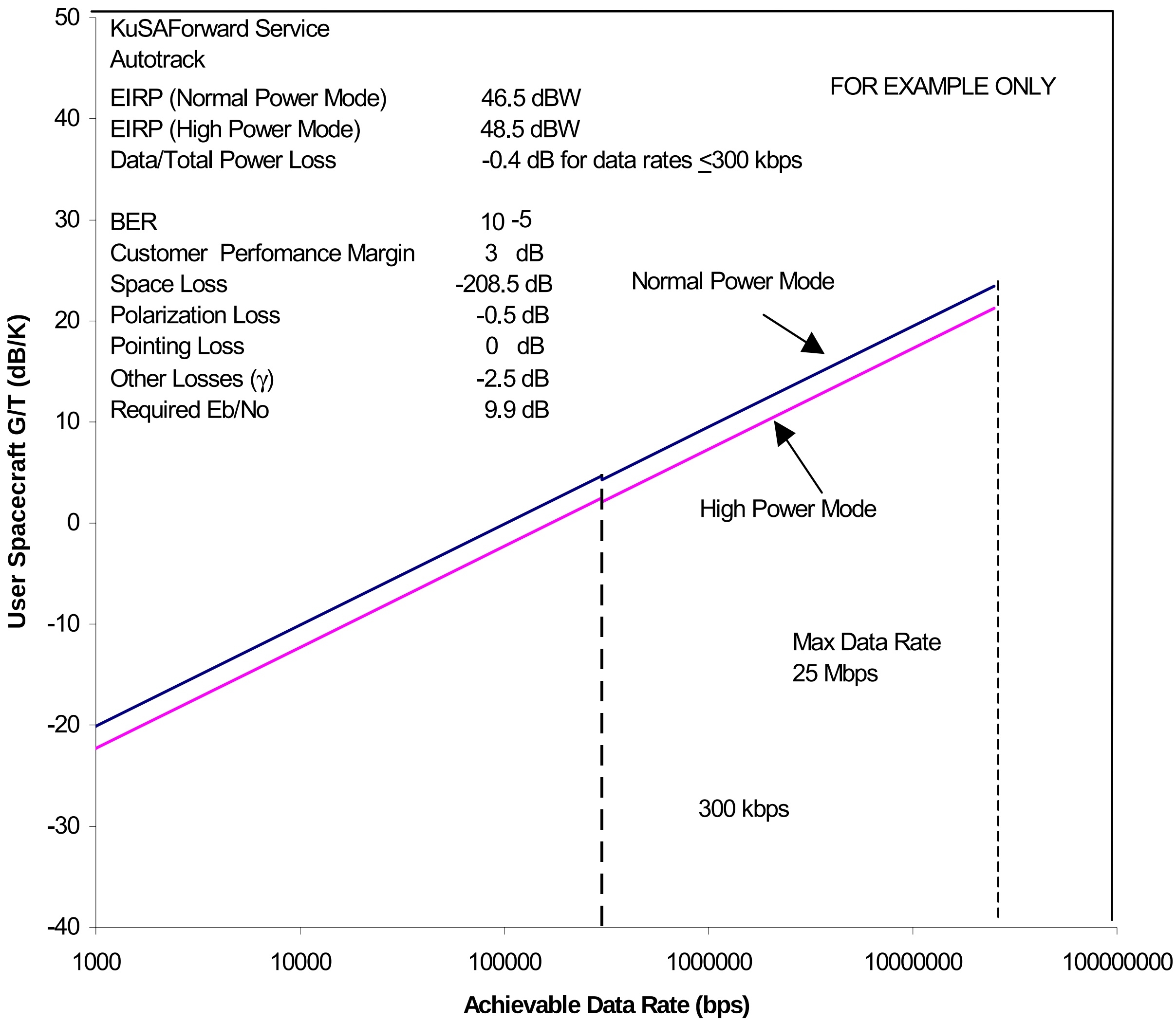


Figure A-6. KuSA Forward ADR versus G/T (Autotrack for F1-F10)

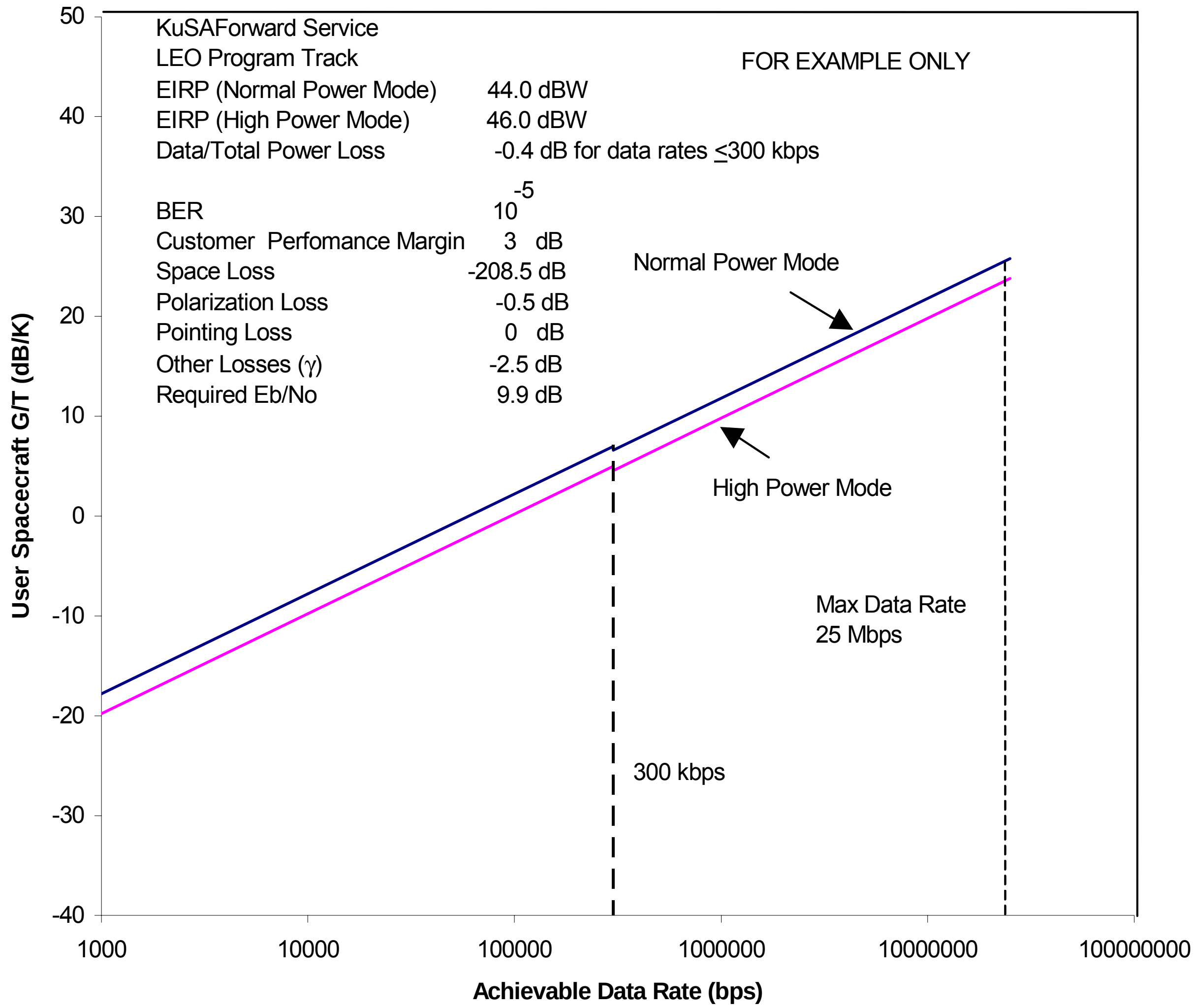


Figure A-7. KuSA Forward ADR versus G/T (LEO Program Track for F1-F10)

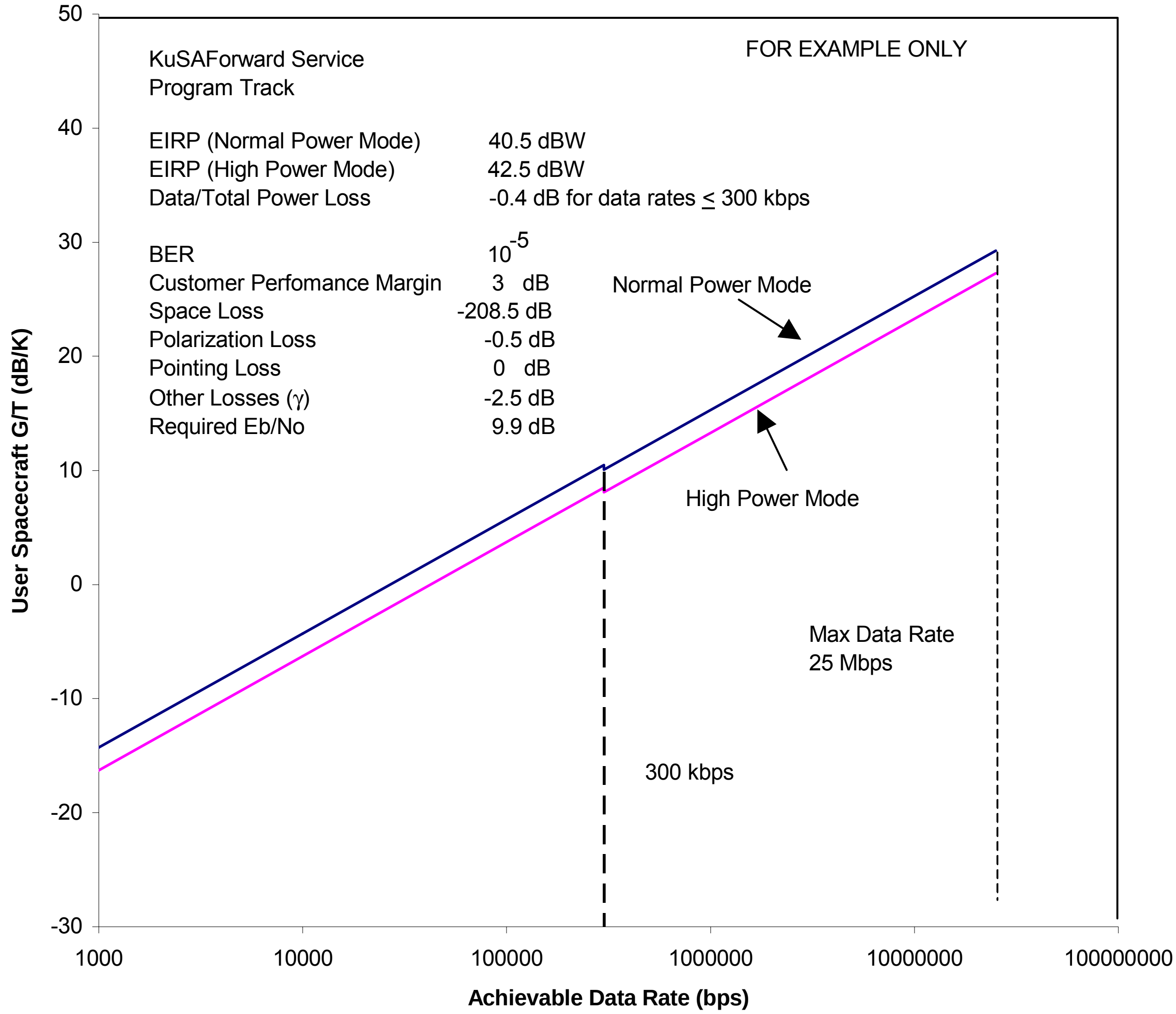


Figure A-8. KuSA Forward ADR versus G/T (Program Track for F1-F10)

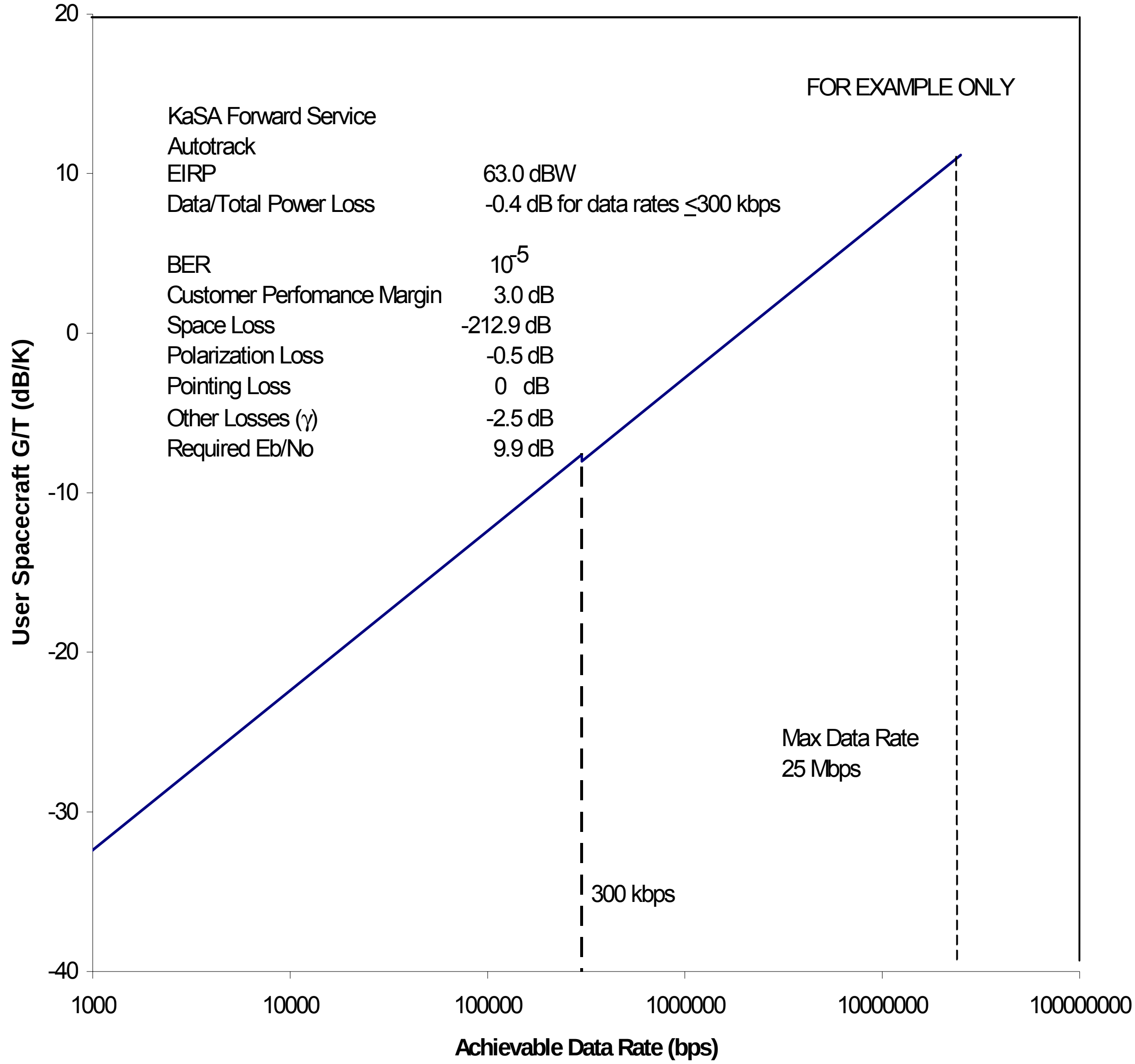


Figure A-9. KaSA Forward ADR versus G/T (Autotrack for F1-F10)

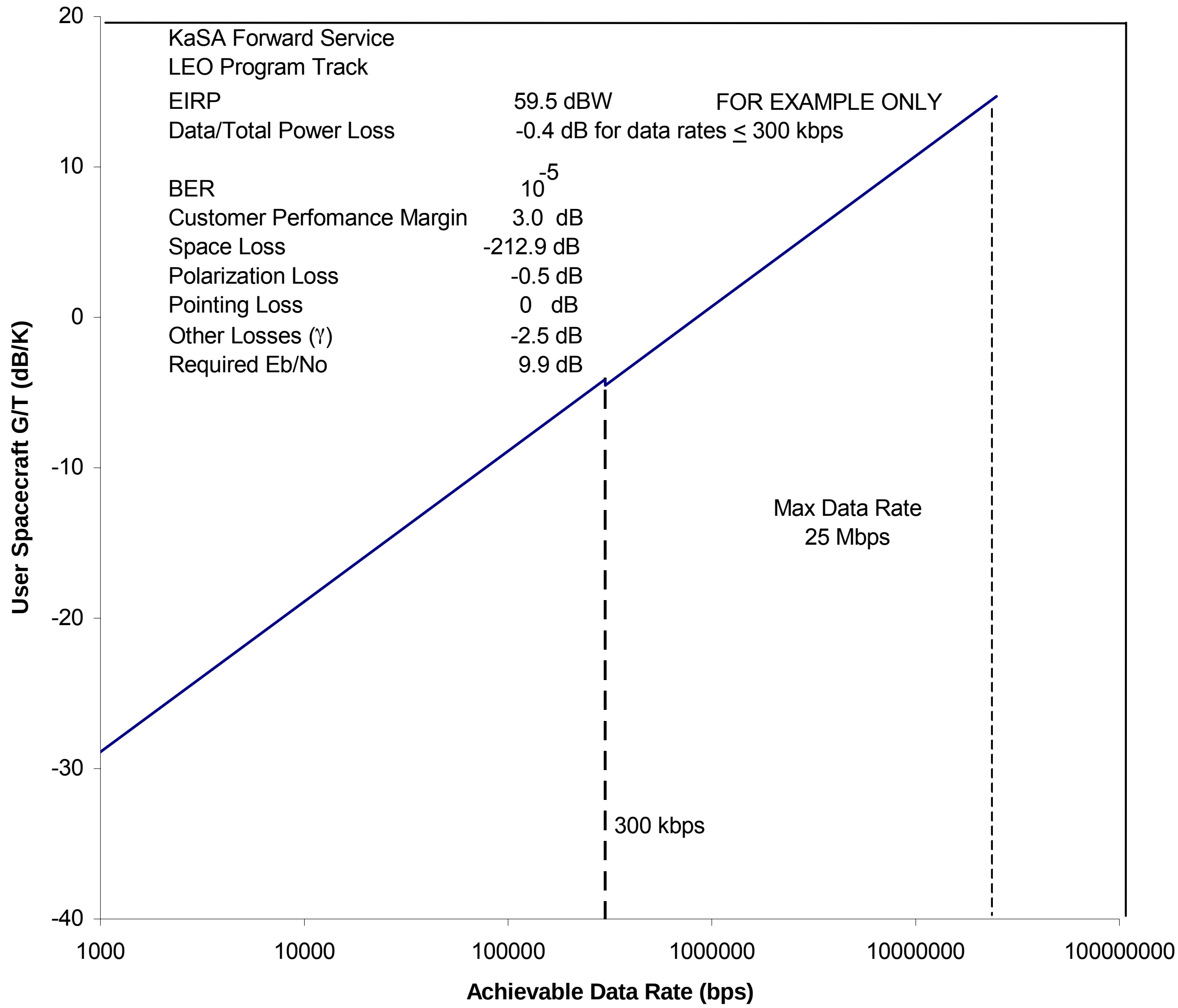


Figure A-10. KaSA Forward ADR versus G/T (LEO Program Track for F1-F10)

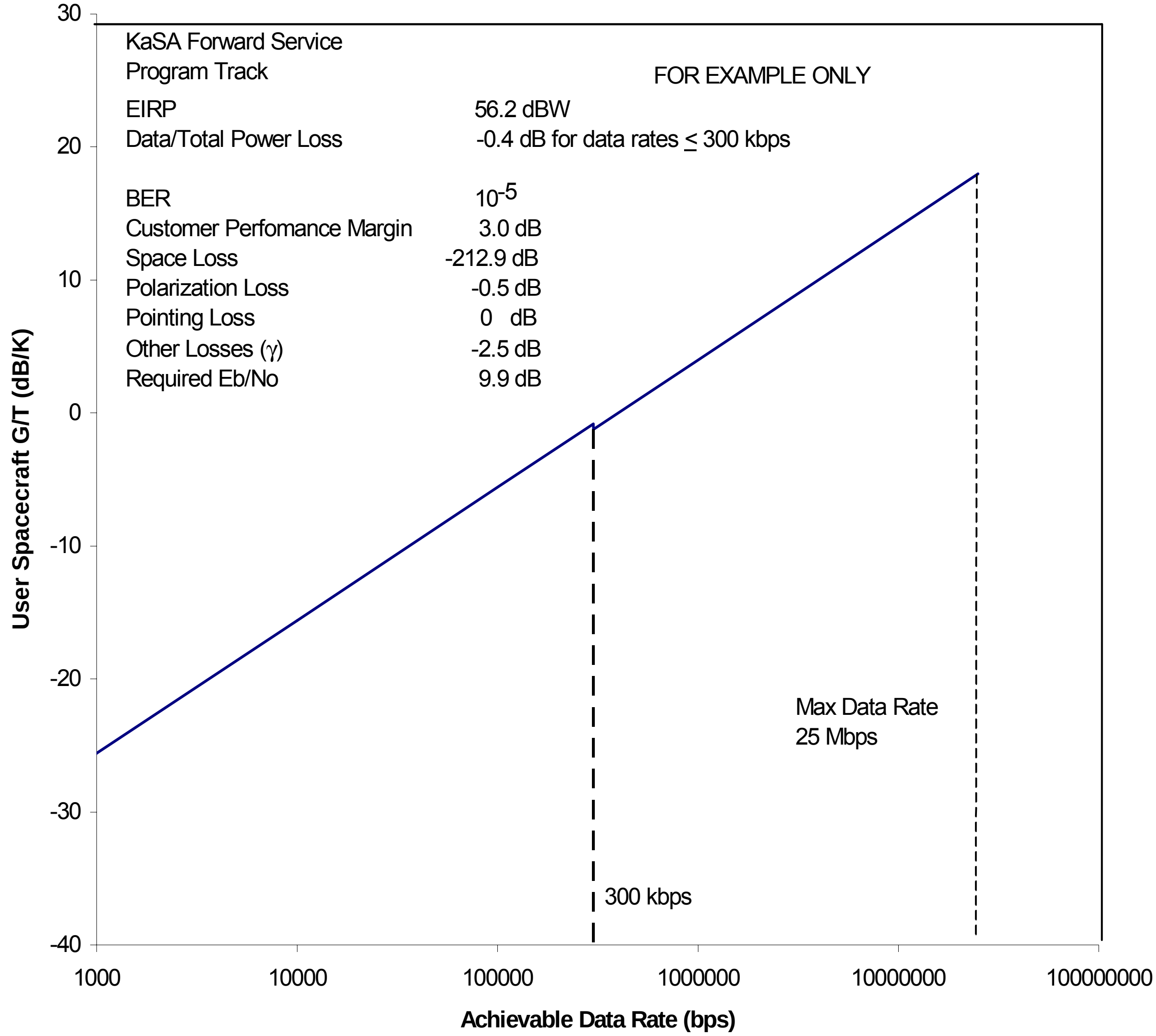


Figure A-11. KaSA Forward ADR versus G/T (Program Track for F1-F10)

b. Required E_b/N_o is 9.9 dB (BER of 10^{-5}).

c. The SSA and KuSA forward services are provided both with normal mode and high mode EIRP.

d. Customer platform/TDRSS incompatibility and RFI degradation (refer to paragraph A.3.3) is 0 dB.

A.3.3

CLASS is used to determine if any incompatibility or RFI degradation exists between the customer platform's receiving system terminal and the TDRSS. Detailed characteristics of the customer platform receiving system and the salient characteristics of the TDRSS forward services determine the magnitude of any compatibility loss. When applicable, these degradation factors, as determined by CLASS, must be included as loss terms on the right side of Equation A-1.

A.4 Return Service Link Calculations

A.4.1

Return service performance is expressed in terms of having sufficient received power (P_{rec}) at the TDRS to achieve a specific data rate (referred to as ADR) for a return service data channel BER of 10^{-5}.

Return service performance is determined by calculating the predicted required P_{rec} at a TDRS (accounting for all system losses), and comparing it to the ideal required P_{rec} at the TDRS for a given data rate.

A.4.2

The ideal required P_{rec} is determined as follows:

Equation A-4

$$\text{Ideal required } P_{rec} = 10 \log_{10} R_d + K$$

where: K is a constant depending on the service, type of tracking and/or field of view, coding, data rate, and mode. These relationships are as shown in Tables 5-8 (MA), 6-9 (SSA), 7-7 (KuSA), and 8-7 (KaSA).

A.4.3

The predicted required P_{rec} is determined by the following equation:

Equation A-5

$$\text{Predicted Required } P_{rec} = \text{Ideal Required } P_{rec} - L_\theta - L_p - L_l - L_{nc}$$

where:

L_θ	=	pointing loss (in dB) due to the inability of the customer platform to point its antenna directly at the TDRS ($L_\theta \leq 0$ dB).
L_p	=	polarization loss (in dB) due to mismatch of the customer platform radiated polarization and that of the TDRS receiving antenna ($L_P \leq 0$ dB).
L_I, L_{nc}	=	RFI and customer platform incompatibility factors (in dB) as determined by CLASS (refer to paragraph A-15) ($L_I \leq 0$ dB, $L_{nc} \leq 0$ dB).

A.4.4
By extension, the minimum customer platform EIRP, $(EIRP)_{min}$, required to produce the predicted required P_{rec} is as follows:

Equation A-6

$$(EIRP)_{min} = \text{Predicted Required } P_{rec} - L_s$$

where: L_s is space loss as defined in paragraph A.3.2.

A.4.5
The return service performance margin M (in dB) is a customer decision that should be coordinated with the GSFC MSP and should consider long-term performance degradation of the customer platform throughout its operational lifetime. M is defined as follows:

Equation A-7

$$M = EIRP - (EIRP)_{min} \quad (M \geq 0 \text{ dB})$$

A.4.6
The return service performance curves in Figure A-12 through Figure A-46 show ideal required (P_{rec}) versus ADR for selected services, type of tracking and/or field of view, codings, modes, data rates and channels. Figure A-47 shows an example ADR versus customer platform EIRP for a hypothetical customer platform, for an assumed performance margin, M, as illustrated in Equation A-7. The service, coding, mode, and channel in Figure A-47 are assumed to be those given in Figure A-19, so as to illustrate how the predicted required P_{rec} is realized, (or alternatively, how the ideal required P_{rec} plus performance margin is realized).

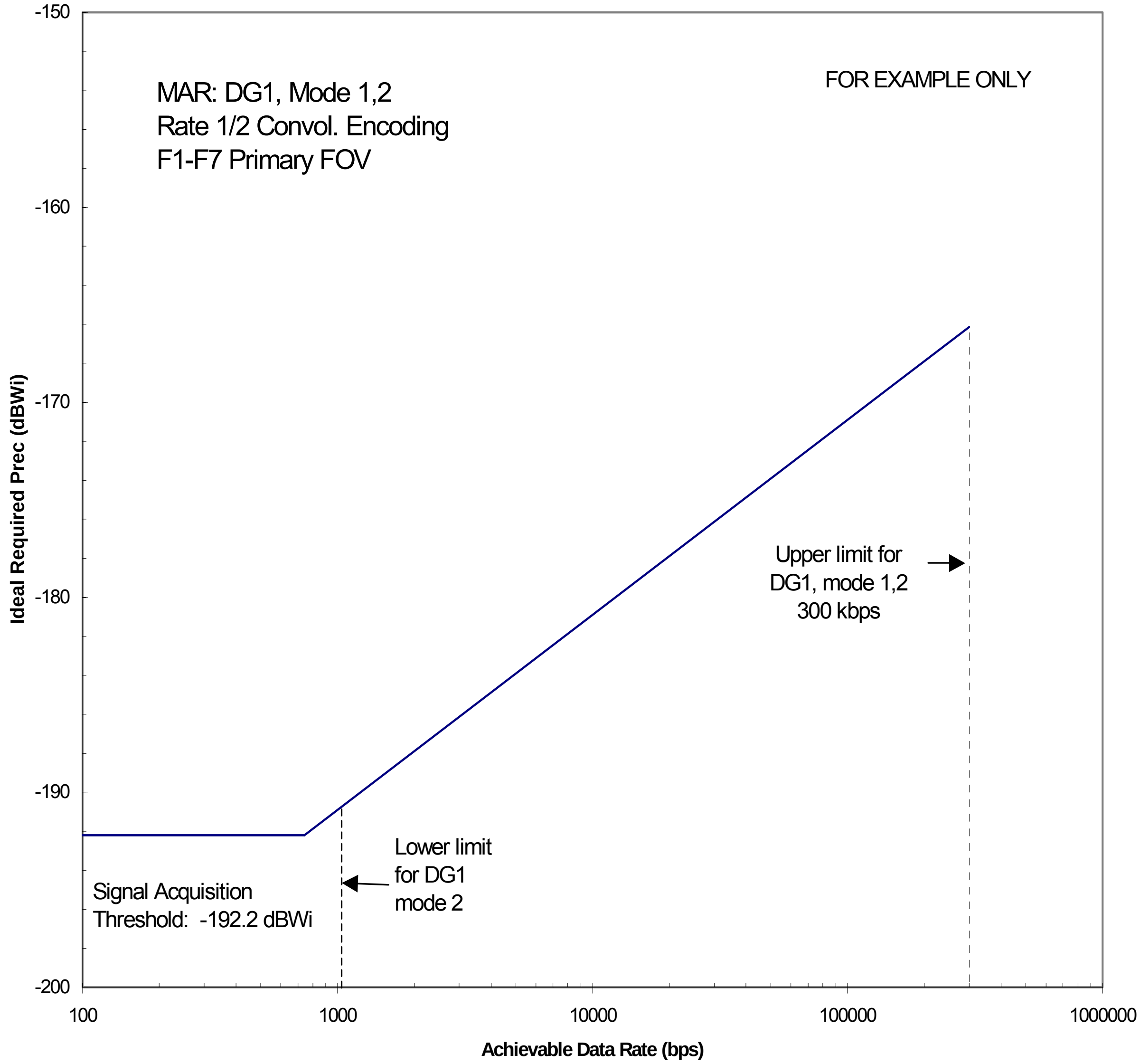


Figure A-12. MA DG1 Modes 1, 2 (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec}) (Primary FOV for F1-F7)

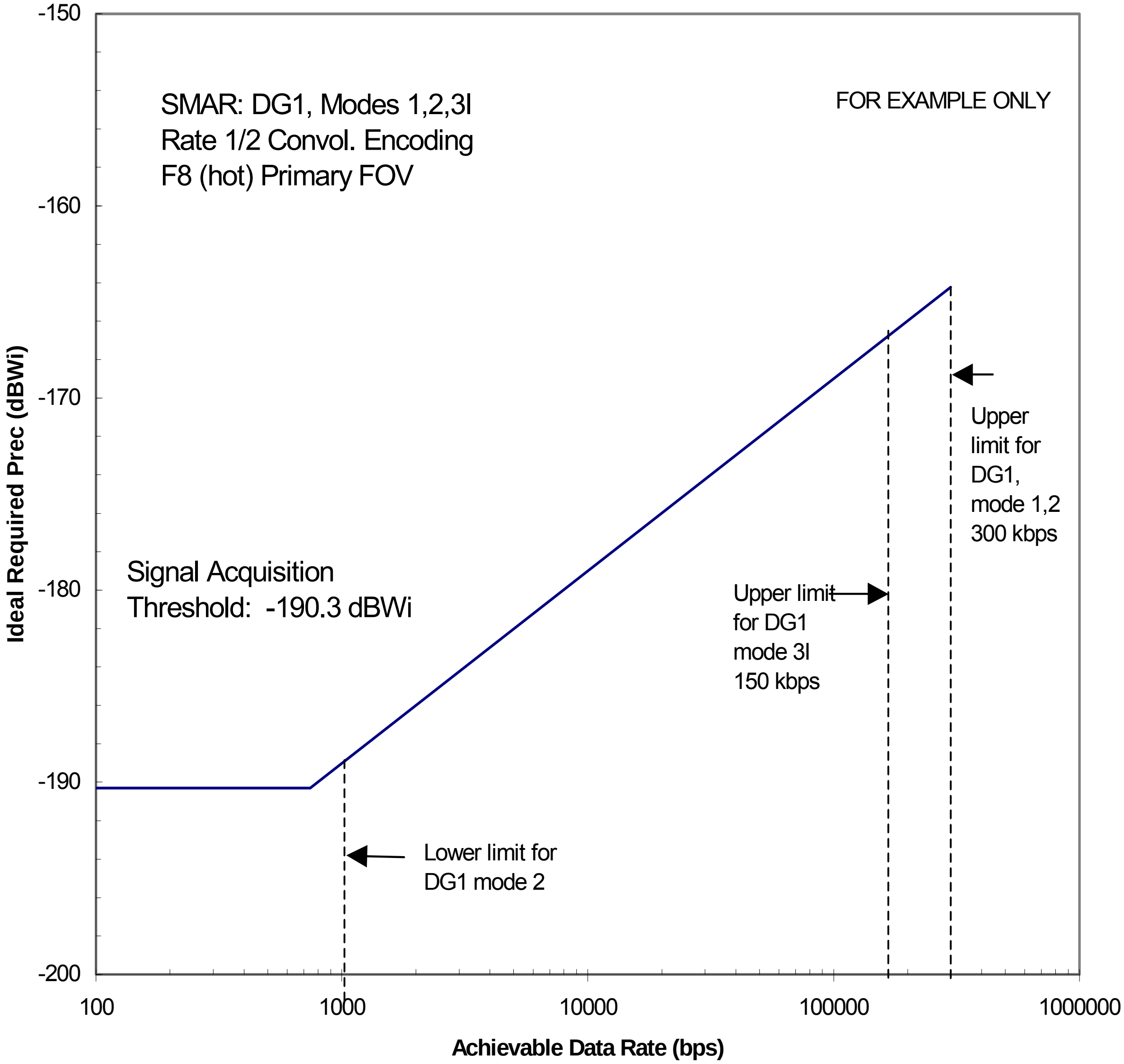


Figure A-13. SMA DG1 Modes 1, 2, 3I (Rate1/2) Return ADR versus Required Received Power at the TDRS (P_{rec}) (Primary FOV for F8 (hot))

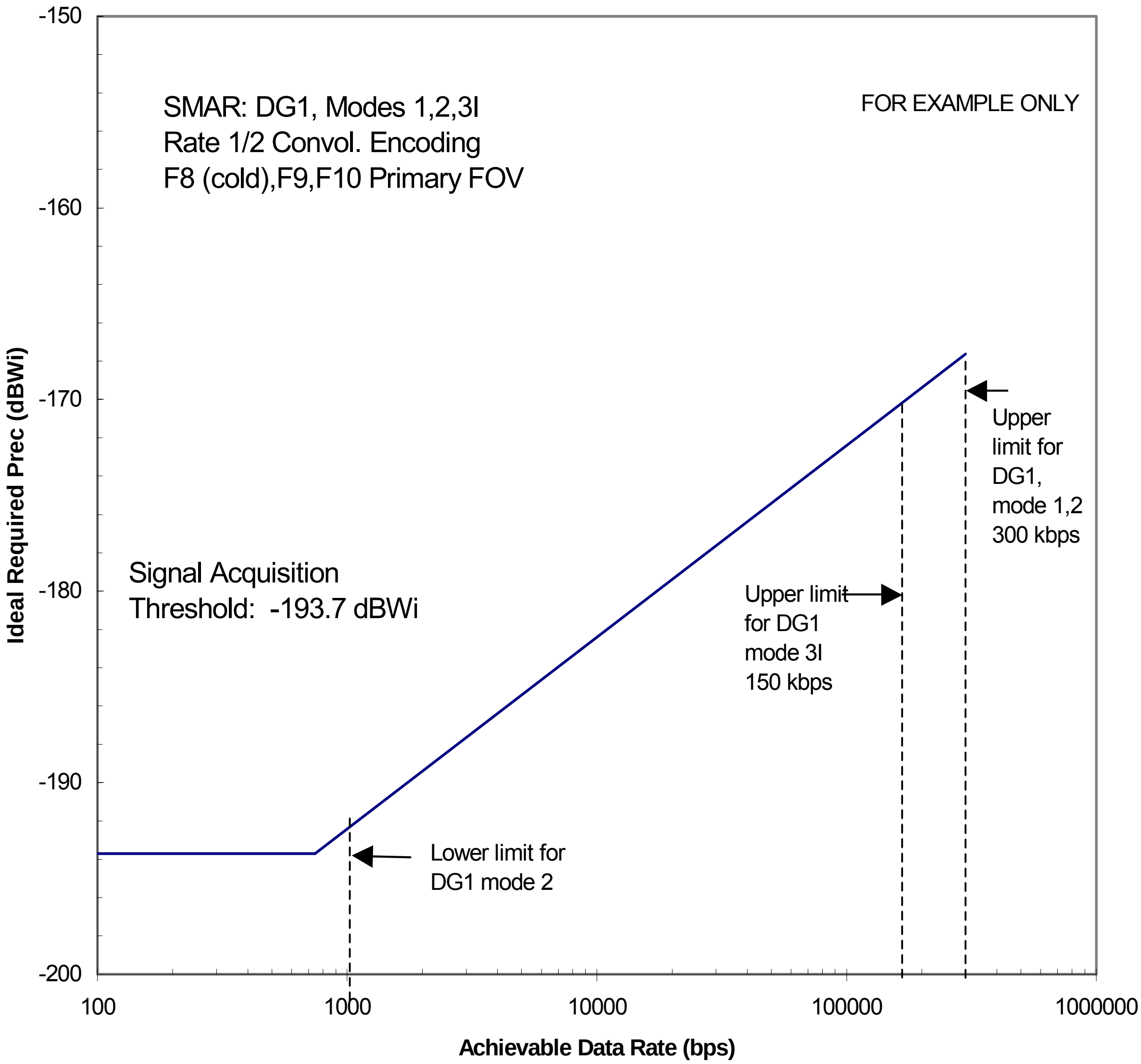


Figure A-14. SMA DG1 Modes 1, 2, 3I (Rate1/2) Return ADR versus Required Received Power at the TDRS (P_{rec}) (Primary FOV for F8 (cold), F9, F10)

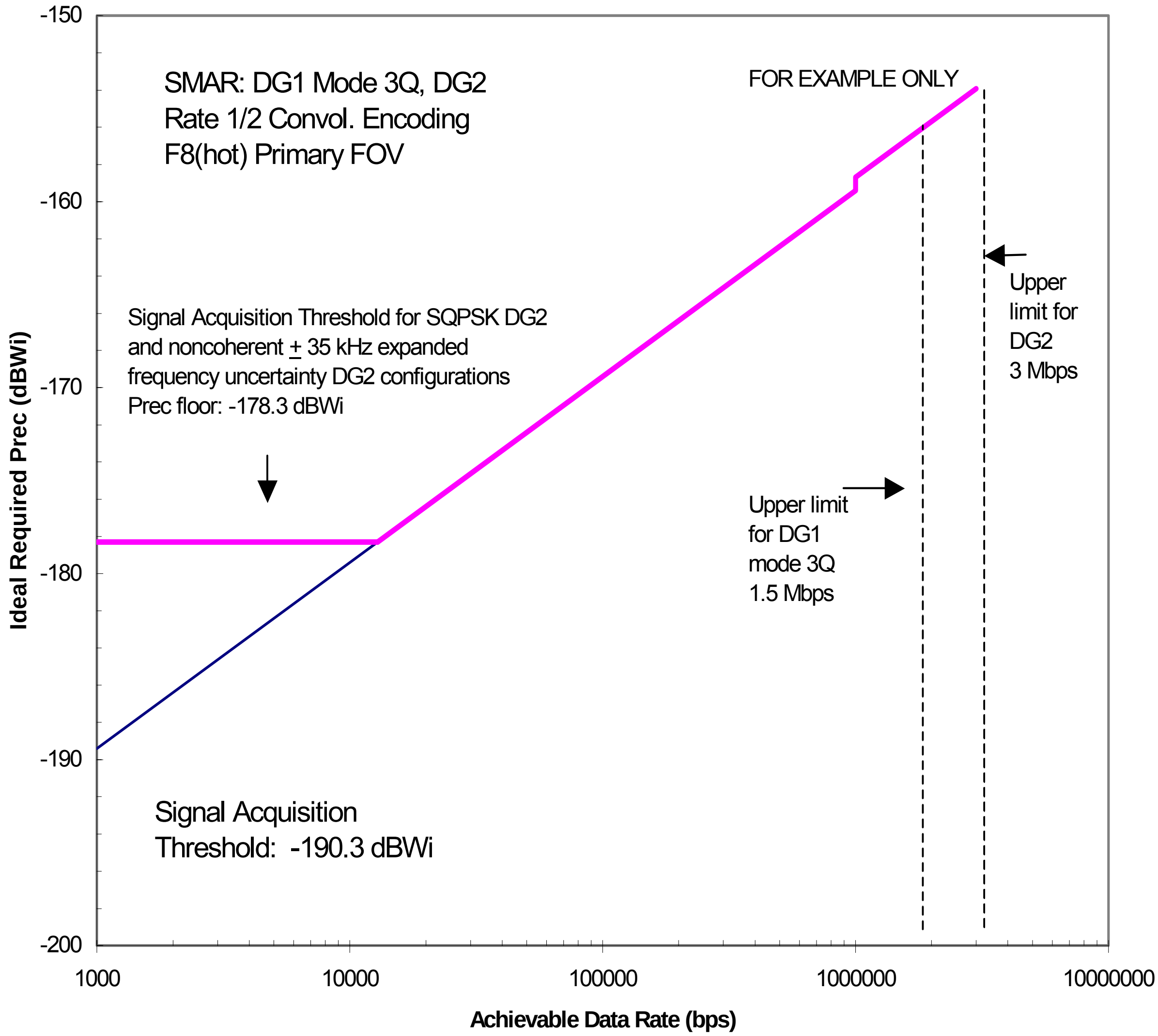


Figure A-15. SMA DG1 Mode 3Q and DG2 (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec}) (Primary FOV for F8 (hot))

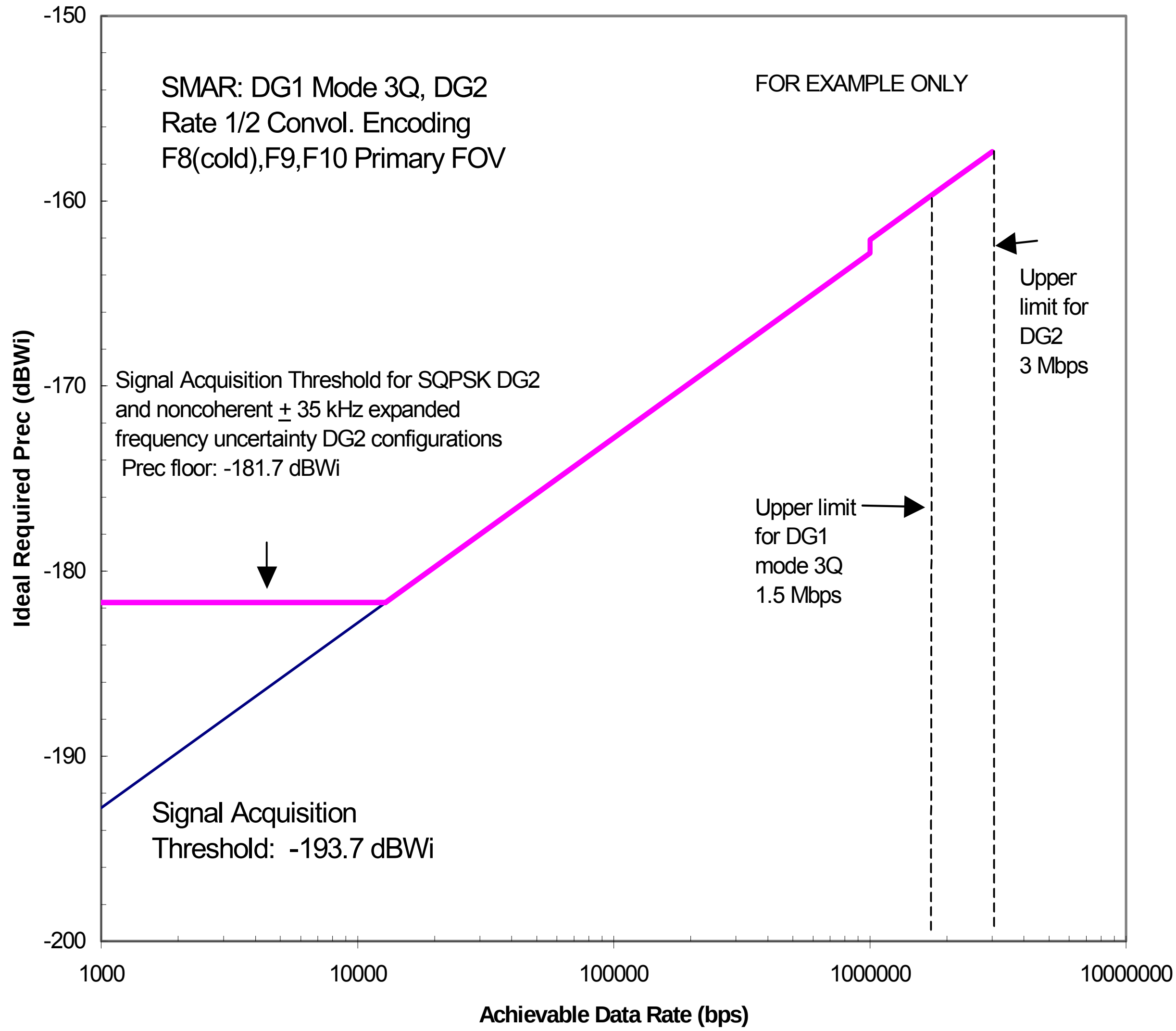


Figure A-16. SMA DG1 Mode 3Q and DG2 (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec}) (Primary FOV for F8 (cold), F9, F10)

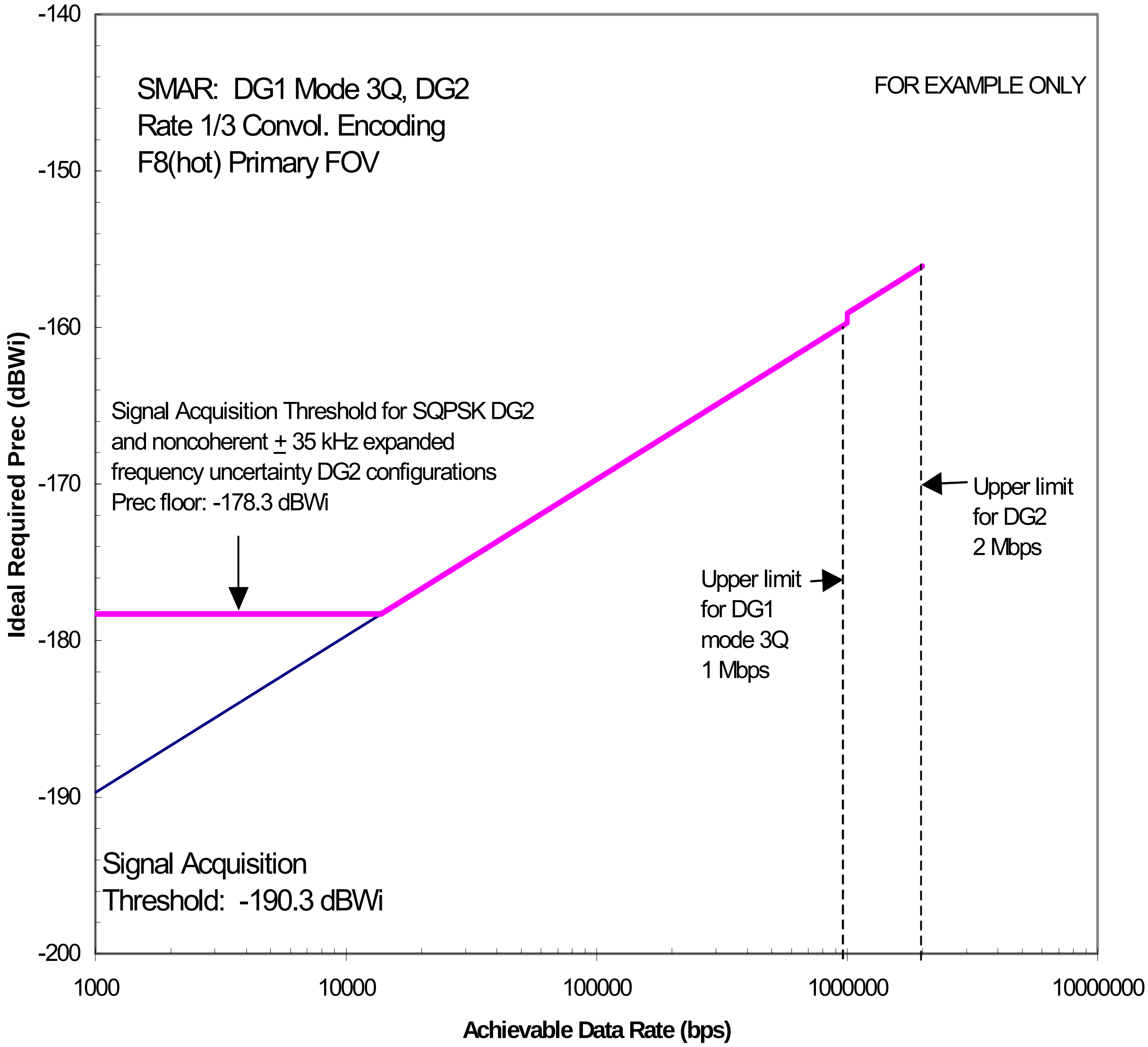


Figure A-17. SMA DG1 Mode 3Q and DG2 (Rate1/3) Return ADR versus Required Received Power at the TDRS (P_{rec}) (Primary FOV for F8 (hot))

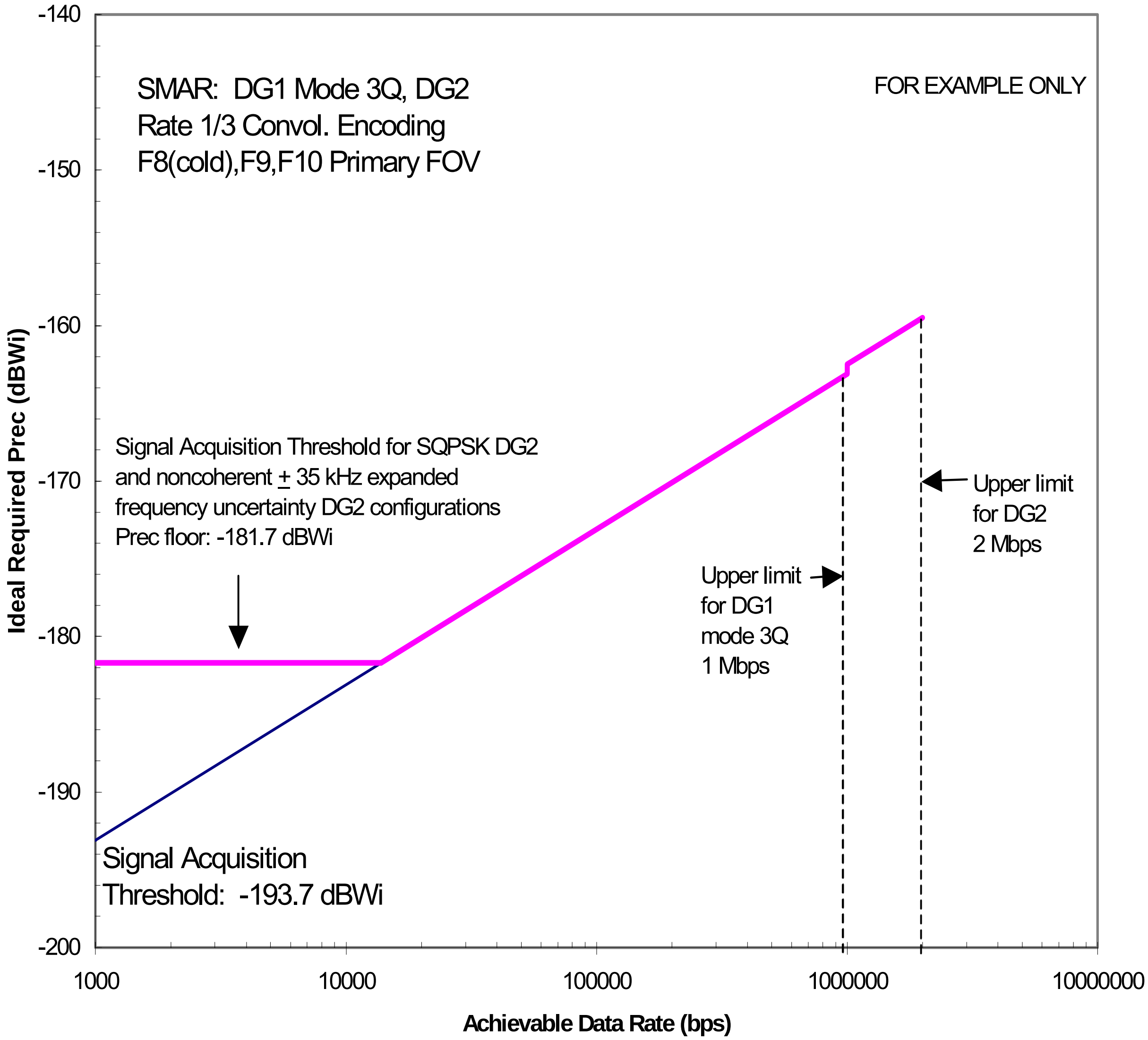


Figure A-18. SMA DG1 Mode 3Q and DG2 (Rate 1/3) Return ADR versus Required Received Power at the TDRS (P_{rec}) (Primary FOV for F8 (cold), F9, F10)

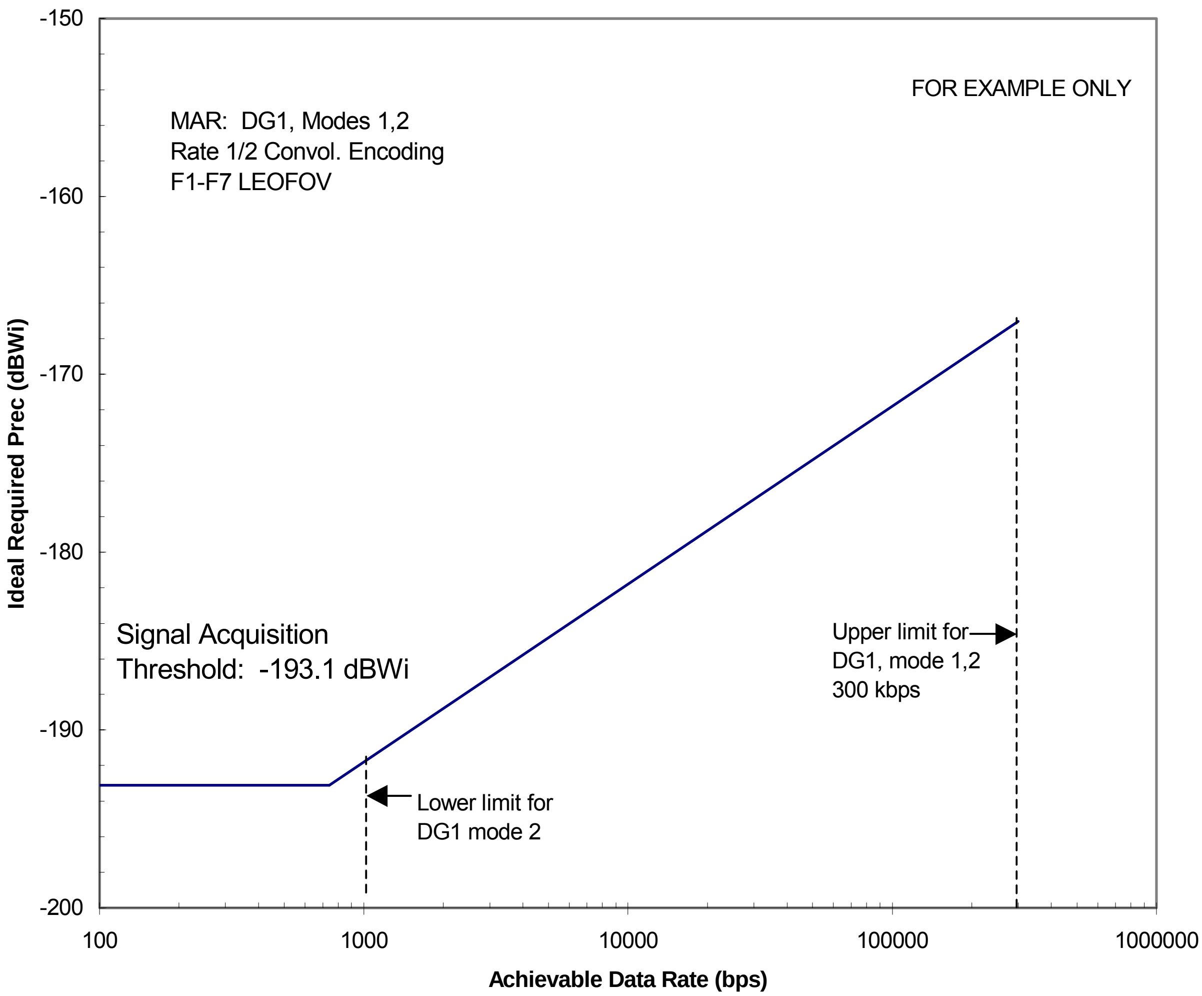


Figure A-19. MA DG1 Modes 1, 2 (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec}) (LEOFOV for F1-F7)

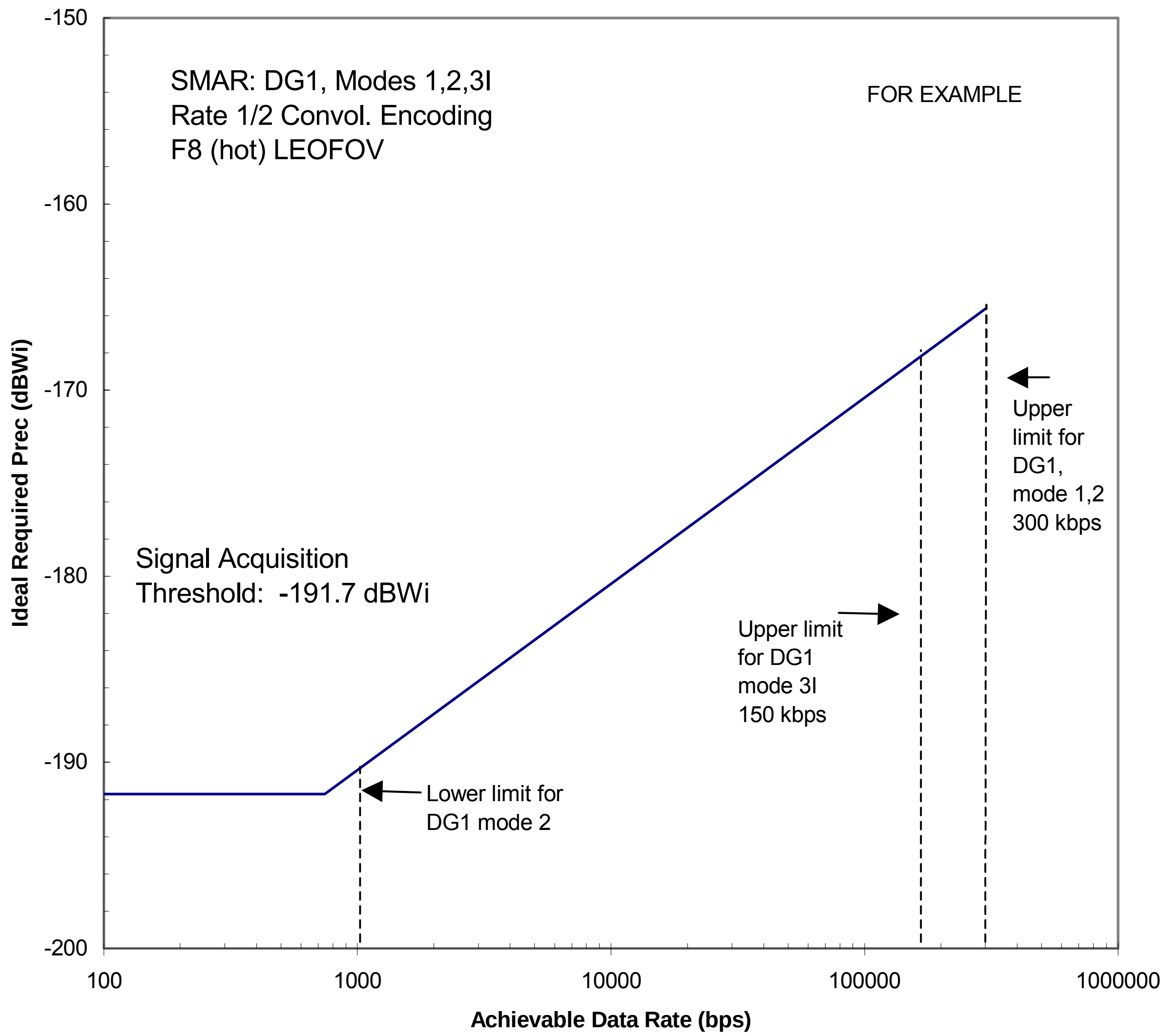


Figure A-20. SMA DG1 Modes 1, 2, 3I (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec}) (LEOFOV for F8 (hot))

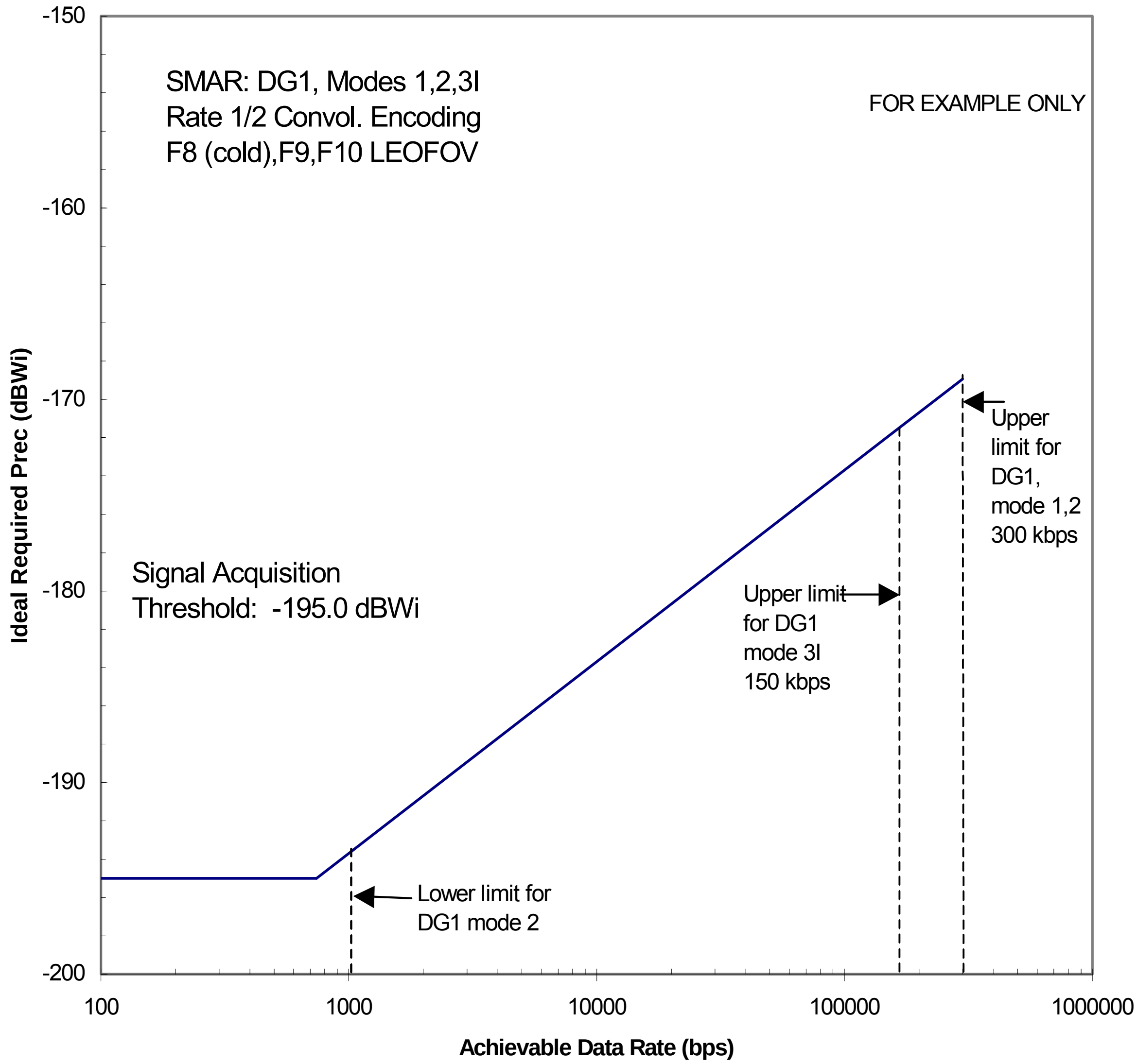


Figure A-21. SMA DG1 Modes 1, 2, 3I (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec}) (LEOFOV for F8 (cold), F9, F10)

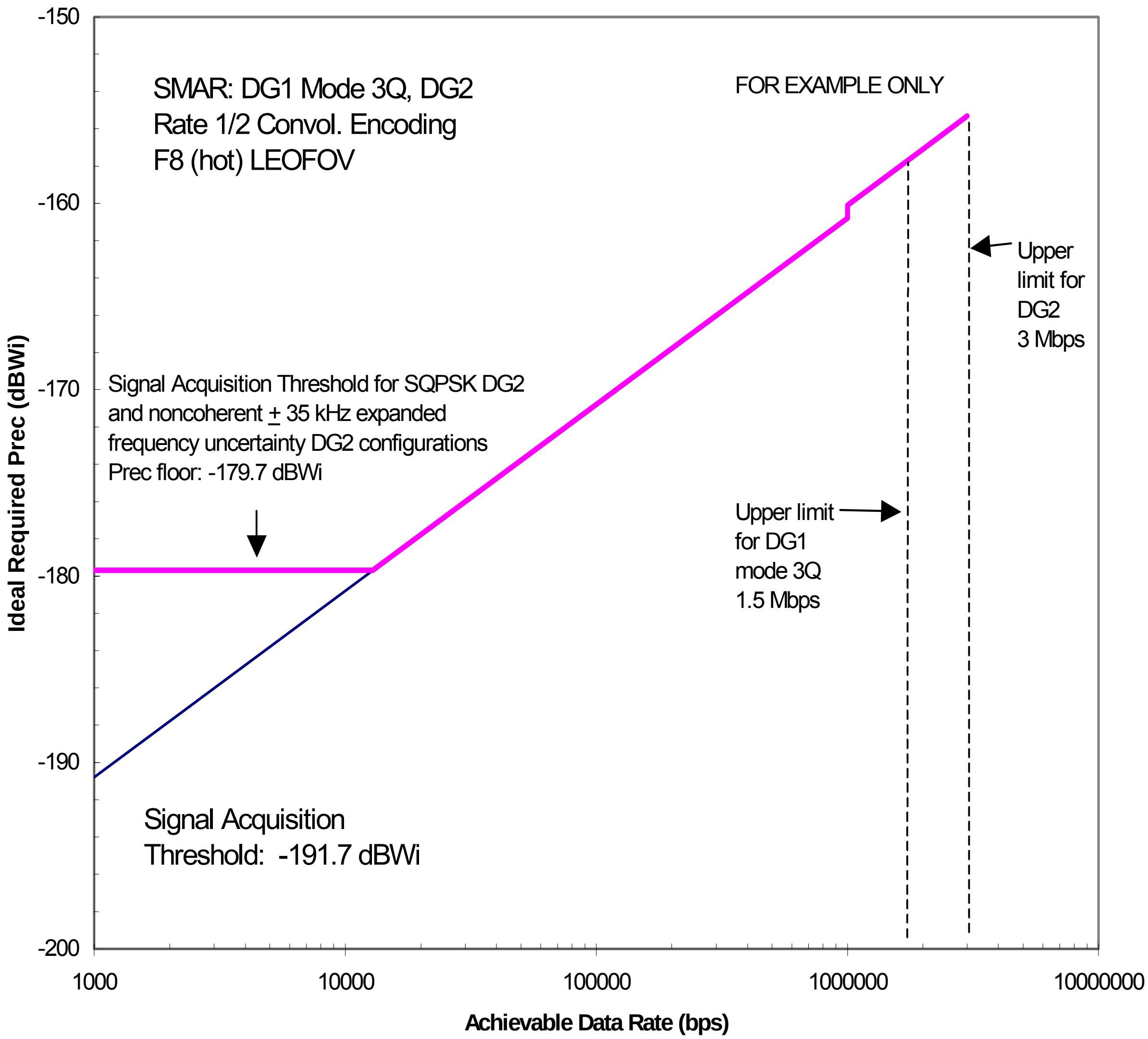


Figure A-22. SMA DG1 Mode 3Q and DG2 (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec}) (LEOFOV for F8 (hot))

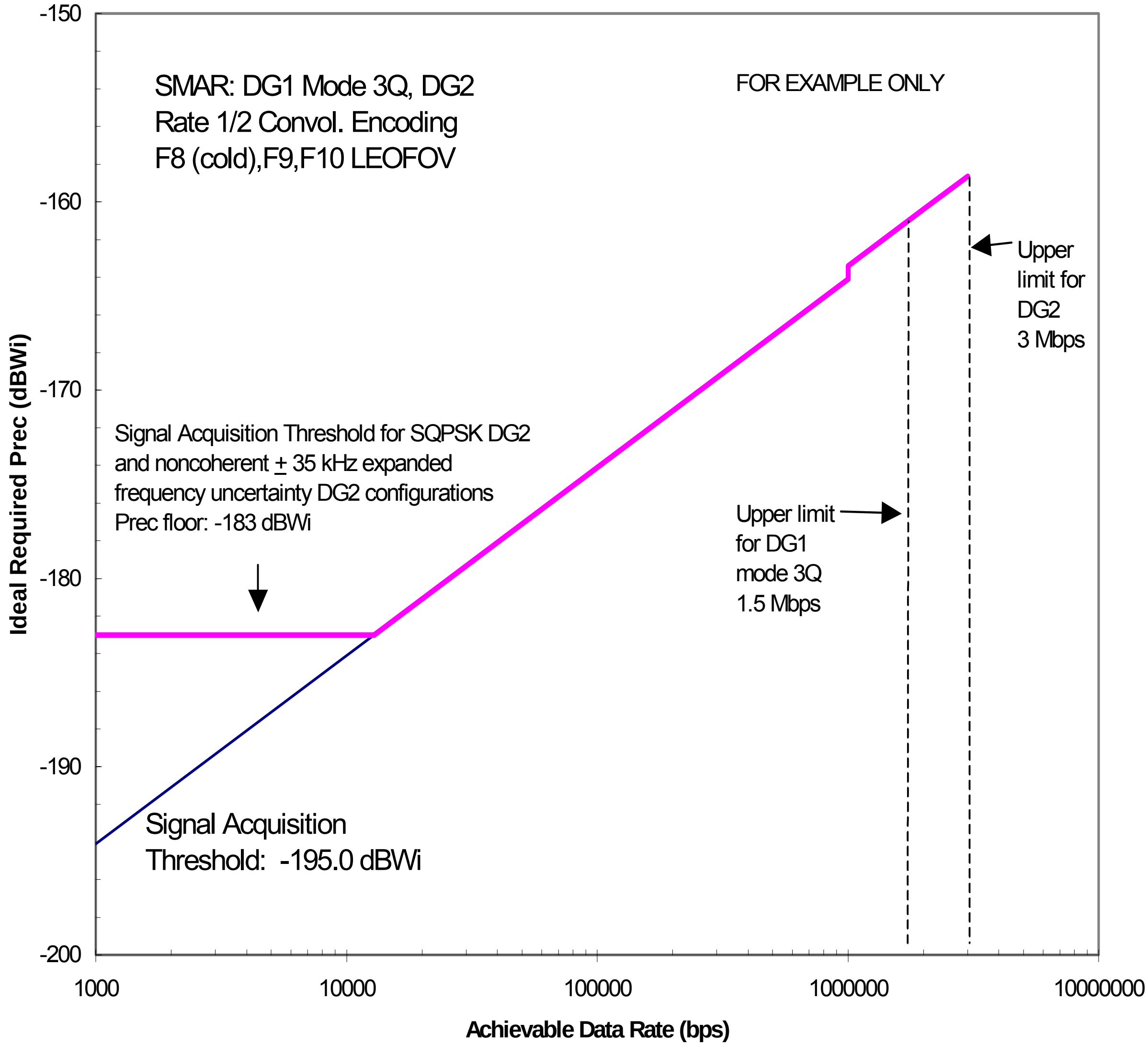


Figure A-23. SMA DG1 Mode 3Q and DG2 (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec}) (LEOFOV for F8 (cold), F9, F10)

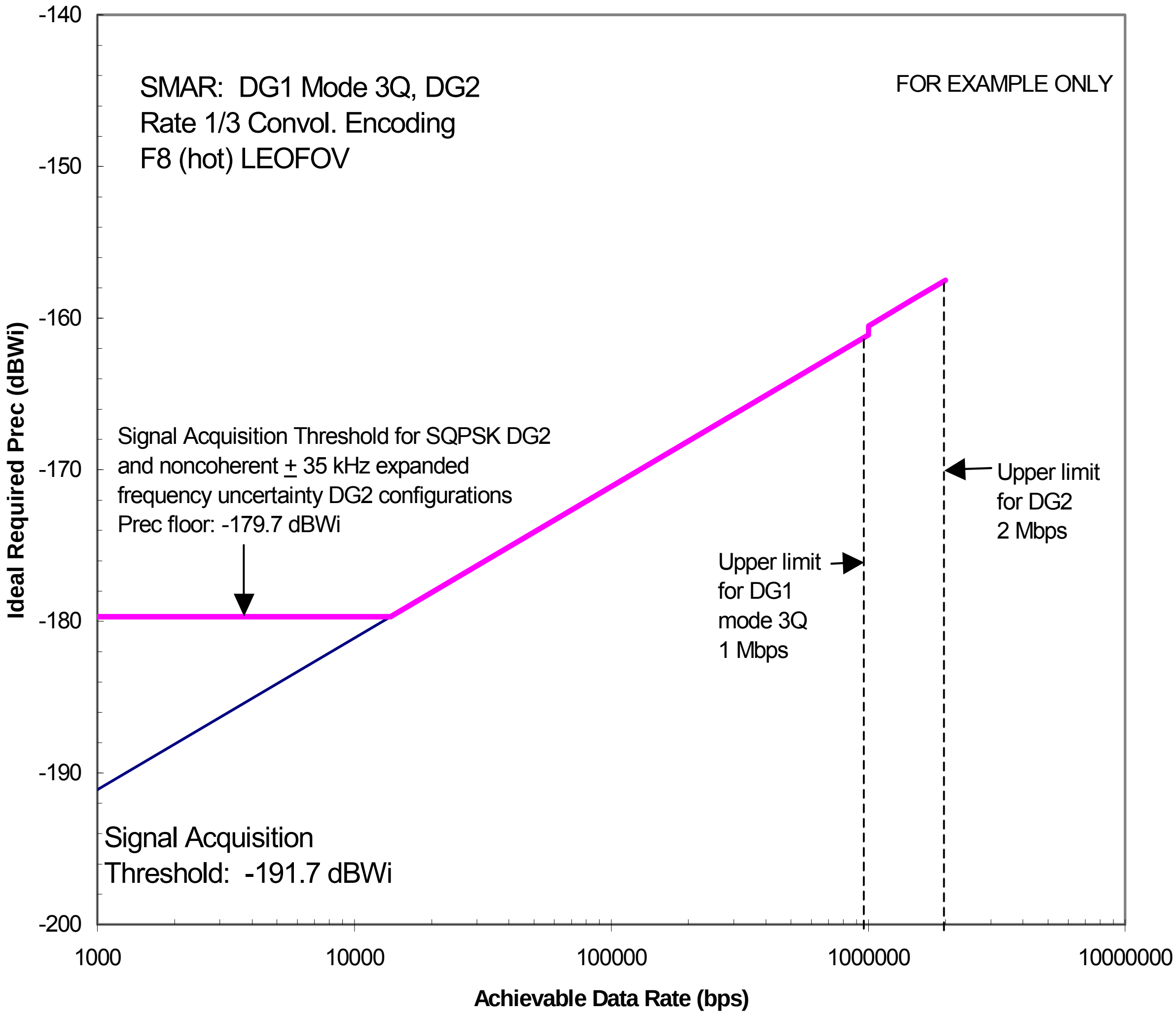


Figure A-24. SMA DG1 Mode 3Q and DG2 (Rate 1/3) Return ADR versus Required Received Power at the TDRS (P_{rec}) (LEOFOV for F8 (hot))

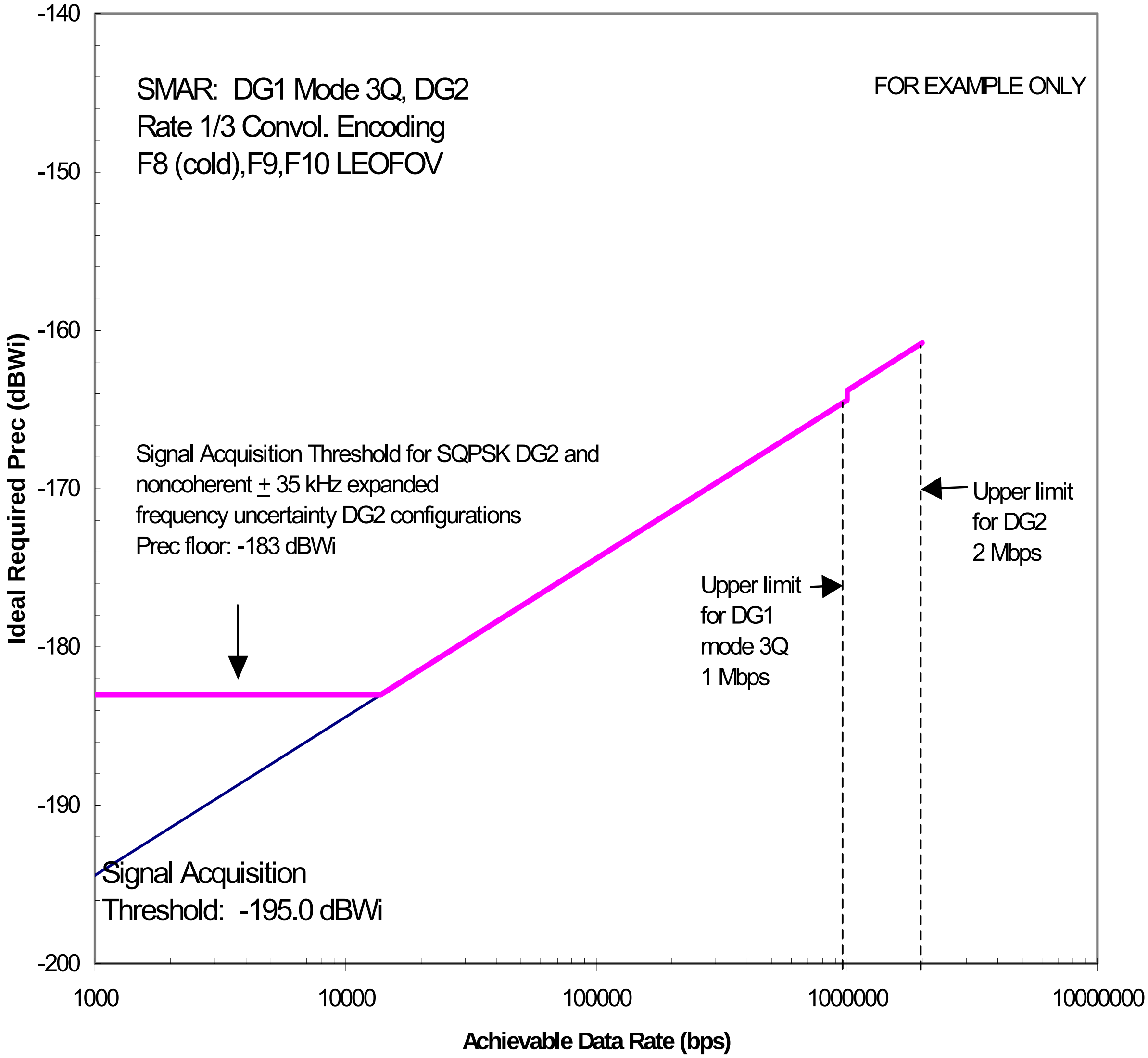


Figure A-25. SMA DG1 Mode 3Q and DG2 (Rate 1/3) Return ADR versus Required Received Power at the TDRS (P_{rec}) (LEOFOV for F8 (cold), F9, F10)

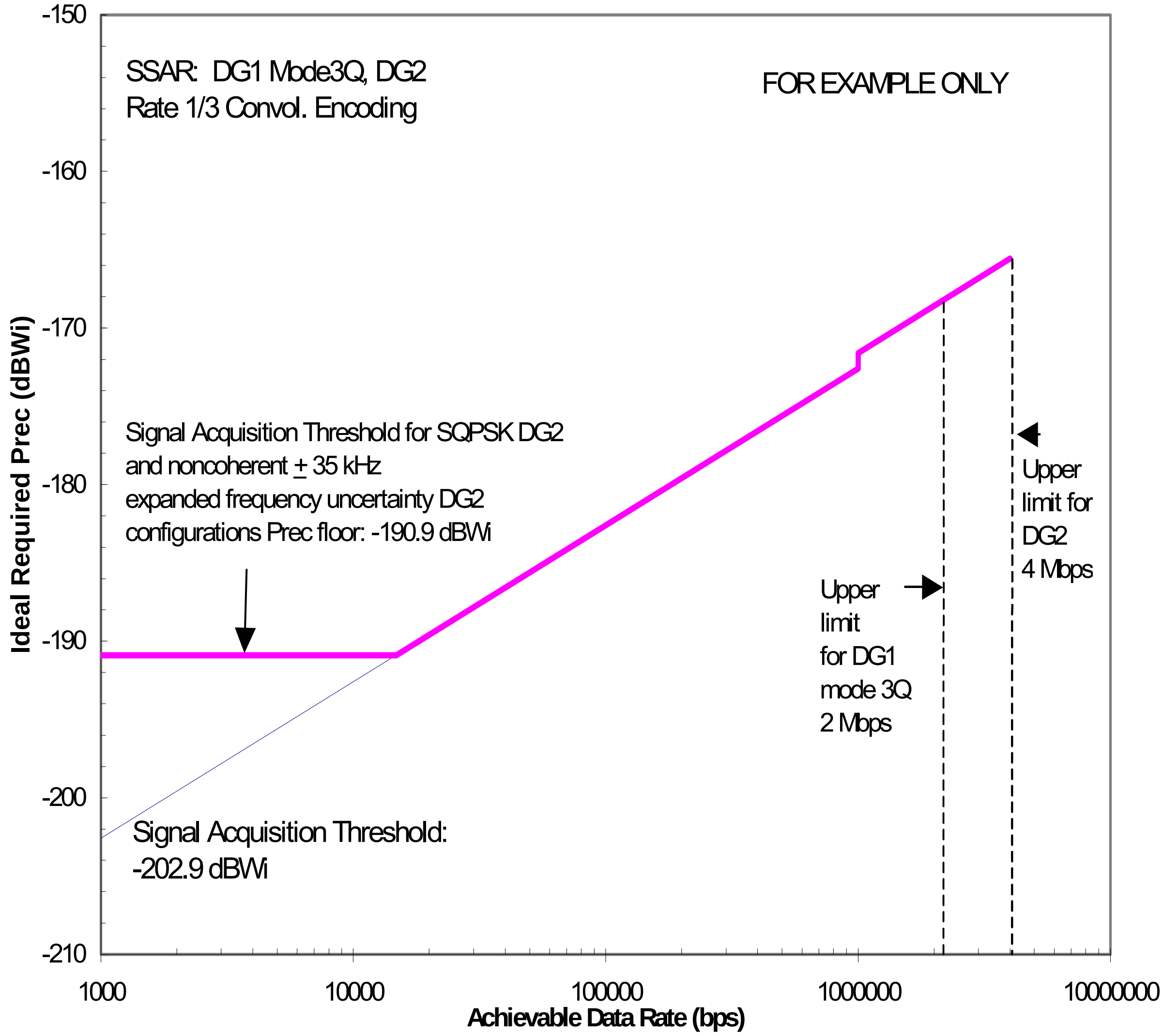


Figure A-26. SSA DG1 Modes 1, 2, 3I (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec})

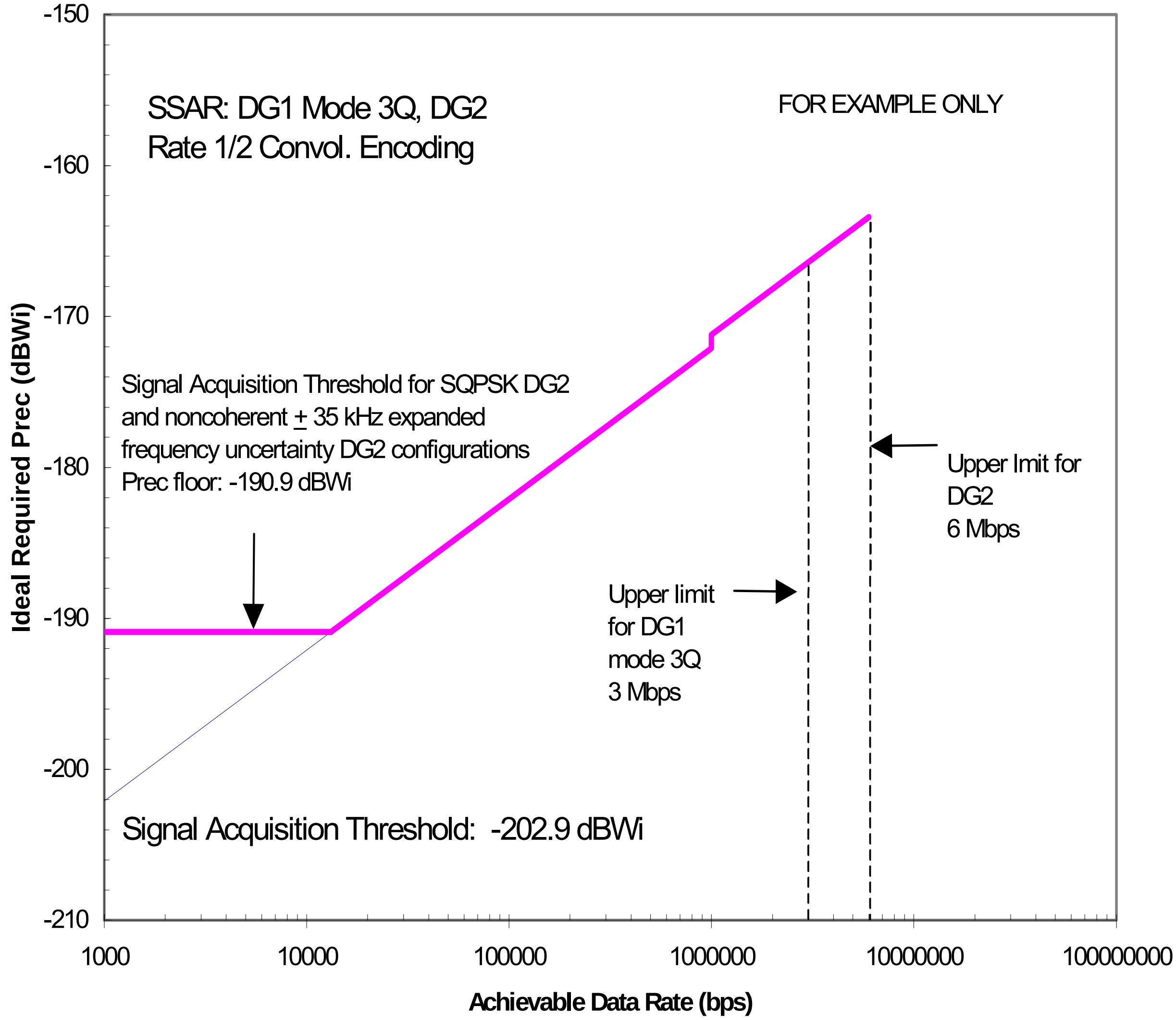


Figure A-27. SSA DG1 Mode 3Q and DG2 (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec})

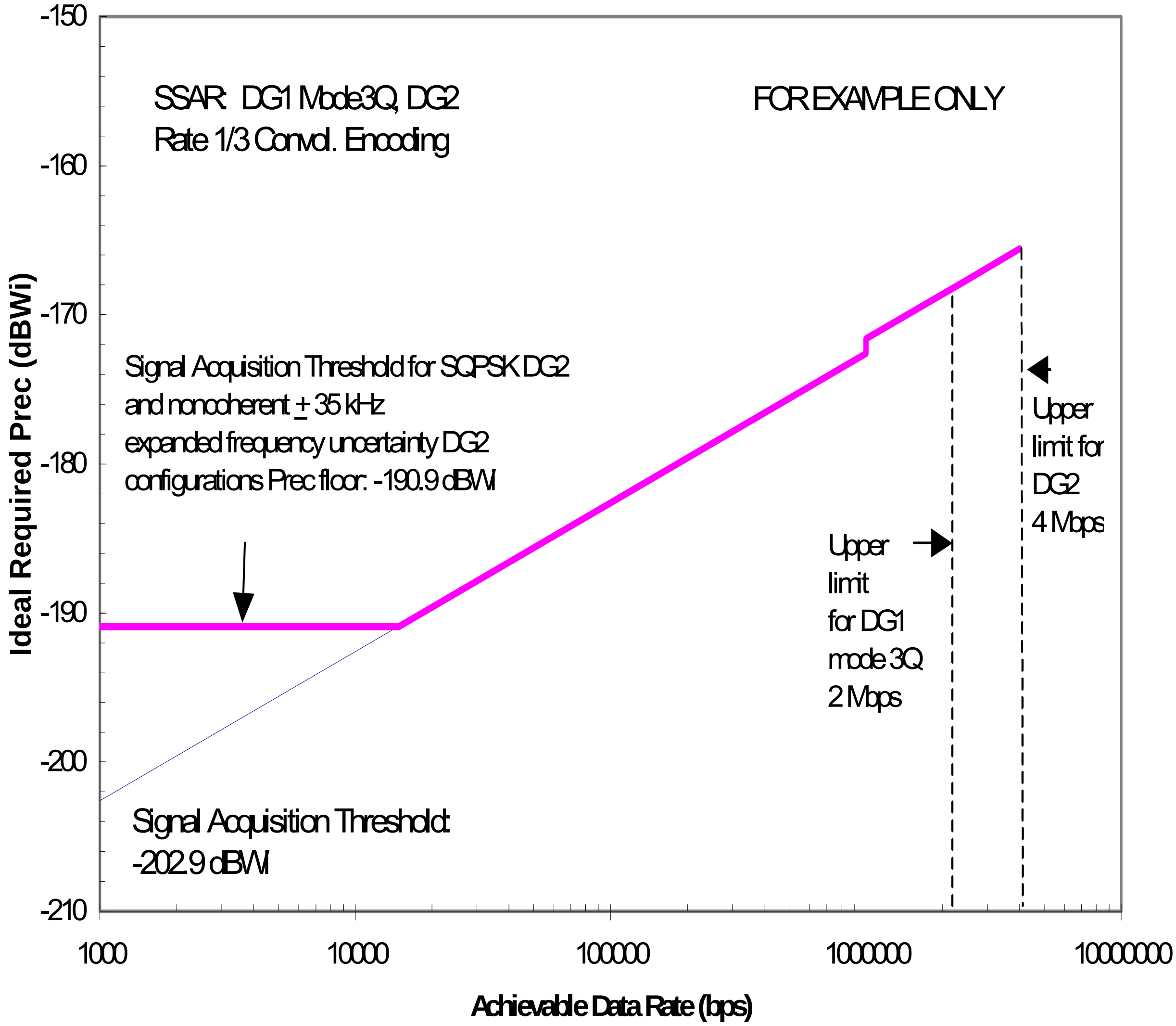


Figure A-28. SSA DG1 Mode 3Q and DG2 (Rate 1/3) Return ADR versus Required Received Power at the TDRS (P_{rec})

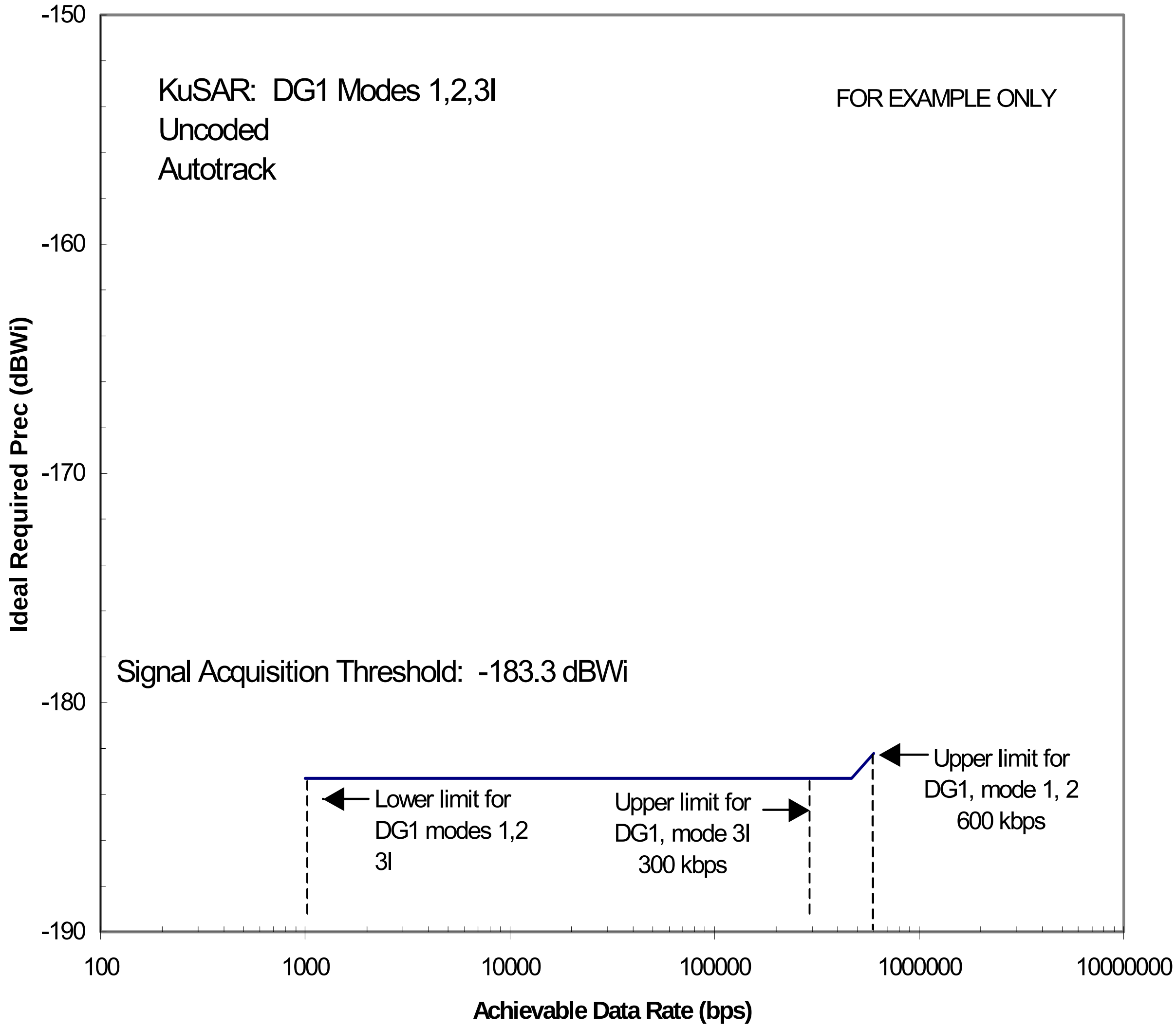


Figure A-29. KuSA Autotrack DG1 Modes 1, 2, 3I (Uncoded) Return ADR versus Required Received Power at the TDRS (P_{rec})

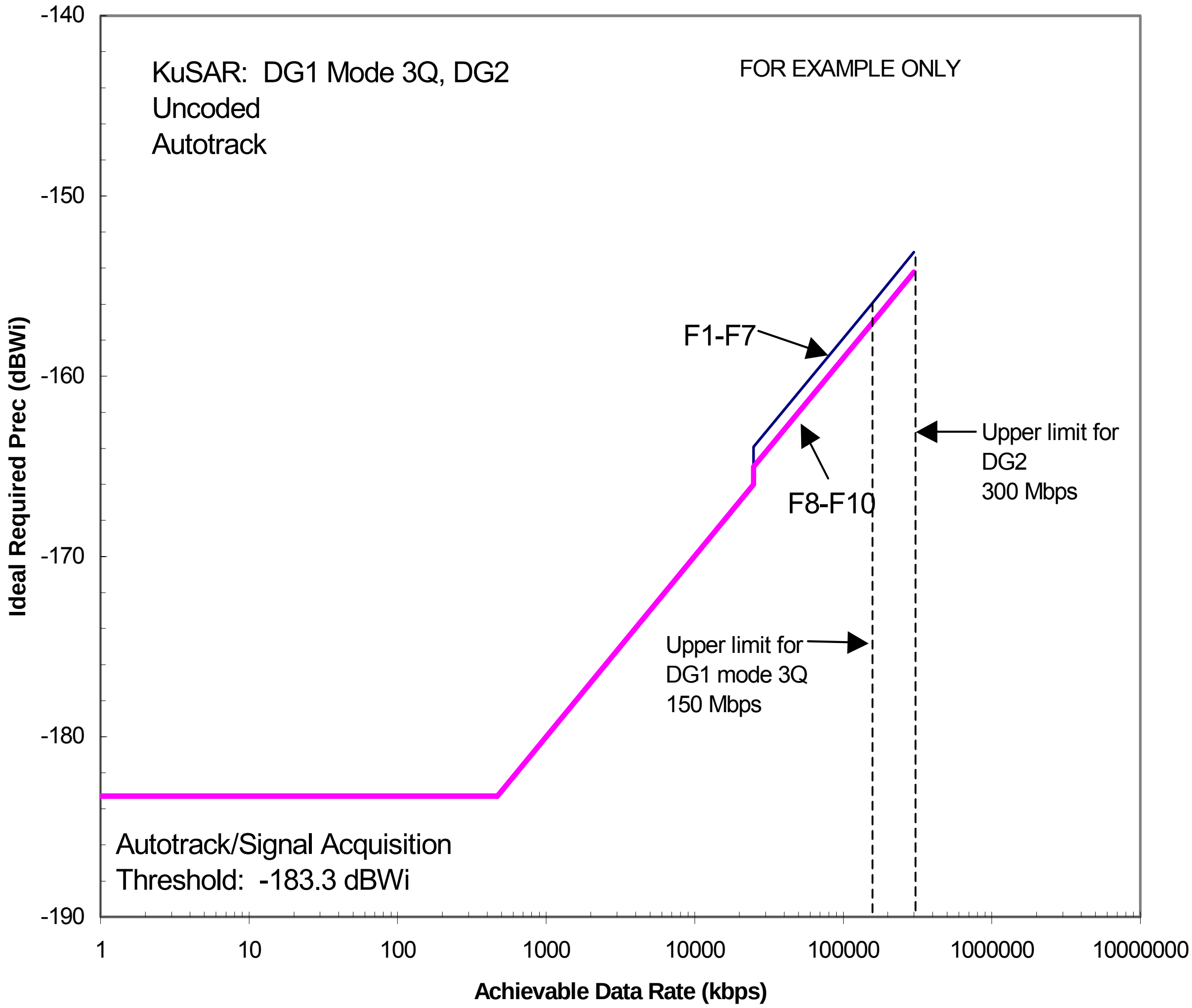


Figure A-30. KuSA Autotrack DG1 Mode 3Q and DG2 (Uncoded) Return ADR versus Required Received Power at the TDRS (P_{rec})

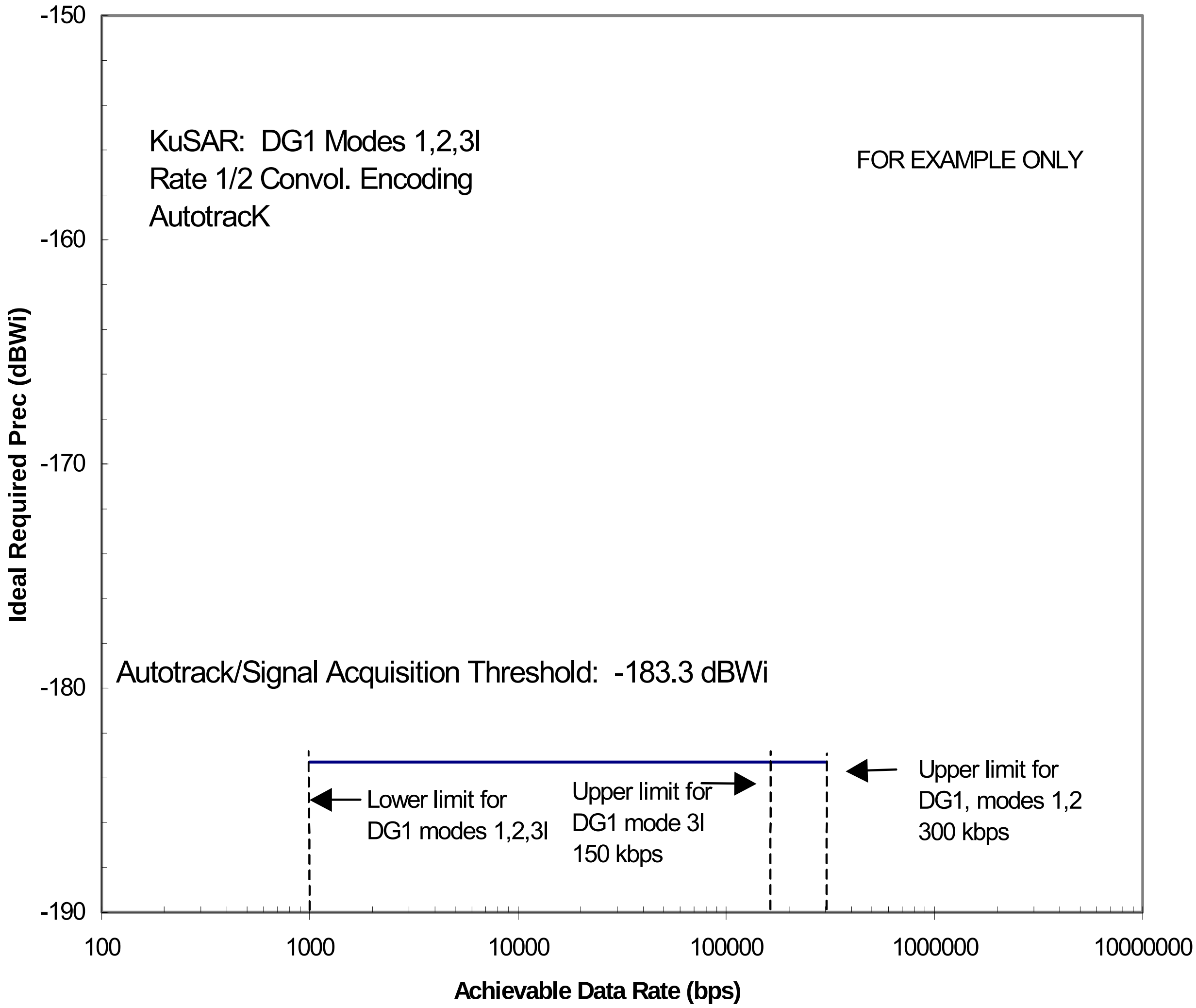


Figure A-31. KuSA Autotrack DG1 Modes 1, 2, 3I (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec})

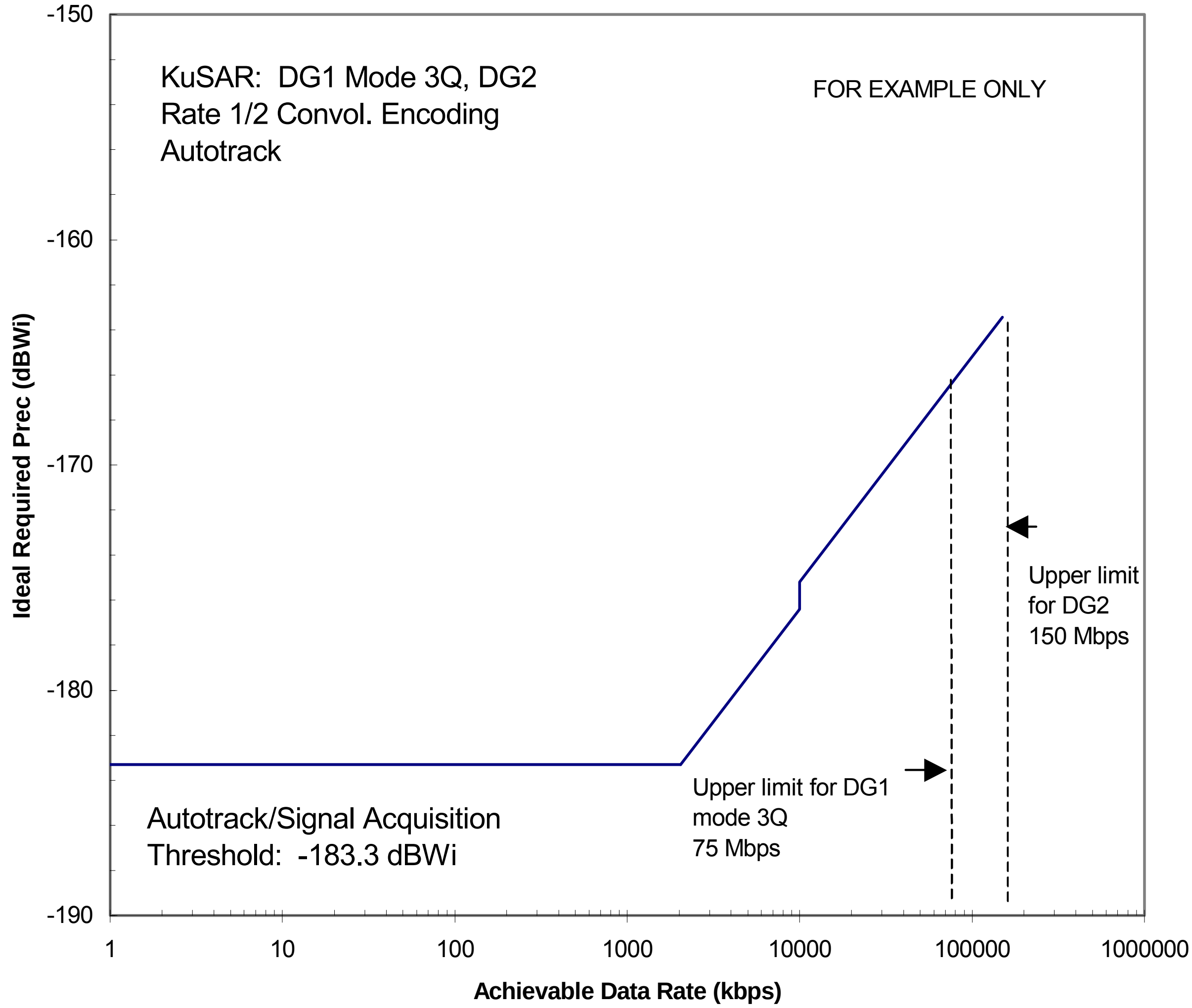


Figure A-32. KuSA Autotrack DG1 Mode 3Q and DG2 (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec})

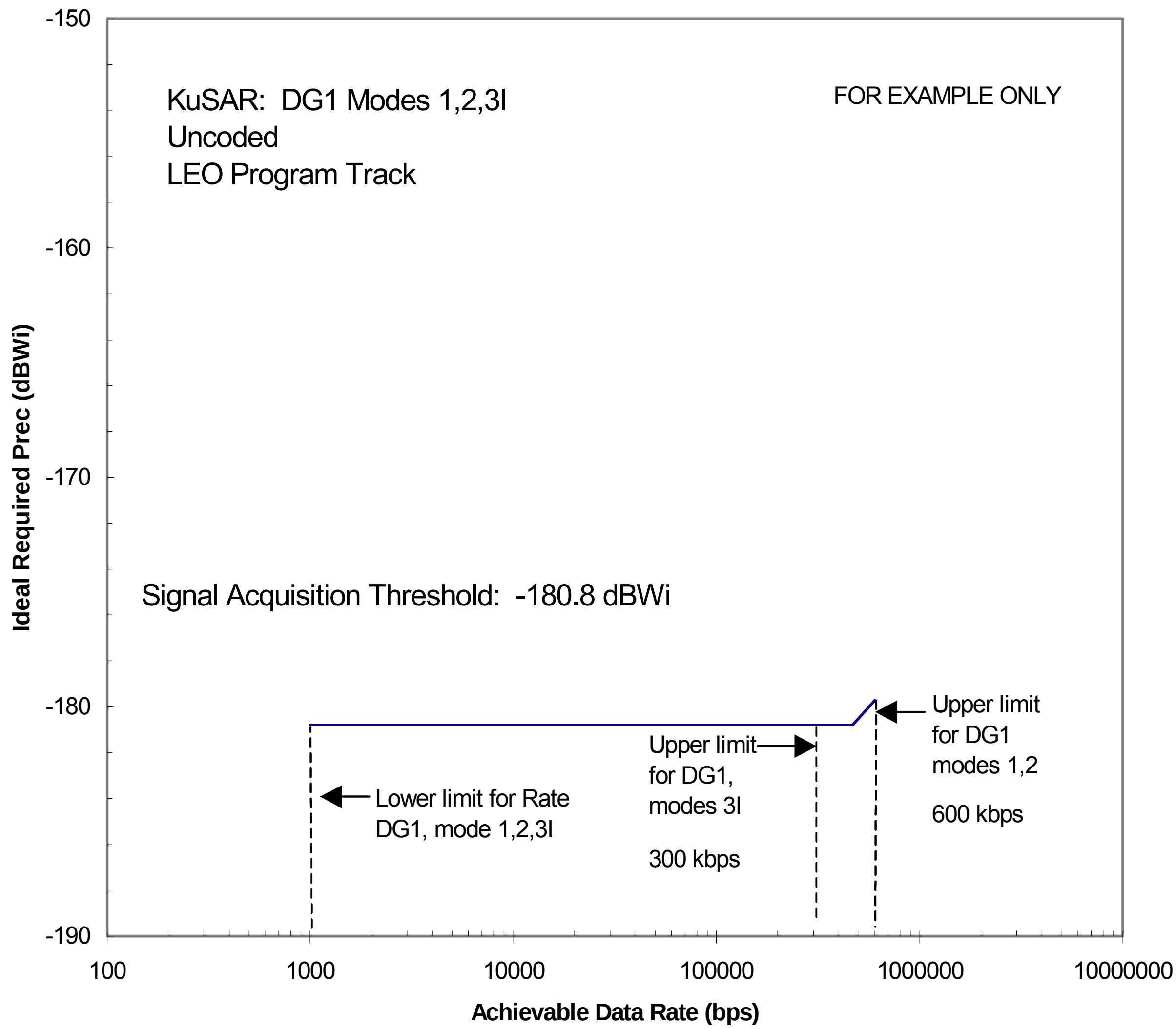


Figure A-33. KuSA LEO Program Track DG1 Modes 1, 2, 3I (Uncoded) Return ADR versus Required Received Power at the TDRS (P_{rec})

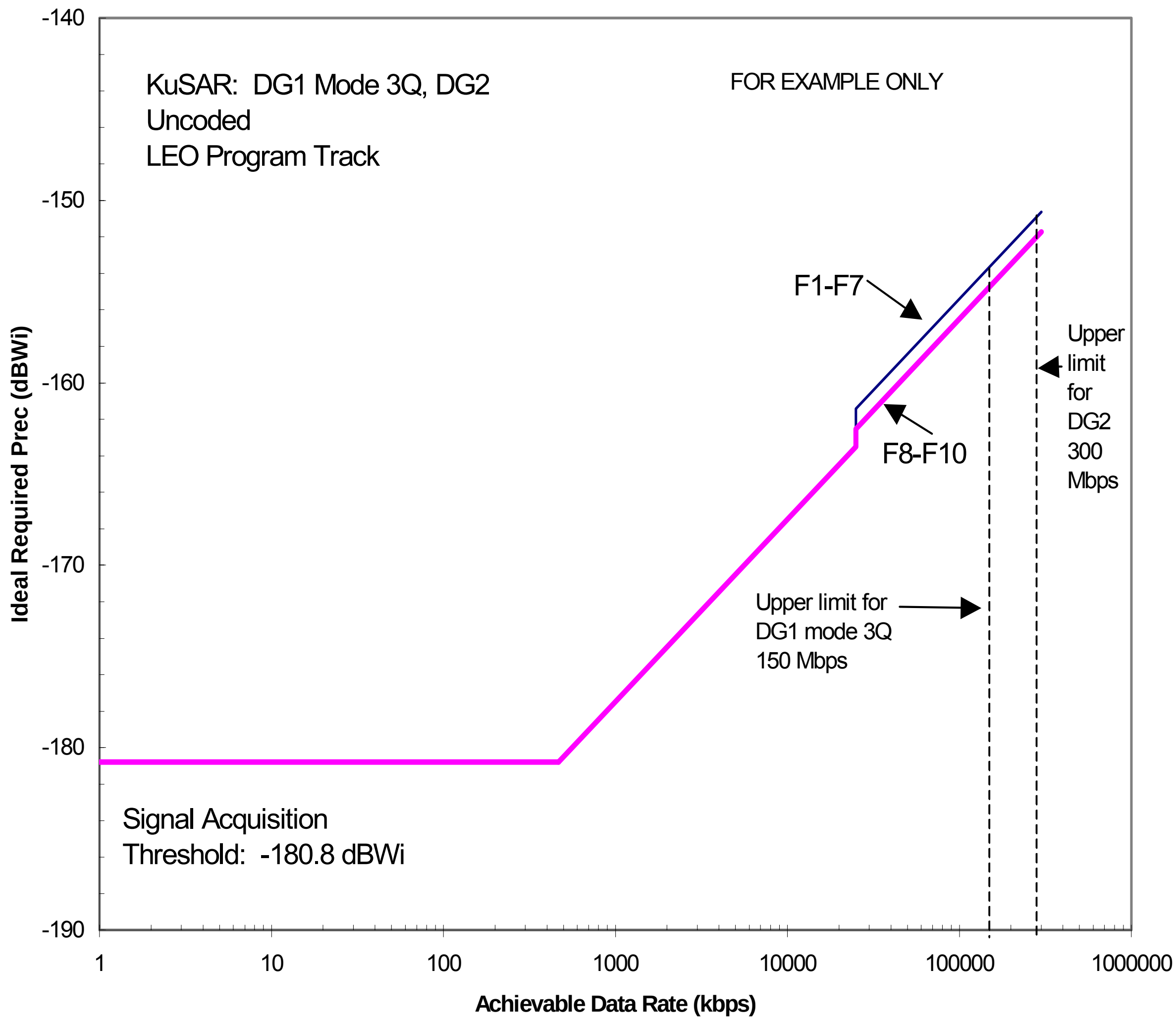


Figure A-34. KuSA LEO Program Track DG1 Mode 3Q and DG2 (Uncoded) Return ADR versus Required Received Power at the TDRS (P_{rec})

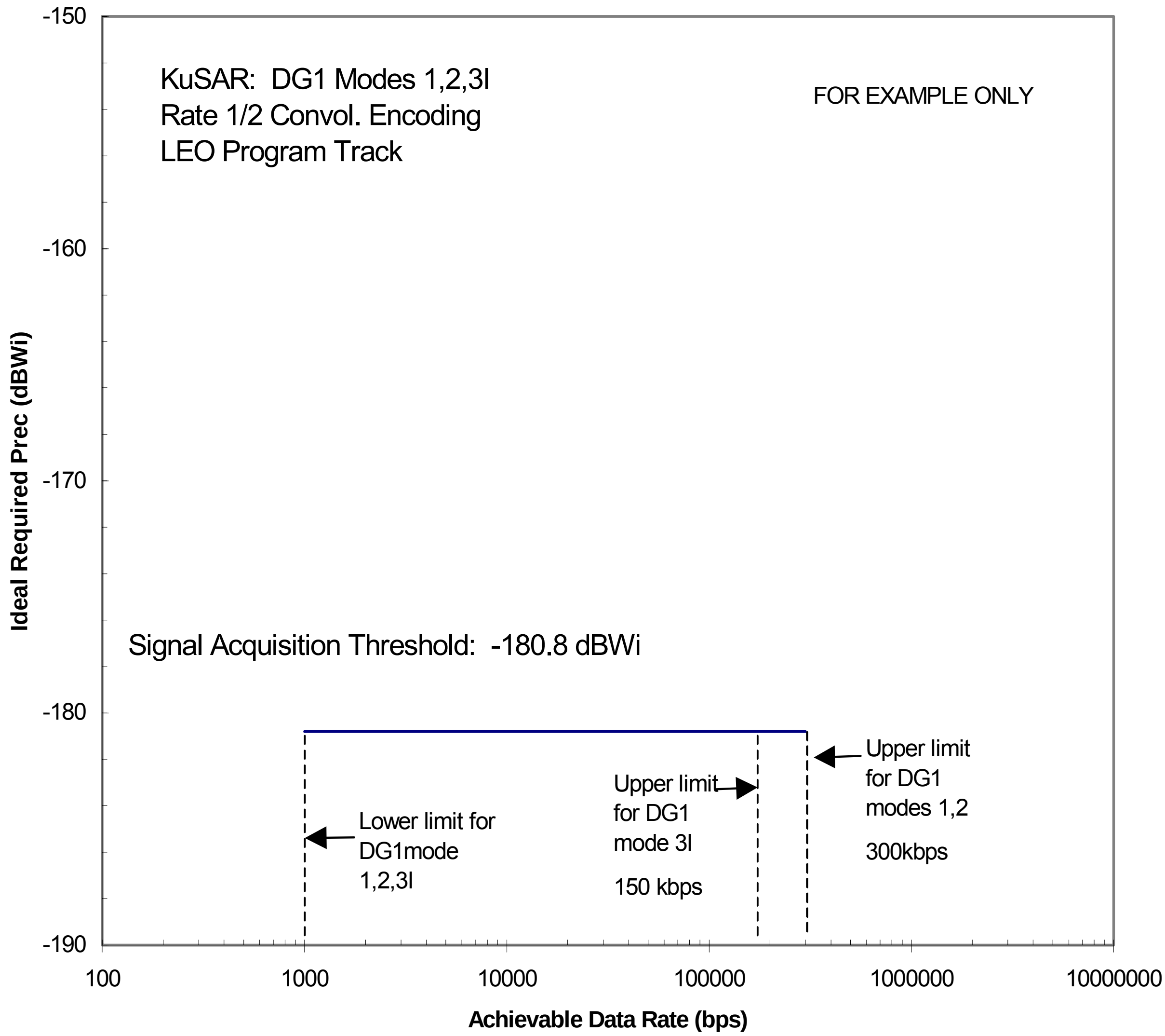


Figure A-35. KuSA LEO Program Track DG1 Modes 1, 2, 3I (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec})

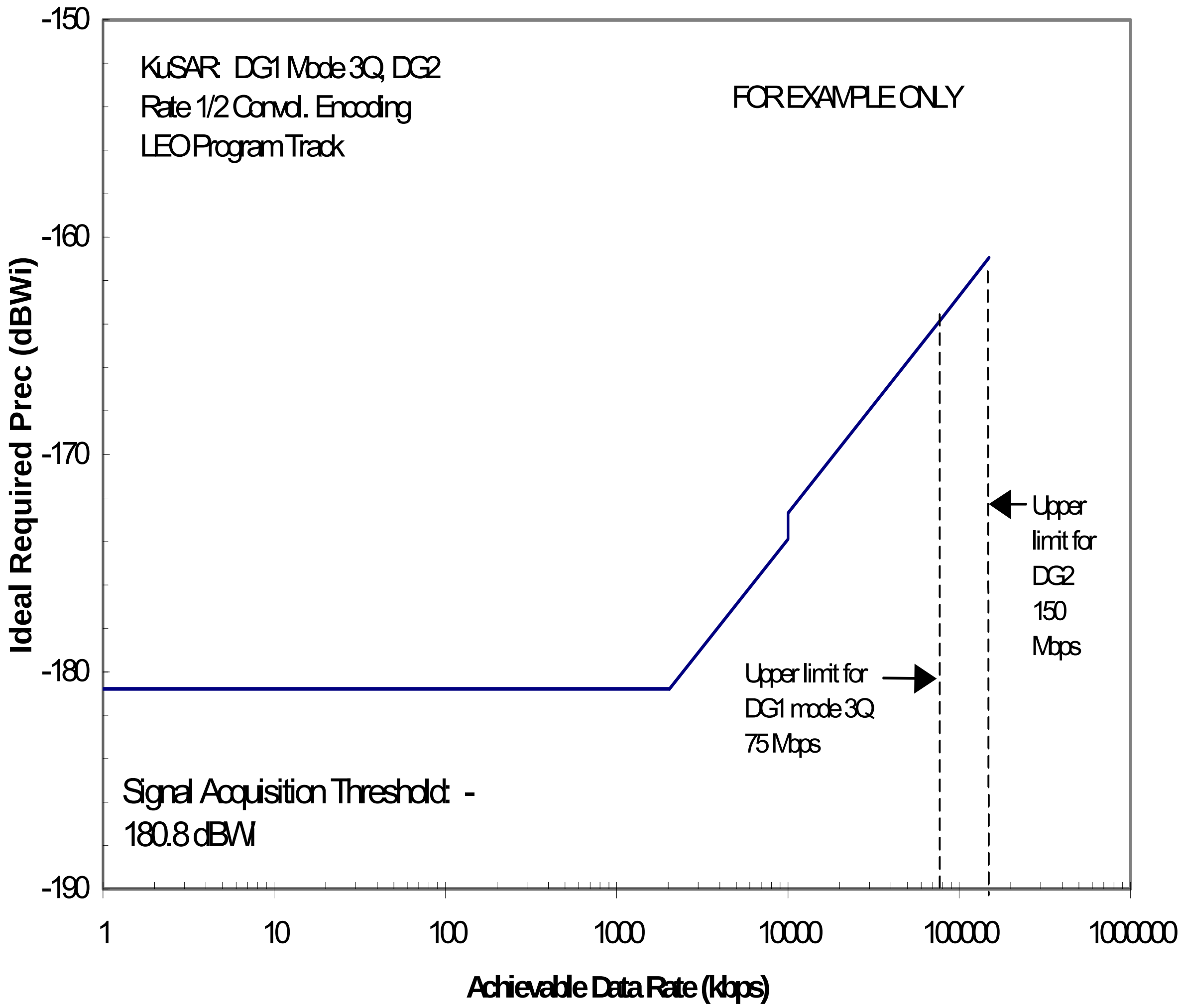


Figure A-36. KuSA LEO Program Track DG1 Mode 3Q and DG2 (Rate1/2) Return ADR versus Required Received Power at the TDRS (P_{rec})

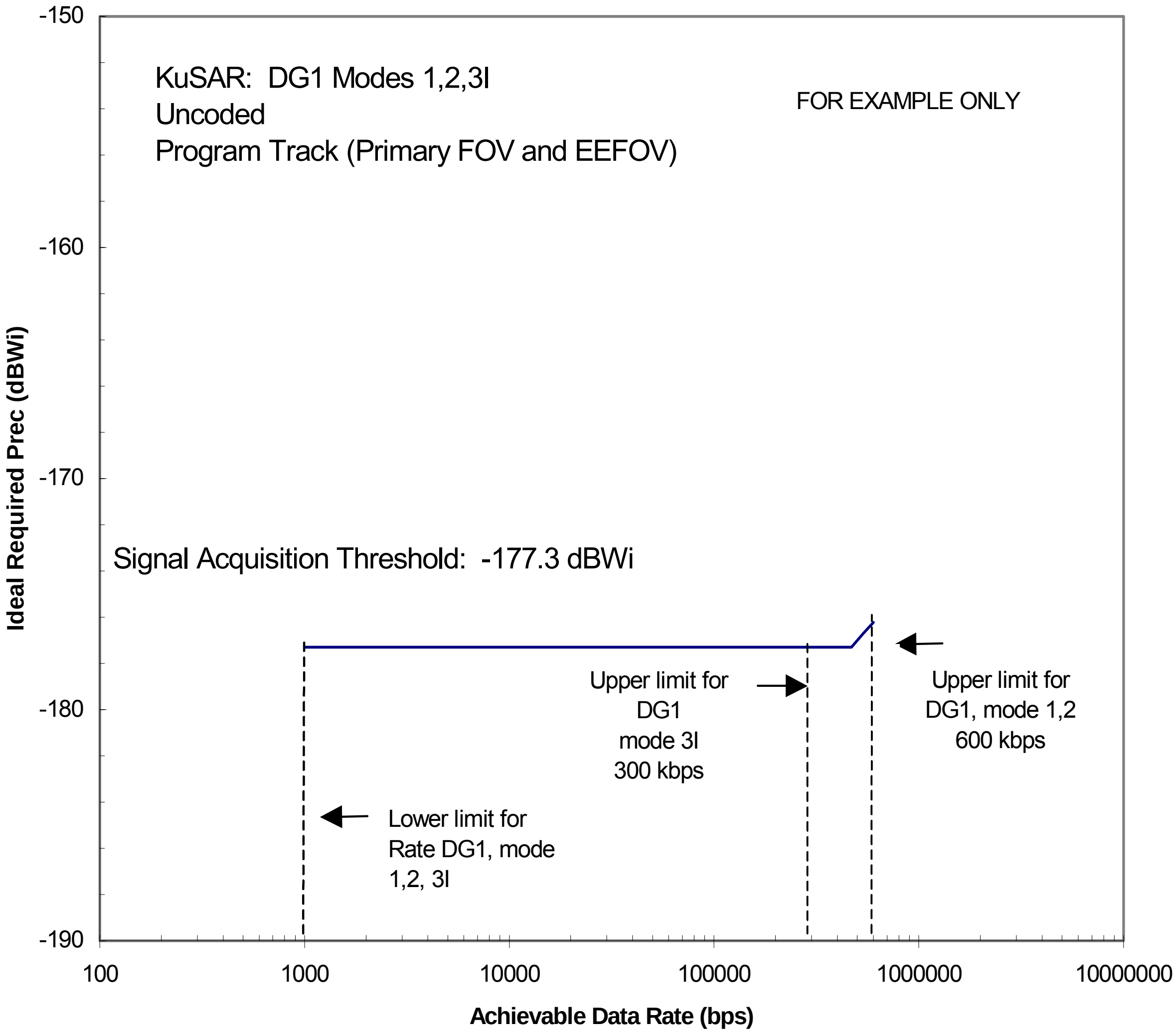


Figure A-37. KuSA Program Track DG1 Modes 1, 2, 3I (Uncoded) Return ADR versus Required Received Power at the TDRS (P_{rec})

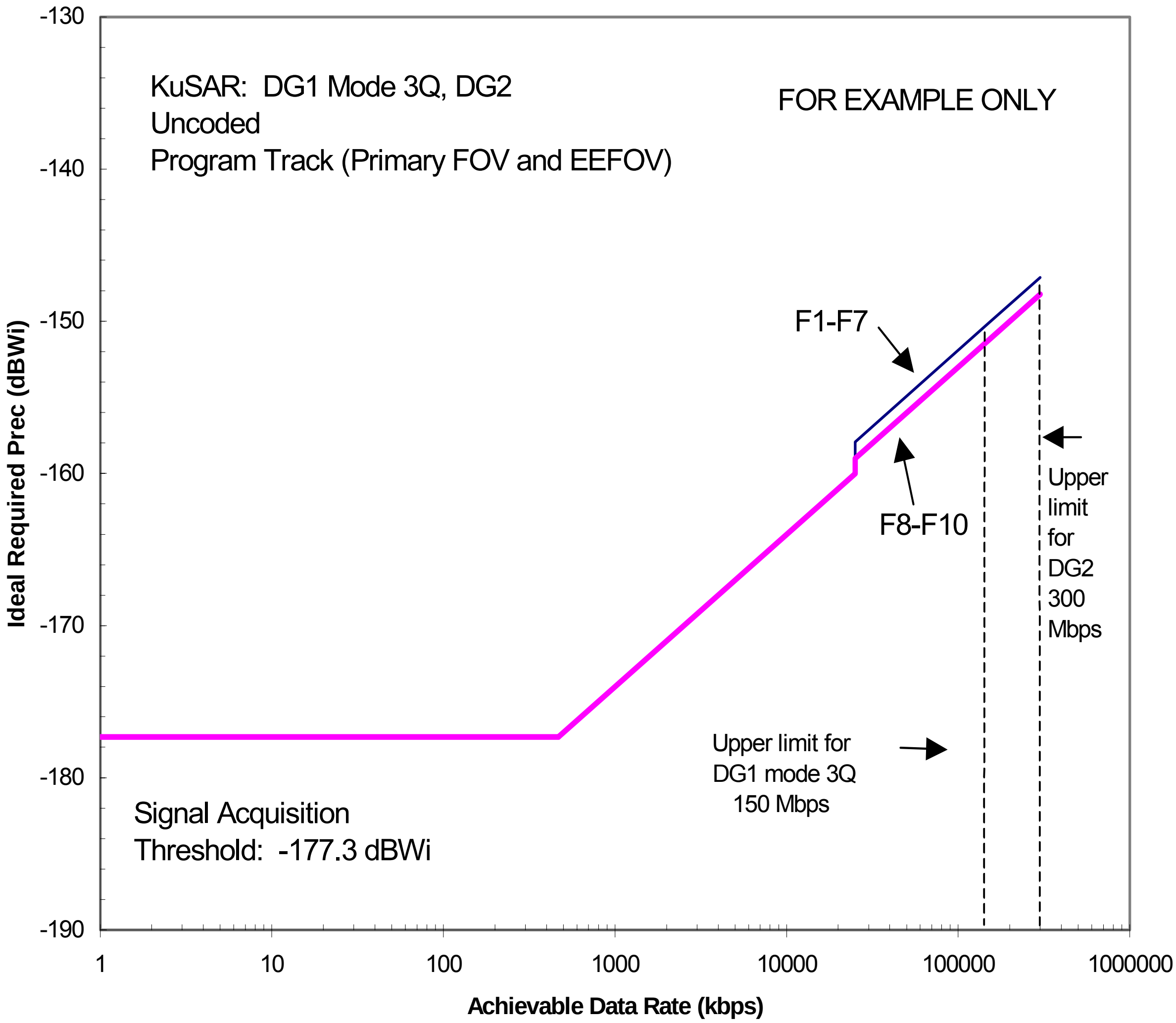


Figure A-38. KuSA Program Track DG1 Mode 3Q and DG2 (Uncoded) Return ADR versus Required Received Power at the TDRS (P_{rec})

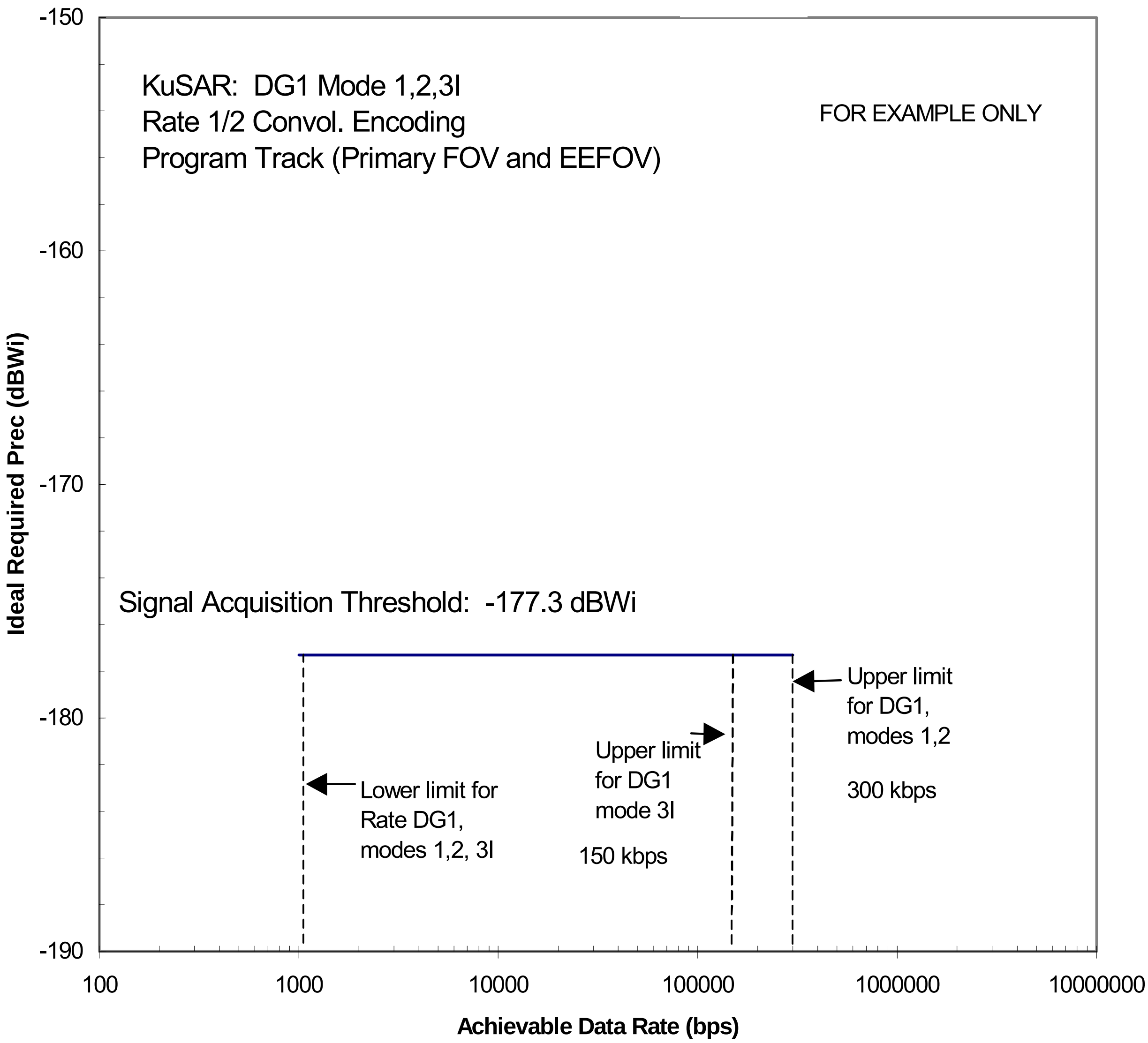


Figure A-39. KuSA Program Track DG1 Modes 1, 2, 3I (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec})

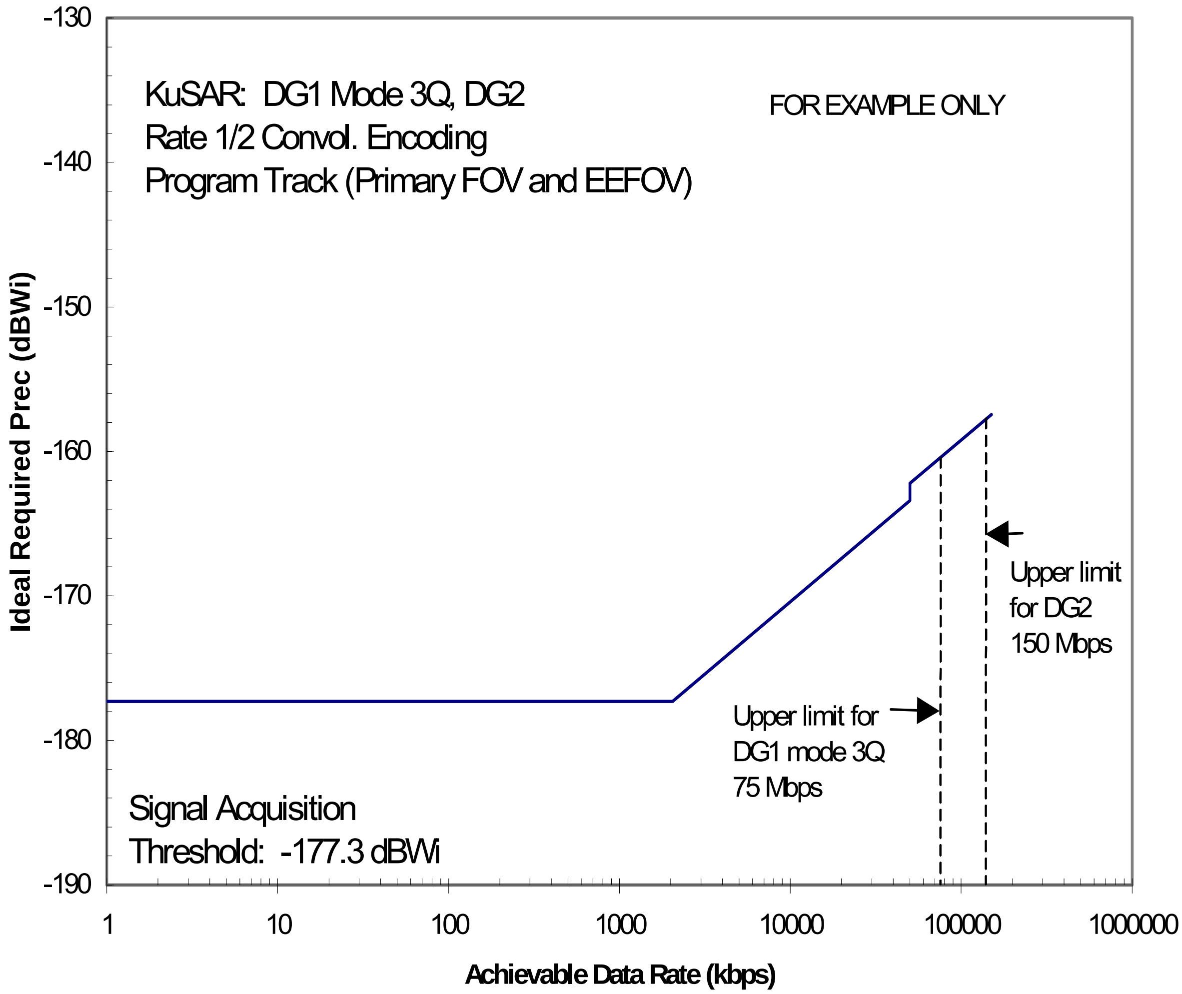


Figure A-40. KuSA Program Track DG1 Mode 3Q and DG2 (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec})

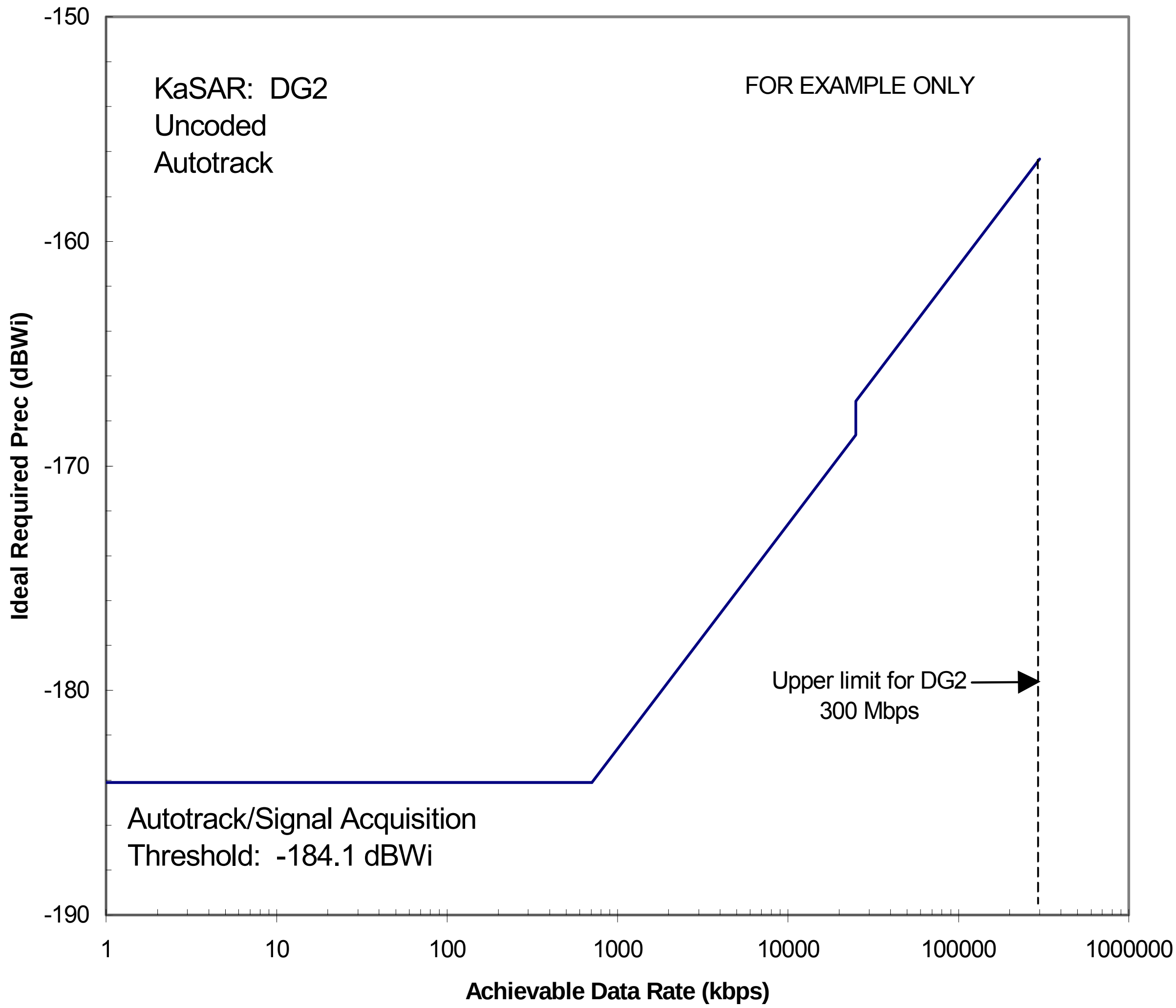


Figure A-41. KaSA Autatrack DG2 (Uncoded) Return ADR versus Required Received Power at the TDRS (P_{rec})

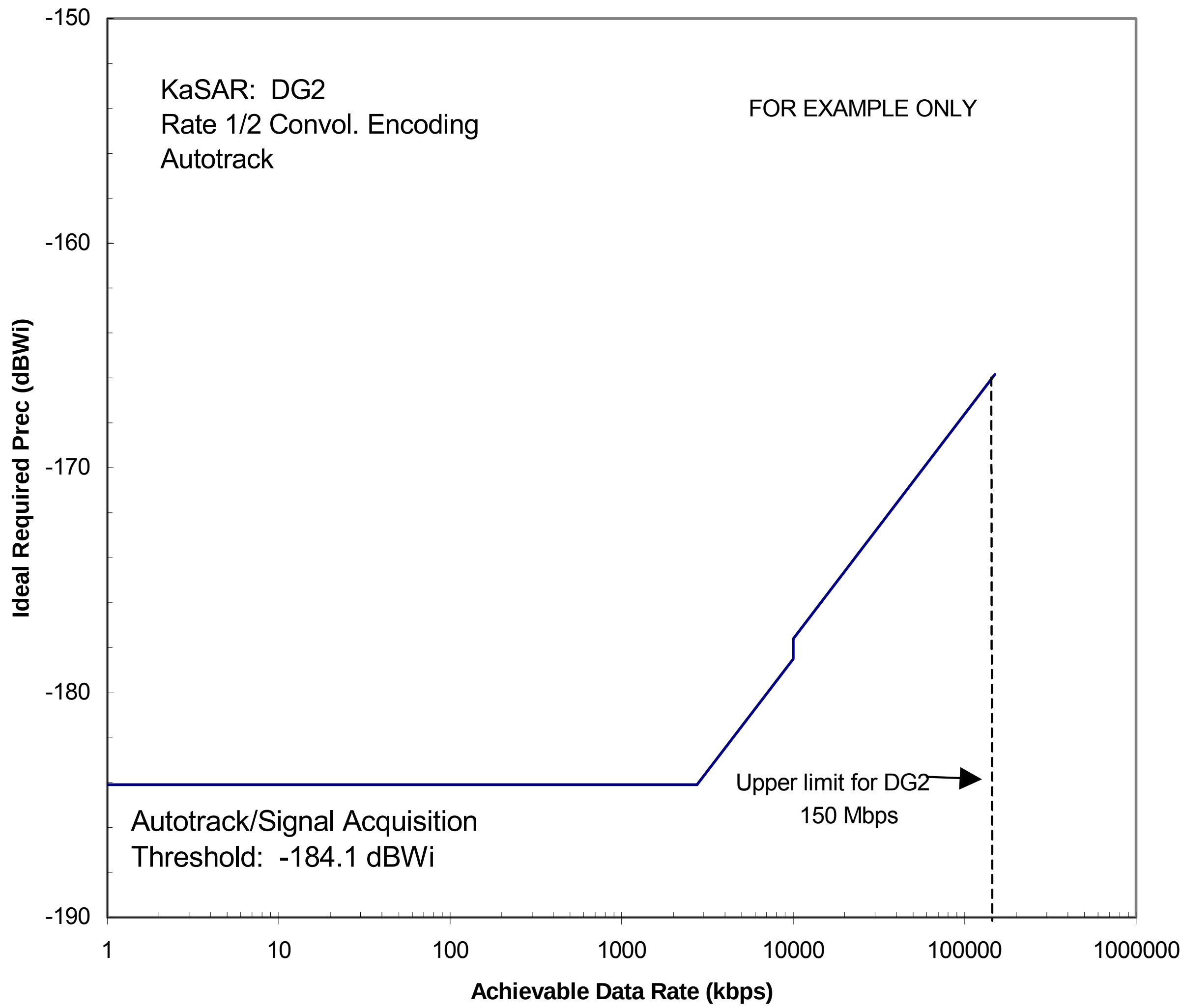


Figure A-42. KaSA Autatrack DG2 (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec})

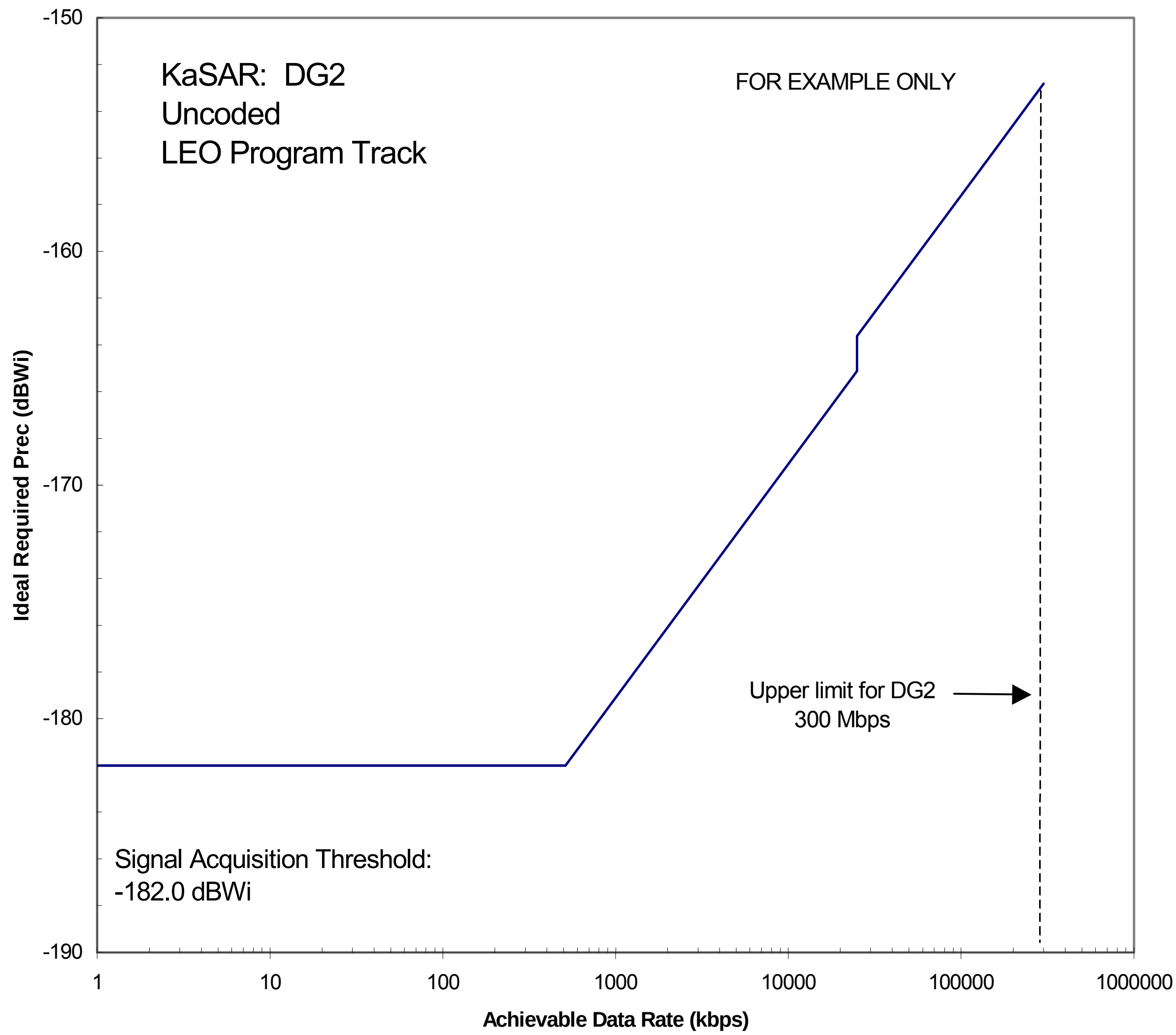


Figure A-43. KaSA LEO Program Track DG2 (Uncoded) Return ADR versus Required Received Power at the TDRS (P_{rec})

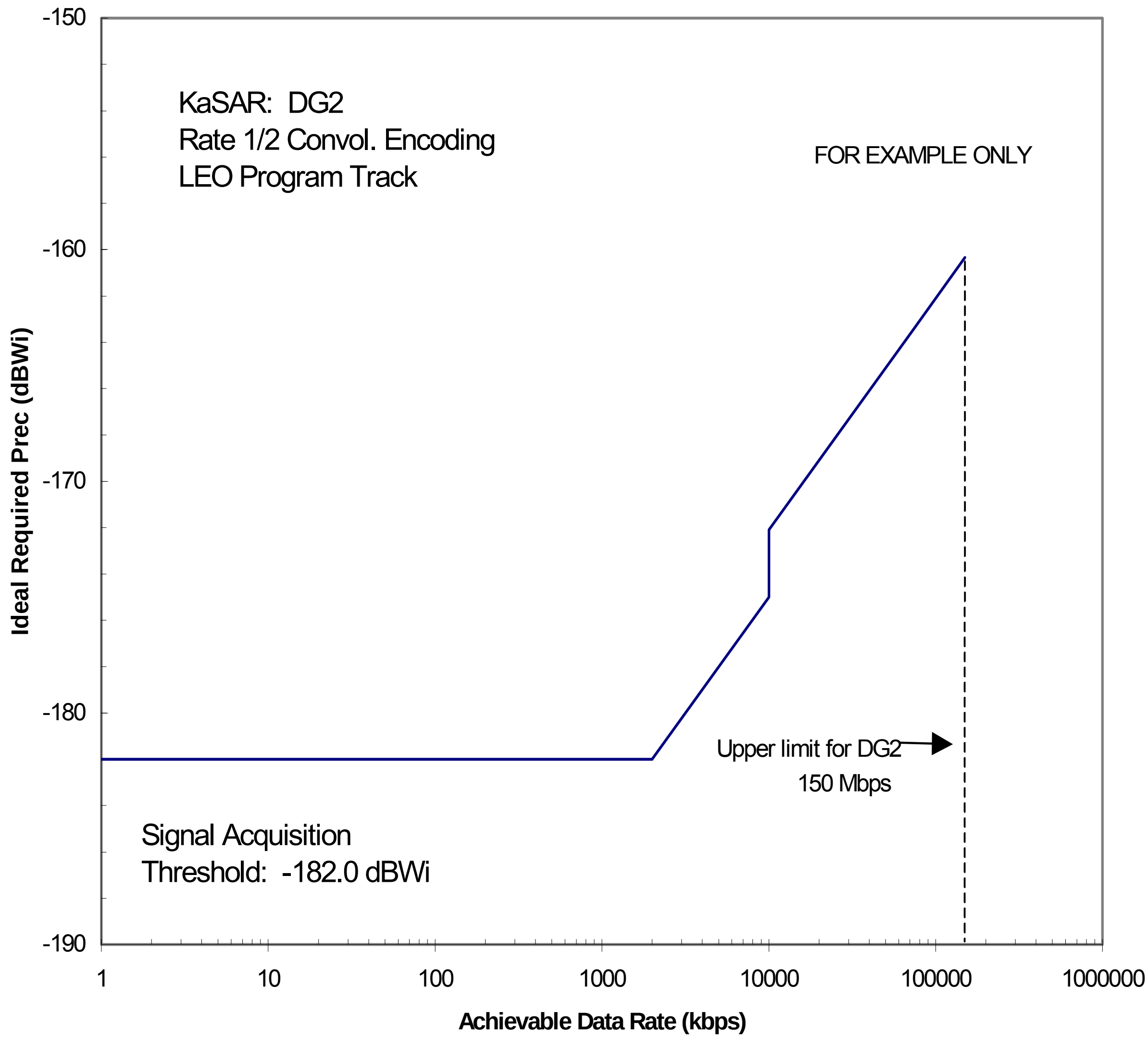


Figure A-44. KaSA LEO Program Track DG2 (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec})

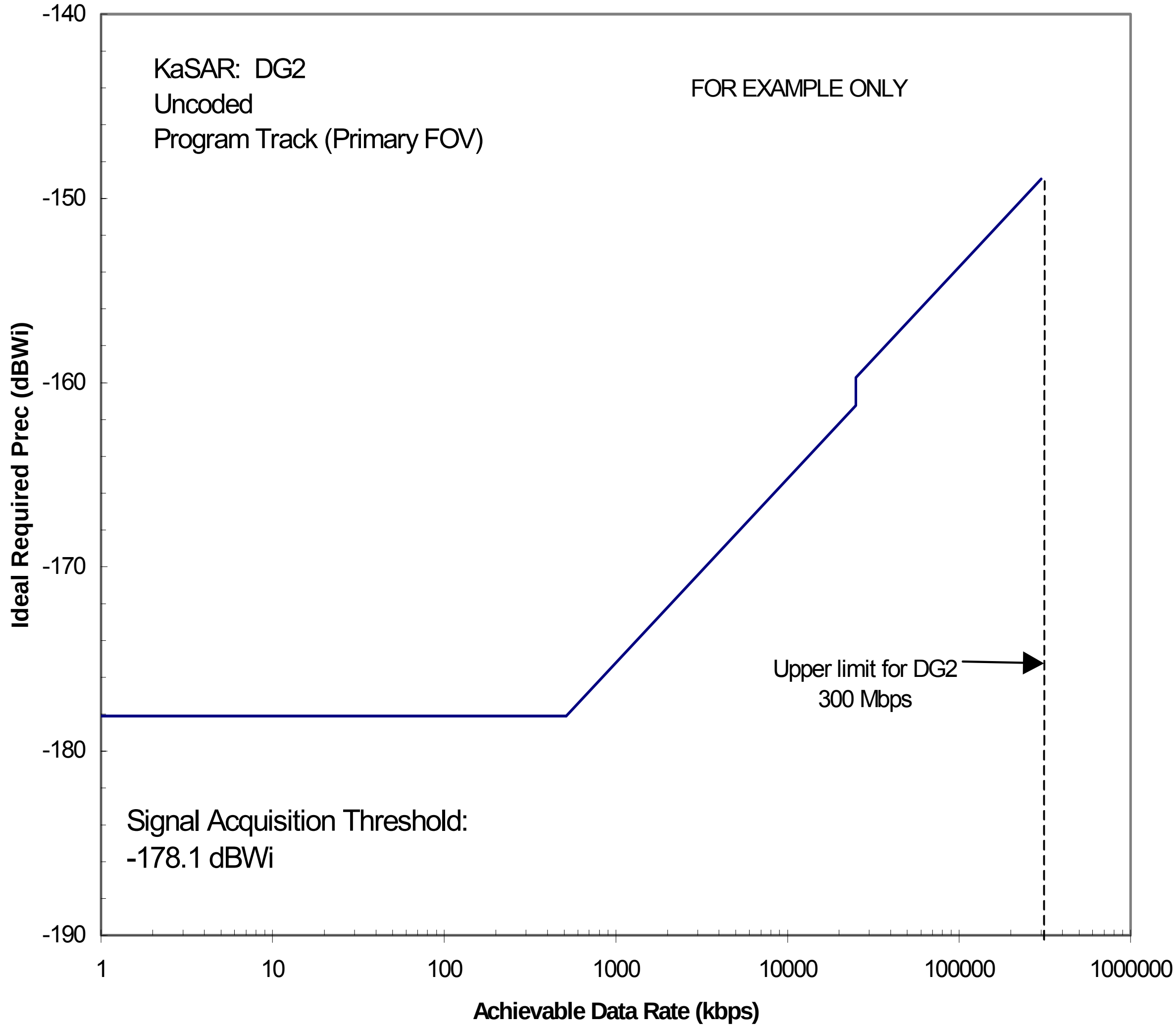


Figure A-45. KaSA Program Track DG2 (Uncoded) Return ADR versus Required Received Power at the TDRS (P_{rec})

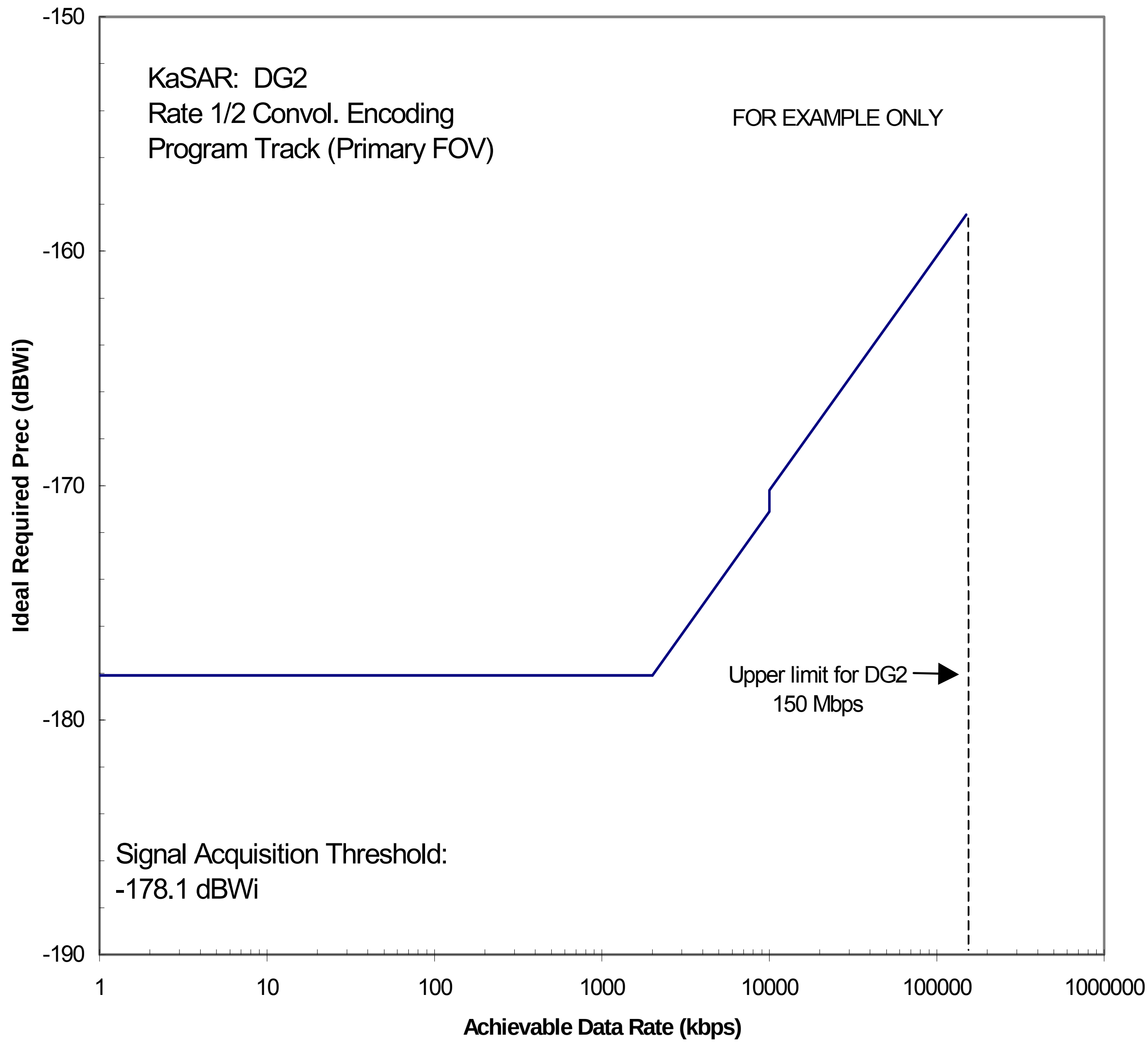


Figure A-46. KaSA Program Track DG2 (Rate 1/2) Return ADR versus Required Received Power at the TDRS (P_{rec})

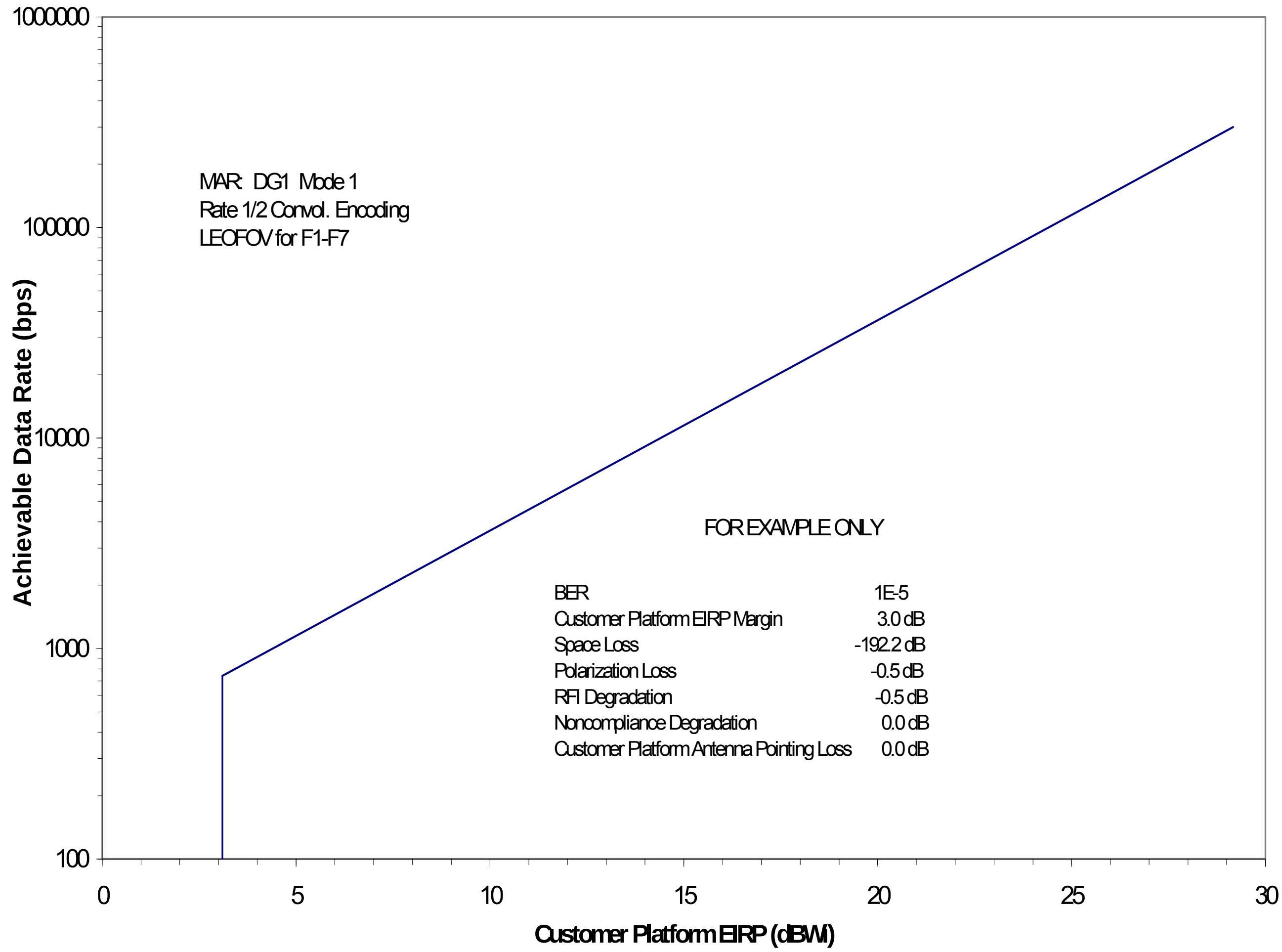


Figure A-47. MAR DG1 Modes 1 (Rate 1/2) ADR versus EIRP (LEOFOV for F1-F7)

Appendix B. Functional Configurations for TDRSS Forward and Return Services (with Emphasis on Resolving Customers' Data Polarity and I-Q Channel Ambiguities)

B.1 General

B.1.1 Purpose

The purpose of this Appendix is to describe the transmitter data communication functional configurations for TDRSS forward services and return services. Additionally, for each configuration, this Appendix identifies the conditions under which either data polarity ambiguity or I-Q channel ambiguity may exist at the SN/customer data interface.

B.1.2 Data Polarity Ambiguity and I-Q Channel Ambiguity

When data polarity ambiguity exists at the SN/customer data interface, the logical sense of the data may be either true or inverted. When I-Q channel ambiguity exists at the SN/customer data interface for the dual-source configurations, received I-channel or Q-channel data may appear on the designated interface port for the I-channel data, and received Q-channel or I-channel data may appear on the designated interface port for the Q-channel data. Data polarity ambiguity and I-Q channel ambiguity are addressed in paragraph B.2 for forward service and paragraph B.3 for return service.

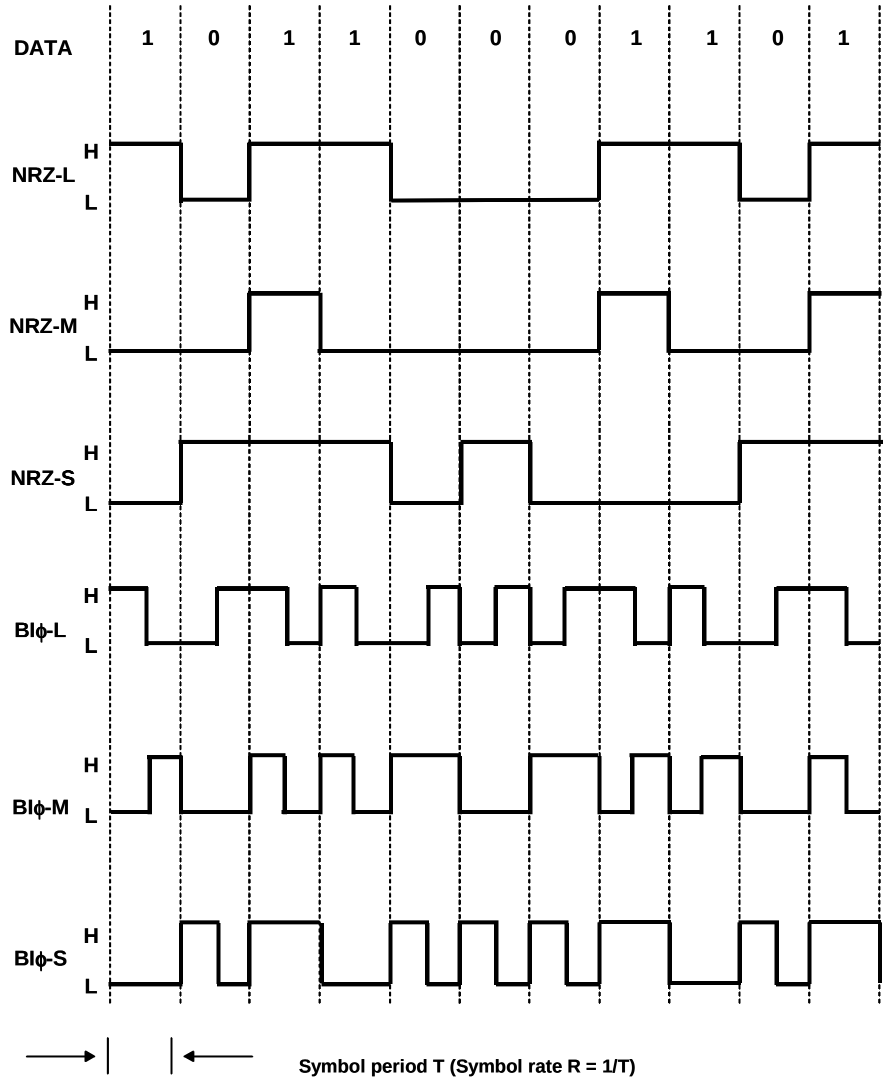
B.1.3 Definitions

In this Appendix, "data format" refers to the format of the source data either prior to transmission (uncoded operation) or prior to convolutional encoding (coded operation). "Symbol format" refers to the format of the channel data that is modulated onto the carrier. Figure B-1 depicts the definition of the various NRZ and Biphase formats.

B.2 Forward Service

B.2.1 General

The customer/SN end-to-end system functional configuration for forward service is shown in Figure B-2. Forward service data generated in the customer MOC is transmitted to the SN data interface. Refer to paragraph 3.6 for information concerning data interface capabilities and restrictions. The NISN, WSC, and TDRS are transparent to the data format and coding scheme of the forward link data originating in the customer MOC, except for WDISC and SSA PM customers. The SN supports forward data conditioning operations for WDISC and SSA PM forward link customers. These



Sequence of binary symbols (bits, chips) "1" and "0"

Non-Return-to-Zero-Level

"1" is represented by a high (H) level during the symbol period

"0" is represented by a low (L) level during the symbol period

Non-Return-to-Zero-Mark

"1" is represented by a change in level

"0" is represented by no change in level

Non-Return-to-Zero-Space

"1" is represented by no change in level

"0" is represented by a change in level

Bi-phase-L (Manchester II)

A transition occurs at the middle of every symbol period

"1" is represented by a midperiod transition from H to L

"0" is represented by a midperiod transition from L to H

Bi-phase-Mark

A transition occurs at the beginning of every symbol period

"1" is represented by a midperiod transition

"0" is represented by no midperiod transition

Bi-phase-Space

A transition occurs at the beginning of every symbol period

"1" is represented by no midperiod transition

"0" is represented by a midperiod transition

Figure B-1. Digital Signal Formats

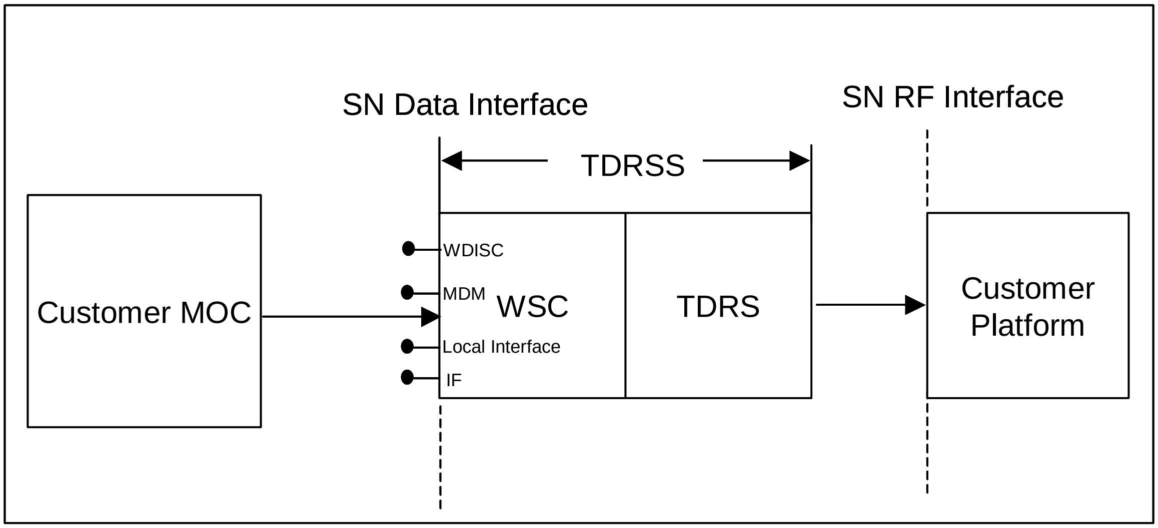


Figure B-2. Forward Service End-to-End System Functional Configuration

data conditioning operations include forward link rate 1/2 convolutional coding, BCH encoding, and data format conversion for WDISC customers and data format conversion for SSA PM customers.

The SN supports two modulation categories, referred to as PSK and PM. The PSK category is supported for MA, SSA, KuSA, and KaSA forward services. The PM category is supported for only SSA forward service. Table B-1 lists the data rate restrictions and the modulation types that are supported for each SN forward service. The TDRS spacecraft is capable of bent-pipe operation to support customer defined (non-TDRSS) signal formats. Non-TDRSS signal formats may require the addition of ground terminal modulation/demodulation equipment. Precise performance and SN support of these customer defined signals will have to be handled on a case-by-case basis.

B.2.2 PSK Services

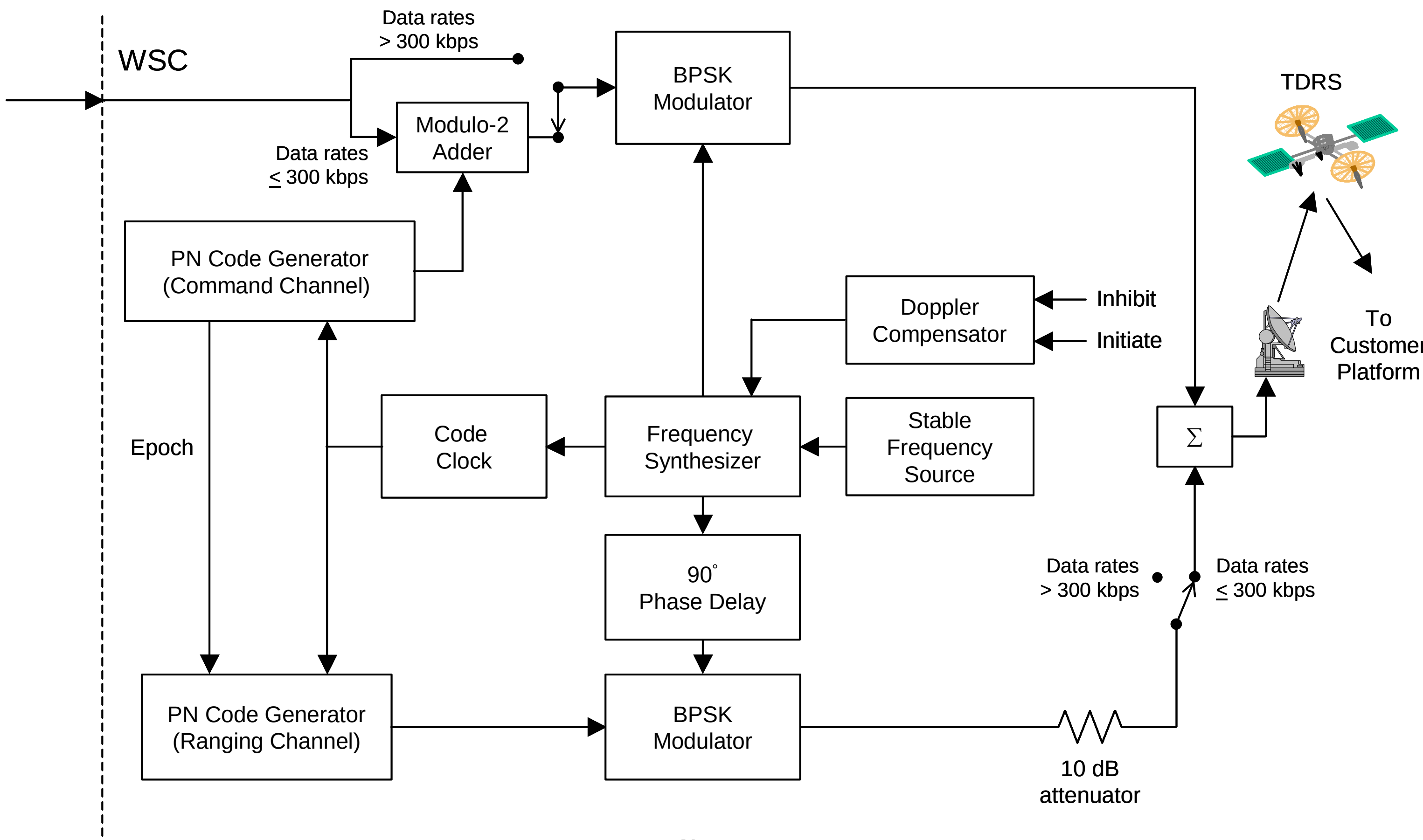
Figure B-3 depicts the functional configuration for the TDRSS for MA, SSA, KuSA and KaSA forward PSK modulation services, which are BPSK and QPSK. For QPSK modulation, the I channel contains the command data and is modulo-2 added to a 3 Mcps PN code and the Q channel is a 3 Mcps PN code, which is used for ranging. For BPSK modulation, the I channel contains the command data and directly PSK modulates the carrier. Forward data formatting, rate 1/2 convolutional, and BCH encoding are available for WDISC customers and should be discussed with the GSFC MSP. Otherwise, the TDRSS does not perform any type of data conditioning on the forward service data.

Table B-1. Forward Service Modulation and Data Rate Restrictions

Modulation Category	**Modulation Scheme (note 1)**	**Service and Data Rate Restrictions (note 5)**			
		MA/SMA	**SSA**	**KuSA**	**KaSA**
PSK	QPSK (note 2)	0.1 – 300 kbps	0.1 – 300 kbps	0.1 – 300 kbps	0.1 – 300 kbps
	BPSK (note 7)	Not available	300 kbps < data rate $\leq$ 7 Mbps	300 kbps < data rate $\leq$ 25 Mbps (note 3)	300 kbps < data rate $\leq$ 25 Mbps (note 3)
PM	Direct PM (note 6)	Not available	0.125 kbps -1 Mbps	Not available	Not available
	PSK Subcarrier PM (note 6)	Not available	0.125 kbps –8 kbps (note 4)	Not available	Not available

Notes:

1. TDRSS spacecraft is capable of bent-pipe operation to support customer defined (non-TDRSS) signal formats. Non-TDRSS signal formats may require the addition of ground terminal modulation/demodulation equipment. Precise performance and the SN support of these customer defined signals will have to be handled on a case-by-case basis.
2. The I channel contains the command data and is modulo-2 added to a 3 Mcps PN code and the Q channel is a 3 Mcps PN code.
3. Current WSC data interface supports up to 7 Mbps; however, upgrades to support up to 25 Mbps are planned.
4. The command data is used to BPSK modulate a sinusoidal or square-wave subcarrier, which will linearly phase modulate the carrier. Subcarrier frequency/bit rate ratio = 2^n, where n=1...7 for NRZ formats and n=2…7 for Biphase formats, where subcarrier frequencies supported are 2, 4, 8, or 16 kHz.
5. For PSK customers, the forward data rate in this table is the baud rate that will be transmitted by the TDRSS (includes all coding and symbol formatting). For PM customers, the data rate restrictions given in this table assume an uncoded signal that is NRZ formatted. The SN supports forward data conditioning operations for WDISC and SSA PM forward link customers. These data conditioning operations include forward link rate 1/2 convolutional coding, BCH encoding, and data format conversion for WDISC customers and data format conversion for SSA PM customers. For all other SN customers, forward link data conditioning is transparent to the SN and, if used, should be performed by the customer prior to transmission to the SN data interface. Refer to paragraph 3.6 for a description of SN data interfaces, associated constraints, and WDISC capabilities.
6. The PM modulation index can be: 1) 0.2 to 1.5 radians or $\pi/2$ radians for Direct PM and PSK Squarewave Subcarrier PM and 2) 0.2 to 1.8 radians for PSK Sinewave Subcarrier PM.
7. For BPSK modulation, the I channel contains the command data and directly PSK modulates the carrier. The SN is capable of supporting BPSK signals at data rates $\leq$ 300 kbps; however, its use will be constrained and must be coordinated with the GSFC MSP.



Notes

1. Data conditioning operations are available to WDISC customers. Otherwise, the TDRSS is transparent to the data format and the particular data format to be used will be established in the customer MOC. Data polarity ambiguity is resolved on the customer platform.
2. The resulting signal to a customer platform must not violate flux density considerations. Operational restrictions must be observed.
3. For data rates > 300 kbps, PN modulation is never used.
4. The SN is capable of supporting BPSK signals at data rates less than 300 kbps; however, its use will be constrained and must be coordinated with the GSFC MSP.

Figure B-3. TDRSS Functional Configuration for PSK Forward Services

B.2.2.1 PSK I-Q Channel Ambiguity

When PN modulation is used on the forward link (i.e., QPSK modulation), the I-Q channel ambiguity is resolved by the PN code and power ratio separation between the command and range channels. When there is no PN modulation on the forward link (i.e., BPSK modulation), there is no I-Q channel ambiguity for these modulation types as they use a single data channel.

B.2.2.2 PSK Data Polarity Ambiguity

If NRZ-M, NRZ-S, Biphase-M, or Biphase-S data formats are used, the customer platform can resolve the data polarity ambiguity by differential decoding of the data; i.e., -M or -S to -L format conversion. If NRZ-L or Biphase-L data format is used, data polarity ambiguity will exist and it is the customer's responsibility to utilize other techniques, such as frame synchronization to an a priori data (sync) word or its complement, to resolve the data polarity ambiguity.

B.2.3 PM Forward Services (SSA Only)

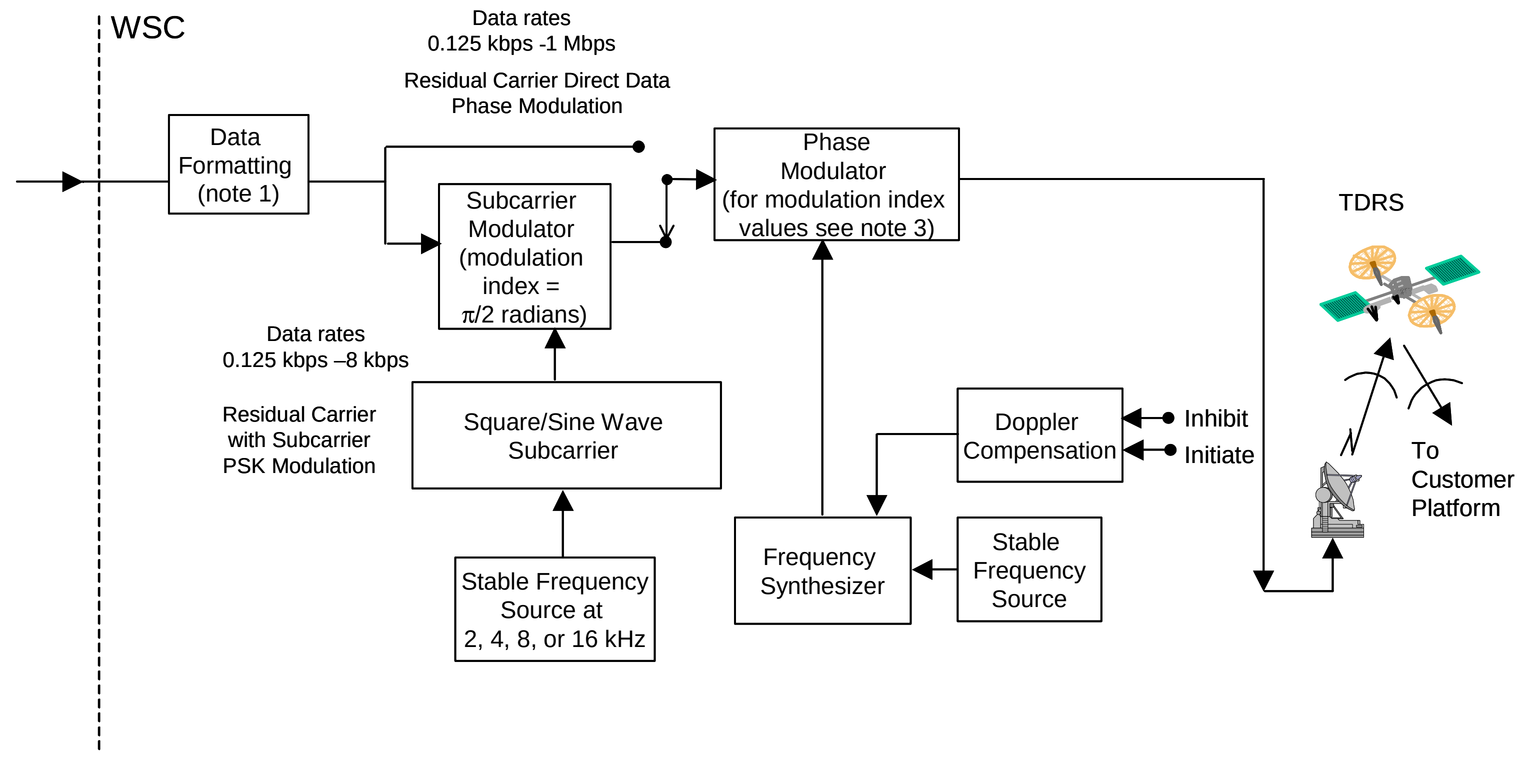
Figure B-4 depicts the functional configuration for the TDRSS SSA PM services. For a Direct PM scheme, the command data directly phase modulates the data with a modulation index of 0.2 to 1.5 radians or $\pi/2$ radians. For a PSK subcarrier PM scheme, the command data BPSK modulates either a sinusoidal or square-wave subcarrier, which linearly phase modulates the carrier. The SN can perform data formatting operations; these customer signal characteristics should be discussed with the GSFC MSP prior to service to determine if the formatting will be performed by the customer MOC prior to the SN interface or at the SN.

B.2.3.1 PM I-Q Channel Ambiguity

There is no I-Q channel ambiguity for these modulation types as they use a single data channel.

B.2.3.2 PM Data Polarity Ambiguity

If NRZ-M, NRZ-S, Biphase-M, or Biphase-S data formats are used, the customer platform can resolve the data polarity ambiguity by differential decoding of the data; i.e., -M or -S to -L format conversion. If NRZ-L or Biphase-L data format is used, data polarity ambiguity will exist and it is the customer's responsibility to utilize other techniques, such as frame synchronization to an a priori data (sync) word or its complement, to resolve the data polarity ambiguity.



Notes

1. The TDRSS may be transparent to the data format; however, the SN can perform symbol/data formatting operations and these customer signal characteristics should be discussed with the GSFC MSP prior to service. Data phase ambiguity is resolved on the customer platform.
2. The resulting signal to a customer platform must not violate flux density considerations. Operational restrictions must be observed.
3. The PM modulation index can be: 1) 0.2 to 1.5 radians or π/2 radians for direct data phase modulation and PSK squarewave subcarrier PM and 2) 0.2 to 1.8 radians for PSK sinewave subcarrier phase modulation.
4. The SN supports subcarrier frequency/bit rate ratio = 2^n, where n=1...7 for NRZ formats and n=2…7 for Biphase formats.

Figure B-4. TDRSS Functional Configuration for PM Forward Services

B.3 Return Service

B.3.1 General

The customer/SN end-to-end system functional configuration for return service is shown in Figure B-5. Return data generated in the customer platform undergoes various baseband data conditioning operations (i.e., data format conversion, data demultiplexing for alternate bits on the I and Q channels, convolutional encoding, symbol format conversion, and symbol interleaving) and RF signal processing (spectrum spreading, modulation, I/Q-channel power weighting, and frequency upconversion) prior to transmission to the TDRSS. At the WSC, the inverse RF signal processing (frequency downconversion, despreading, and demodulation) and baseband signal processing (symbol synchronization, symbol format conversion, symbol deinterleaving, Viterbi decoding, data format conversion, and data interleaving of the I- and Q-channel data bits) are performed. The return service data at the WSC/SN data interface will always be treated as NRZ-L. For example, if NRZ-M data formatting is scheduled, the SN will perform NRZ-M to NRZ-L data format conversion. If SN customers would like their data format to be unaltered by the SN (i.e., in the example just given, they would like to receive NRZ-M data rather than NRZ-L data at the SN data interface), then customers need to schedule through the SN as if their data format is NRZ-L; then the SN will not perform any data format conversion. Refer to paragraph 3.6 for information concerning data interface capabilities and restrictions.

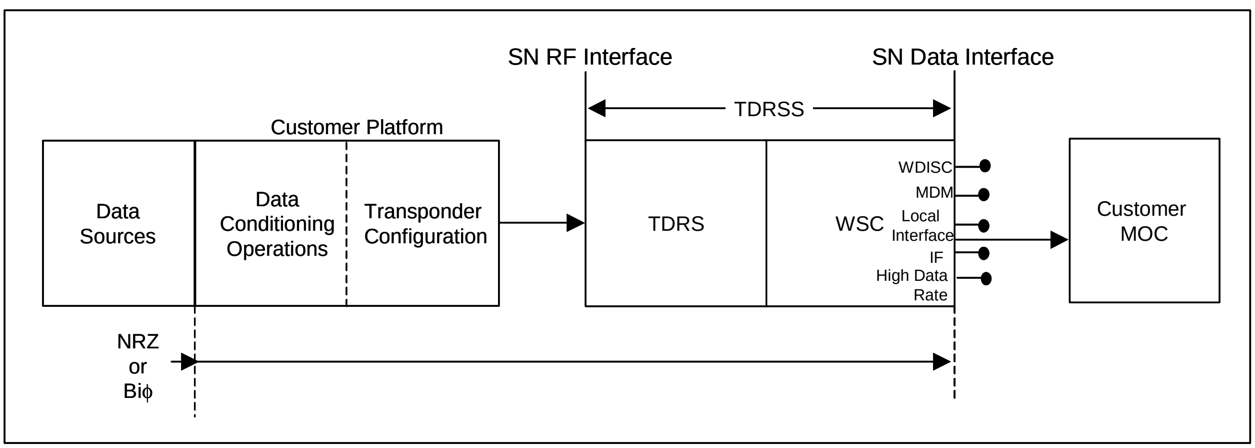


Figure B-5. Return Service End-to-End System Functional Configuration

The SN return services are divided into 2 major groups, Data Group 1 (DG1) and Data Group 2 (DG2). DG1 services utilize spread spectrum modulation while DG2 services are non-spread. Figure B-6 depicts the customer platform data communication functional configurations for DG1 and DG2 return services, where the data conditioning operations are shown in Figure B-7 through Figure B-9 for the specific Data Group and mode configuration.

NOTE

KaSA return does not support DG1 services.

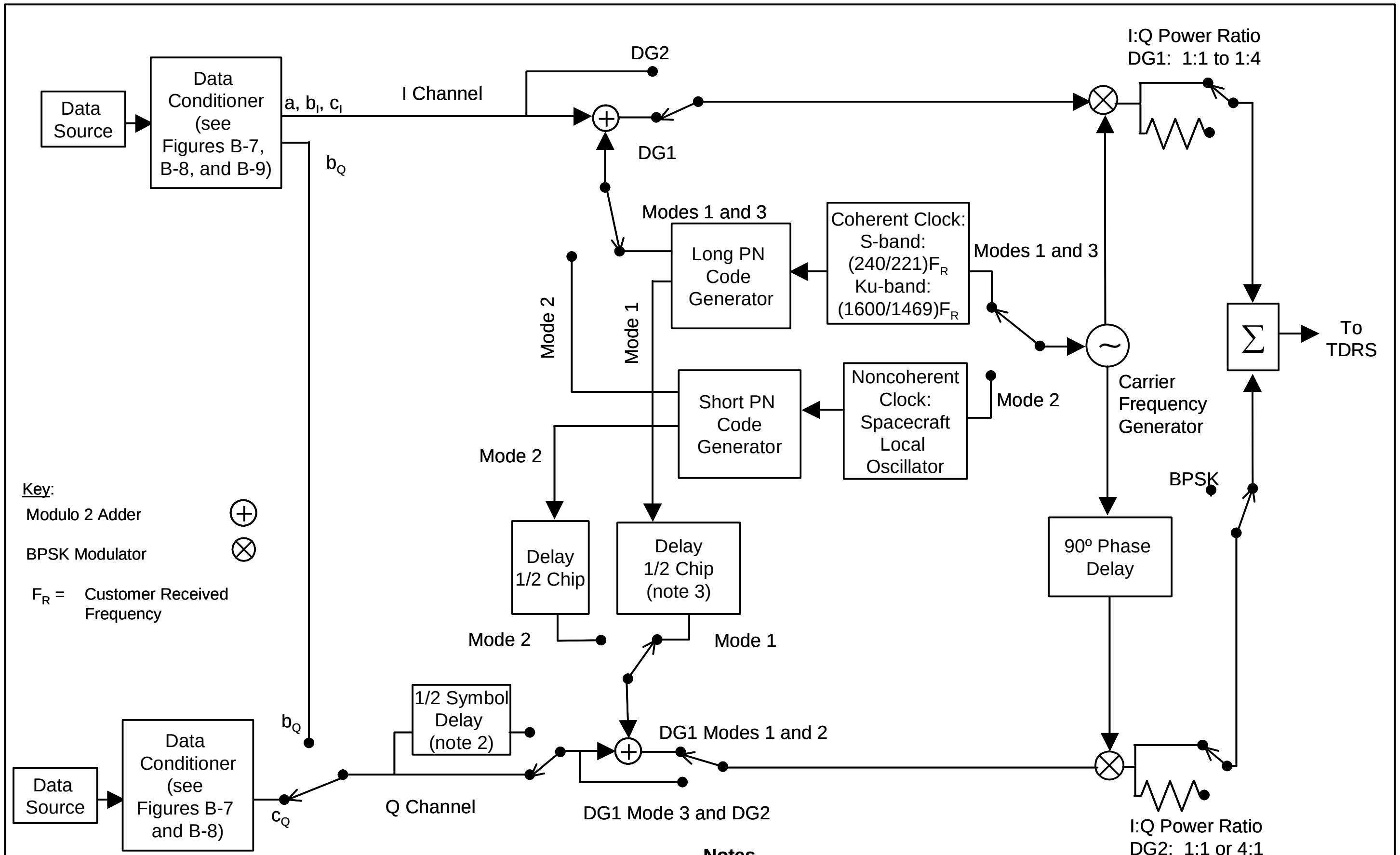
B.3.2 DG1 Services

Within each data group, there are several types of modulation. DG1 services are subdivided into three modes of operation, DG1 modes 1, 2, and 3. DG1 services support several types of modulation and configurations, which are described in paragraph B.3.2.1. Paragraphs B.3.2.2 and B.3.2.3 describe DG1 I-Q channel ambiguity and data polarity ambiguity, respectively.

B.3.2.1 DG1 Configurations

a. Balanced Power Single Data Source-Identical Data on the I and Q Channels (DG1 mode 1 and 2 only). I and Q channels consist of identical data that is synchronous and identically formatted and rate 1/2 convolutionally coded (if applicable). The signal is transmitted using balanced (I/Q power ratio is 1:1) SQPN modulation. Table B-2 lists the service configuration constraints, where the I channel data rate = Q channel data rate = source data rate. The data conditioning operations supported are shown in Figure B-7 for this configuration, where the channel data source represents the single data source with identical data conditioning operations performed on both the I and Q channels. Figure B-10 describes the rate 1/2 convolutional encoder supported by the SN.

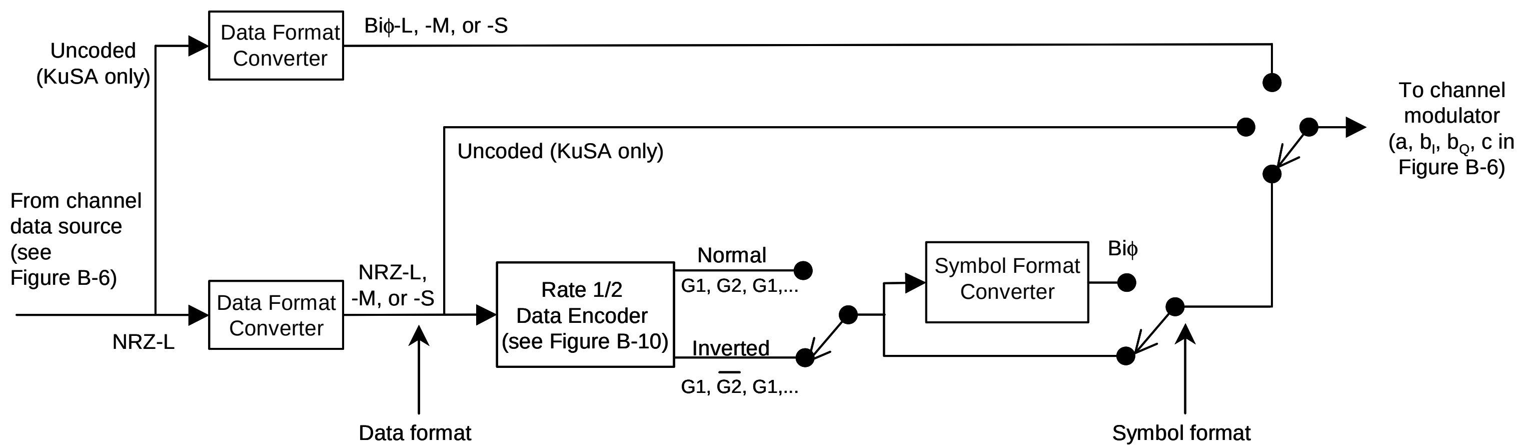
b. Balanced Power Single Data Source-Alternate I/Q Bits (SMAR and SSAR DG1 mode 1 and 2). I and Q channels consist of alternate bits of the same data source and each channel will be identically but independently differentially formatted and rate 1/2 convolutionally encoded. The Q channel encoder output symbol will be delayed by a half symbol period relative to the I channel encoder output symbol. The signal is transmitted using balanced (I/Q power ratio is 1:1) SQPN modulation. Table B-2 lists the service configuration constraints, where the I channel data rate = Q channel data rate = 1/2 source data rate. The data conditioning operations supported are shown in Figure B-7 for this configuration, where the channel data source represents the I and Q channels after decommutation from the single data source and the I and Q channels are identically but independently data conditioned. Figure B-10 describes the rate 1/2 convolutional encoder supported by the SN.



Notes

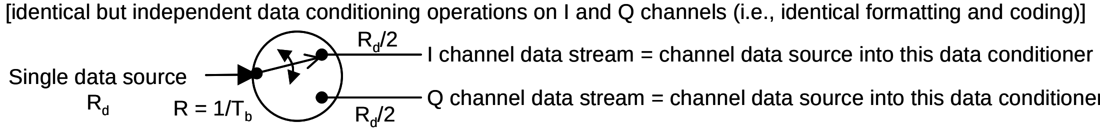
1. a, b, c denote the output of the data conditioner, where:
   - a = Single data source with data on single data channel (BPSK)
   - b = Single data source with data on both the I channel (b_I) and Q channel (b_Q), which can be configured as either:
     1) Identical data on I and Q channels (DG1 Modes 1 and 2);
     2) Alternate I/Q data bits (DG1 Modes 1 and 2 for SSA and SMA and DG2) with 1:1 I:Q power ratio;
     3) Alternate I/Q encoded symbols (DG2) with 1:1 I:Q power ratio
   - c = Dual data sources with data on both the I channel (c_I) and Q channel (c_Q)
2. Delay is required for DG1 and DG2 alternate I/Q data bit configuration, DG2 alternate symbol configuration, and DG2 dual data source SQPSK configuration.
3. Q channel PN code sequence is identical to the I channel PN Code sequence, but delayed by X + 1/2 chip, where X is dependent upon the unique customer PN code assignment.

Figure B-6. Customer Platform Functional Configuration for DG1 and DG2



Where channel data source is as follows for each possible configuration:

a. Single data source with single data channel (BPSK): I channel data stream = channel data source
b. Single data source with data on both the I channel and Q channel, which can be configured as either:
   1) Identical data on I and Q channels: channel data source = I channel data source = Q channel data source [identical data conditioning operations on I and Q channels (i.e., data/symbol format/coding and synchronous data (time aligned)]
   2) Alternate data bits on I and Q channels (SSA and SMA only): I and Q channel data streams are alternate data bits of the same single data source [identical but independent data conditioning operations on I and Q channels (i.e., identical formatting and coding)]



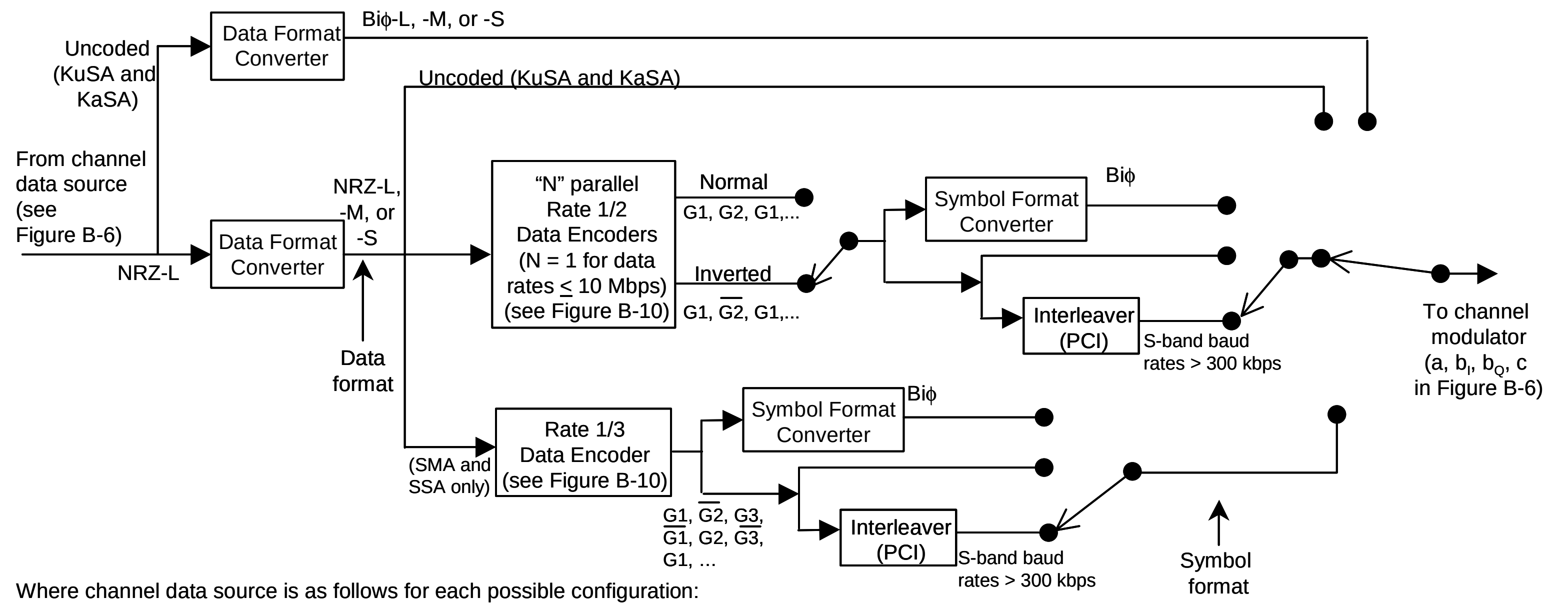
Switch is at each position for T_d seconds, where $T_d=1/R_d$

c. Dual Data Sources: channel data source represents I and Q channel data sources separately [independent data conditioning operations]; channel data source = I Channel of DG1 mode 3

Note

1. For the single data source alternate I/Q data-bit configuration, NRZ-to-Biϕ conversion is not allowed. However, NRZ-M or NRZ-S data format conversion is required to resolve the data polarity ambiguity and to reconstruct the single data channel at WSC.
2. If the data format is NRZ-L or Biphase-L, WSC does not resolve the data polarity ambiguity. If the data format is NRZ-M, NRZ-S, Biphase-M, or Biphase-S, WSC resolves the data polarity ambiguity.

Figure B-7. Data Conditioning Operations for DG1 Modes 1 and 2 (I and Q Channels) and DG1 Mode 3 I Channel

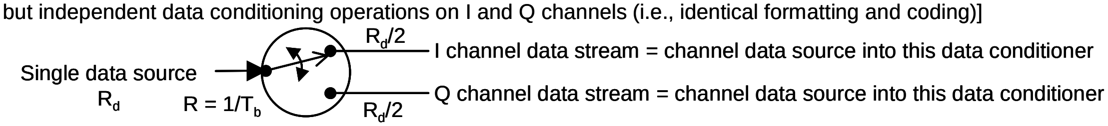


Where channel data source is as follows for each possible configuration:

a. Single data source with single data channel (BPSK): I channel data stream = channel data source

b. Single data source with data on both the I channel and Q channel, which can be configured as:

1) Alternate data bits on I and Q channels: I and Q channel data streams are alternate data bits of the same single data source [identical but independent data conditioning operations on I and Q channels (i.e., identical formatting and coding)]



Switch is at each position for T_d seconds, where T_d=1/R_d

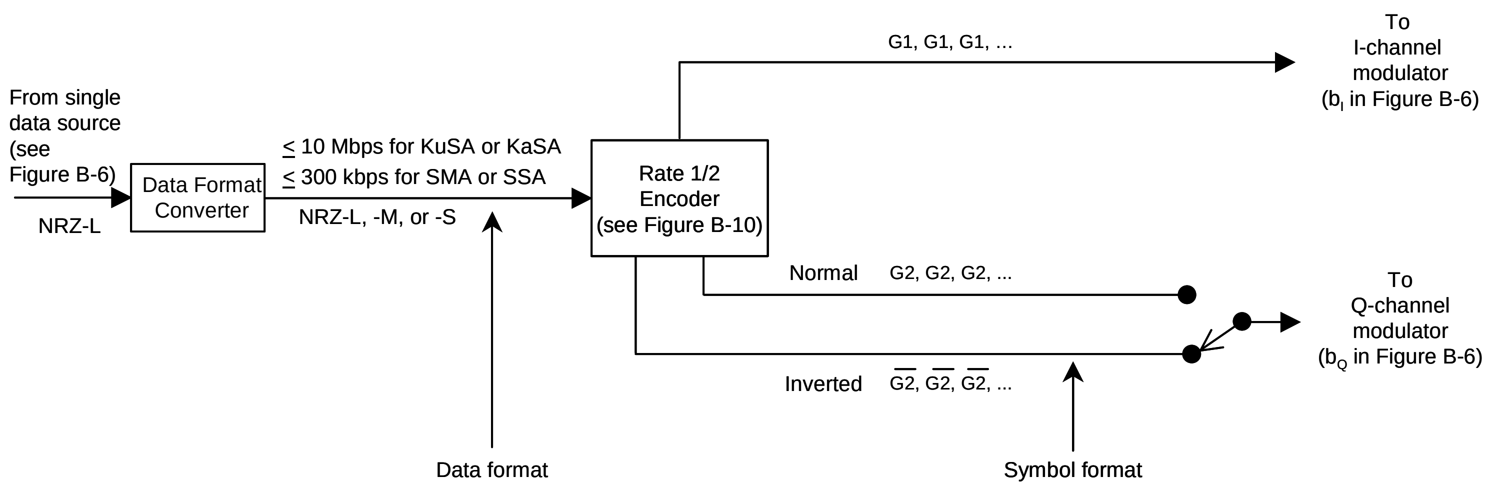
c. Dual Data Sources: channel data source represents I and Q channel data sources separately [independent data conditioning operations]; channel data source = Q Channel of DG1 mode 3

Notes

1. For the SQPSK alternate I/Q data-bit configuration, NRZ to Biϕ conversion not allowed. However, NRZ-M or NRZ-S data format conversion is required to resolve the data polarity ambiguity and to reconstruct the single data channel at WSC. This configuration is supported for KuSAR and KaSAR single data sources > 10 Mbps.

2. If the data format is NRZ-L or Biphase-L, WSC does not resolve the data polarity ambiguity. If the data format is NRZ-M, NRZ-S, Biphase-M, or Biphase-S, WSC resolves the data polarity ambiguity.

Figure B-8. Data Conditioning Operations for DG1 Mode 3 Q Channel and DG2 (except SQPSK with Alternate I/Q Encoded Symbols)



Notes

1. If the data format is NRZ-L, WSC does not resolve the data polarity ambiguity.
2. If the data format is NRZ-M or NRZ-S, WSC resolves the data polarity ambiguity.

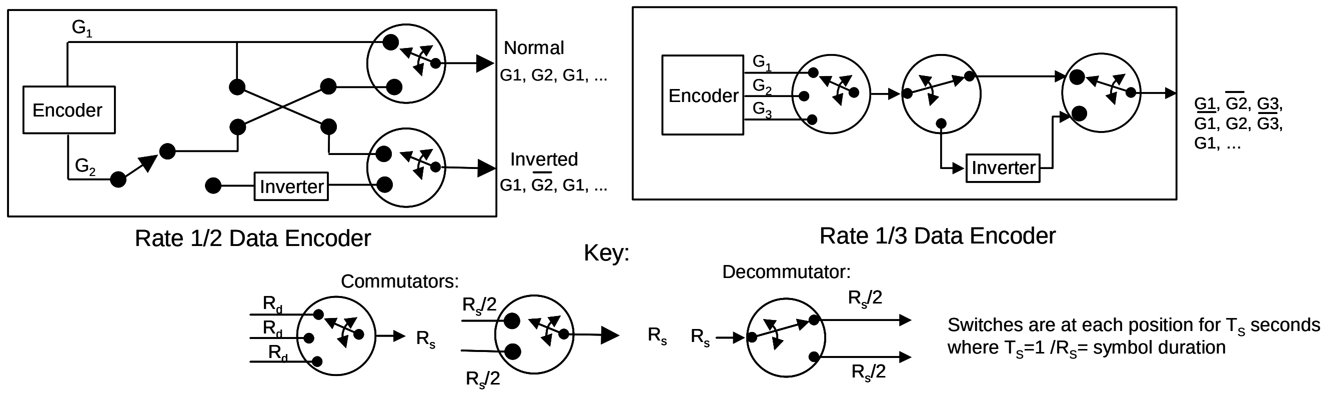
Figure B-9. Data Conditioning Operations for DG2 SQPSK with Alternate I/Q Encoded Symbols

Table B-2. Data Configuration Constraints for DG1 Modes 1 and 2, Single Data Source

Coding (note 4)	Data Format	Configuration	Source Data Rate Restrictions and Availability (note 1)			
			MA (note 2)	SMA and SSA (note 2)	KuSA	KaSA
Rate 1/2	NRZ	Single Data Channel (BPSK)	≤ 150 kbps	≤ 150 kbps	1 kbps - 150 kbps	NA
		Identical Data on I and Q channels				
		Alternate I and Q bits	NA	≤ 300 kbps	NA	NA
	NRZ with Biϕ symbols	Single Data Channel (BPSK)	≤ 75 kbps	≤ 75 kbps	1 kbps - 75 kbps	NA
		Identical Data on I and Q channels				
Rate 1/3	NRZ	NA	NA	NA	NA	NA
Uncoded	NRZ	Single Data Channel (BPSK)	NA	Note 3	1 kbps - 300 kbps	NA
		Identical Data on I and Q channels				
	Biϕ	Single Data Channel (BPSK)	NA	Note 3	1 kbps - 150 kbps	NA
		Identical Data on I and Q channels				

Notes: NA: Not Available

1. The channel data rate restrictions are as follows:
   a. For single data source configurations with identical data on both I and Q channels:
      channel data rate = source data rate
   b. For single data source configuration with alternate bits on the I and Q channels:
      channel data rate = I channel data rate = Q channel data rate = 1/2 the source data rate. The I/Q (power) must be 1:1.
   c. For a BPSK signal configuration:
      channel data rate restriction is maximum data rate for the channel
2. Minimum data rate for MA, SMA, and SSA services:
   DG1 Mode 1: 0.1 kbps
   DG1 Mode 2: 1 kbps
3. The SN is capable of supporting SMA and SSA uncoded return link signals; however, its use will be constrained and must be coordinated with the GSFC MSP.
4. Figure B-10 describes the convolutional encoders supported by the SN.



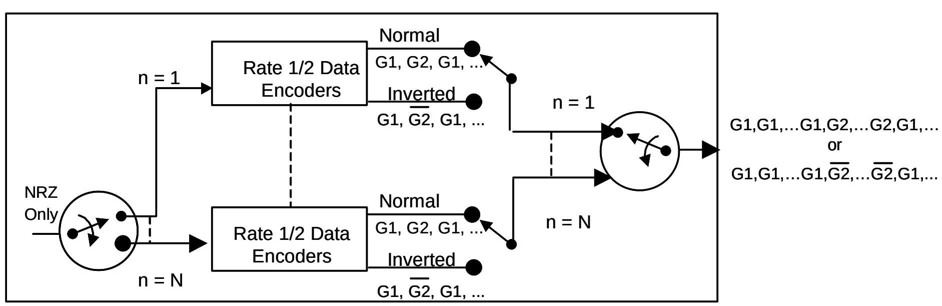
Encoders: convolutional, nonsystematic, transparent

Rate 1/2:

- Generator Functions: G1 = 1111001; G2 = 1011011
- Symbols generated from G1 must precede symbols generated from G2 relative to the data bit period.
- The SN can support symbols generated from G2 that are either true or complemented. However, G_2 symbol inversion provides an increased symbol transition density for a convolutional encoder input data signal with low transition density, which aids WSC clock (symbol) synchronization.

Rate 1/3:

- Generator Functions: G1 = 1111001; G2 = 1011011; G3 = 1110101
- The symbol sequence must be generated from G1, G2, and G3 successively relative to the data bit period.
- Alternate symbols generated from the convolutional encoding must be complemented.



N Parallel Rate 1/2 Data Encoders

$$N = \frac{R_d}{1 \times 10^7}$$ Rounded to the next highest integer if $N \neq$ Integer

N = Number of parallel code 1 data encoders for the channel

R_d = Channel data rate (bps)

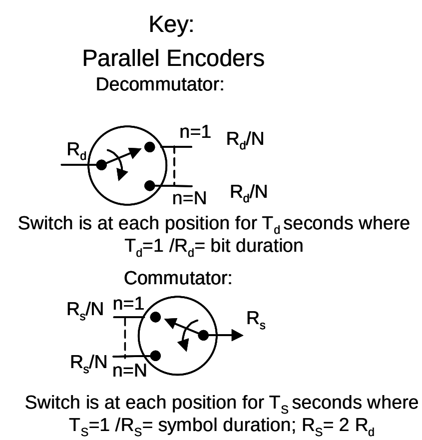


Figure B-10. Data Encoders

c. Unbalanced Power Single Data Source-Identical Data on the I and Q Channels (DG1 mode 1 and 2 only). I and Q channels consist of identical data that is synchronous and identically formatted and rate 1/2 convolutionally coded (if applicable). The signal is transmitted using unbalanced (I/Q power ratio can be weighted up to a maximum of 1:4) SQPN modulation. Table B-2 lists the service configuration constraints, where the I channel data rate = Q channel data rate = source data rate. The data conditioning operations supported are shown in Figure B-7 for this configuration, where the channel data source represents the single data source with identical data conditioning operations performed on both the I and Q channels. Figure B-10 describes the rate 1/2 convolutional encoder supported by the SN.

d. Single Data Source with Single Data Channel (DG1 modes 1 and 2 only). Either the I or Q channel consists of data that has been formatted and rate 1/2 convolutionally encoded (if applicable). The channel is modulo-2 added asynchronously to the channel PN code. The signal is transmitted using BPSK modulation. Table B-2 lists the service configuration constraints. The data conditioning operations supported are shown in Figure B-7 for this configuration. Figure B-10 describes the rate 1/2 convolutional encoder supported by the SN.

e. Balanced Power Dual Data Sources. The I and Q channel consist of independent data that is independently formatted, convolutionally coded (if applicable), and symbol interleaved (if applicable on the Q channel only). For DG1 modes 1 and 2, the signal is transmitted using balanced (I/Q power ratio is 1:1) SQPN modulation. For DG1 mode 3, the I channel is modulo-2 added asynchronously to the channel PN code and the Q channel directly PSK modulates the carrier. The signal is transmitted using balanced (I/Q power ratio is 1:1) power. Table B-3 lists the service configuration constraints for DG1 modes 1 and 2, where the source data rate constraints apply to each channel separately. Table B-4 lists the service configuration constraints for DG1 mode 3, where the source data rate constraints apply to each channel separately. The data conditioning operations supported for this configuration are shown in Figure B-7 for DG1 modes 1, 2, and 3 I channel, where the channel data source represents each of the I and Q channel sources separately for independent data conditioning operations. Figure B-8 presents the data conditioning operations for DG1 mode 3 Q channel. Figure B-10 describes the convolutional encoders supported by the SN.

f. Unbalanced Power Dual Data Sources. The I and Q channel consist of independent data that is independently formatted, convolutionally coded (if applicable), and symbol interleaved (if applicable on the Q channel only). For DG1 modes 1 and 2, the signal is transmitted using unbalanced (I/Q power ratio can be weighted up to a maximum of 1:4) SQPN modulation. For DG1 mode 3, the I channel is modulo-2 added asynchronously to the channel PN code and

Table B-3. Data Configuration Constraints for DG1 Modes 1 and 2, Dual Data Sources

Channel Coding (note 4)	**Data Format**	**Source Data Rate Restrictions and Availability (note 1)**			
		MA and SMA (note 2)	**SSA (note 2)**	**KuSA**	**KaSA**
Rate 1/2	NRZ	≤ 150 kbps	≤ 150 kbps	1 kbps - 150 kbps	NA
	NRZ with Biϕ symbols	≤ 75 kbps	≤ 75 kbps	1 kbps - 75 kbps	NA
Rate 1/3	NRZ	NA	NA	NA	NA
Uncoded	NRZ	Note 3	Note 3	1 kbps - 300 kbps	NA
	Biϕ	Note 3	Note 3	1 kbps - 150 kbps	NA

Notes: NA: Not Available

1. For dual data source configurations, the channel data rate restrictions are equivalent to the source data rate and apply to each channel separately.
2. Minimum data rate for MA, SMA, and SSA services:
   DG1 Mode 1: 0.1 kbps
   DG1 Mode 2: 1 kbps
3. The SN is capable of supporting uncoded SSA and SMA return link signals; however, its use will be constrained and must be coordinated with the GSFC MSP.
4. Figure B-10 describes the convolutional encoders supported by the SN.

Table B-4. Data Configuration Constraints for DG1, Mode 3

Coding (note 4)	**Data Format**	**I Channel Data Rate and Availability**				**Q Channel Data Rate and Availability**			
		SMA	**SSA**	**KuSA**	**MA and KaSA**	**SMA**	**SSA**	**KuSA**	**MA and KaSA**
Rate 1/2	NRZ	0.1 kbps - 150 kbps	0.1 kbps - 150 kbps	1 kbps - 150 kbps	NA	1 kbps - 1.5 Mbps (note 1)	1 kbps - 3 Mbps (note 1)	1 kbps - 75 Mbps (note 5)	NA
	NRZ with Biϕ symbols	0.1 kbps - 75 kbps	0.1 kbps - 75 kbps	1 kbps - 75 kbps	NA	1 kbps - 0.75 Mbps (notes 1, 2)	1 kbps - 1.5 Mbps (notes 1, 2)	1 kbps - 5 Mbps	NA
Rate 1/3	NRZ	NA	NA	NA	NA	1 kbps - 1 Mbps (note 1)	1 kbps - 2 Mbps (note 1)	NA	NA
	NRZ with Biϕ symbols	NA	NA	NA	NA	1 kbps - 0.5 Mbps (notes 1, 2)	1 kbps - 1 Mbps (notes 1, 2)	NA	NA
Uncoded	NRZ	Note 3	Note 3	1 kbps - 300 kbps	NA	Note 3	Note 3	1 kbps - 150 Mbps	NA
	NRZ with Biϕ symbols	Note 3	Note 3	1 kbps - 150 kbps	NA	Note 3	Note 3	1 kbps - 5 Mbps	NA

Notes: NA: Not Available

1. Periodic convolutional interleaving (PCI) recommended on SMA and SSA return service for baud rates > 300 kbps. When interleaving is not employed for baud rates > 300 kbps, SSA and SMA performance may not be guaranteed.
2. Biϕ symbol formats are not allowed with PCI.
3. The SN is capable of supporting SMA and SSA uncoded return link signals; however, its use will be constrained and must be coordinated with the GSFC MSP.
4. Figure B-10 describes the convolutional encoders supported by the SN.
5. For channels with rate 1/2 coding and data rates greater than 10 Mbps, the customer transmitter must be configured to use an N-parallel encoder, where N is the number of branch rate 1/2 encoders for the channel. N = channel data rate in bps/$1x10^7$, where N is rounded to the next higher integer if N is not an integer.

the Q channel directly PSK modulates the carrier. The signal is transmitted using unbalanced (I/Q power ratio can be weighted up to a maximum of 1:4) power. Table B-3 lists the service configuration constraints for DG1 modes 1 and 2, where the source data rate constraints apply to each channel separately. Table B-4 lists the service configuration constraints for DG1 mode 3, where the source data rate constraints apply to each channel separately. The data conditioning operations supported for this configuration are shown in Figure B-7 for DG1 modes 1, 2, and 3 I channel, where the channel data source represents each of the I and Q channel sources separately for independent data conditioning operations. Figure B-8 presents the data conditioning operations for DG1 mode 3 Q channel. Figure B-10 describes the convolutional encoders supported by the SN.

B.3.2.2 DG1 I-Q Channel Ambiguity

For DG1 modes 1 and 2 operation, there is no I-Q channel ambiguity because the PN codes on the I and Q channels are different. For DG1 mode 3 operation, there is no I-Q channel ambiguity since the WSC resolves the I and Q channels by PN correlation and knowledge of the I/Q power ratio.

B.3.2.3 DG1 Data Polarity Ambiguity

For NRZ-M, NRZ-S, Biphase-M, or Biphase-S customer data formats, the WSC resolves the data polarity ambiguity by differentially decoding the return service data to NRZ-L. For NRZ-L or Biphase-L customer data formats, data polarity ambiguity will exist at the WSC/SN data interface and it is the customer’s responsibility to utilize other techniques, such as frame synchronization to an a priori data (sync) word or its complement, to resolve the data polarity ambiguity.

NOTE

The DG1 modes 1 and 2 single data source configuration with alternate I/Q data bits requires that the I and Q channels be differentially encoded to either NRZ-M or NRZ-S in order to recover the single data source as well as resolve data polarity ambiguity. Without differential encoding, the single data source may have the alternate bits inverted.

B.3.3 DG2 Services

DG2 services support several types of modulation and configurations, which are described in paragraph B.3.3.1. Paragraphs B.3.3.2 and B.3.3.3 describe DG2 I-Q channel ambiguity and data polarity ambiguity, respectively.

NOTE

MA return does not support DG2 services.

B.3.3.1 DG2 Configurations

a. Balanced Power Single Data Source-Alternate I/Q Bits. I and Q channels consist of alternate bits of the same data source and each channel will be identically but independently differentially formatted and rate 1/2 convolutionally encoded (if applicable). The Q channel symbol will be delayed by a half symbol period relative to the I channel symbol. The signal is transmitted using balanced (I/Q power ratio is 1:1) SQPSK modulation. Table B-5 lists the service configuration constraints, where the I channel data rate = Q channel data rate = 1/2 source data rate. The data conditioning operations supported are shown in Figure B-8 for this configuration, where the channel data source represents the I and Q channels after decommutation from the single data source and the I and Q channels are identically but independently data conditioned. Figure B-10 describes the rate 1/2 convolutional encoder supported by the SN.

b. Balanced Power Single Data Source-Alternate I/Q Encoded Symbols. I and Q channels consist of the two concurrent output symbols of a rate 1/2 convolutional encoder, where the G_1 output of the encoder is on the I channel and the G_2 output of the encoder is on the Q channel. The Q channel will be delayed by a half symbol period relative to the I channel. The channels are transmitted using balanced (I/Q power ratio is 1:1) SQPSK modulation. Table B-5 lists the service configuration constraints, where the I channel data rate = Q channel data rate = 1/2 source data rate. The data conditioning operations supported are shown in Figure B-9 for this configuration. Figure B-10 describes the rate 1/2 convolutional encoder supported by the SN.

c. Single Data Source with Single Data Channel. The source data, that has been formatted and convolutionally encoded (if applicable), directly BPSK modulates the carrier. Table B-6 lists the service configuration constraints. The data conditioning operations supported are shown in Figure B-8 for this configuration. Figure B-10 describes the convolutional encoders supported by the SN.

d. Balanced Power Dual Data Sources. The I and Q channel consist of independent data that is independently formatted, convolutionally coded (if applicable), and symbol interleaved (if applicable). The signal is transmitted using balanced (I/Q power ratio is 1:1) QPSK or SQPSK modulation. Table B-7 lists the service configuration constraints, where the source data rate constraints apply to each channel separately. The data conditioning operations supported are shown in Figure B-8 for this configuration, where the channel

Table B-5. Data Configuration Constraints for DG2, Single Data Source (SQPSK)

Coding (note 5)	Data Format	Configuration	Source Data Rate Restrictions and Availability (note 1)			
			MA	SMA	SSA	KuSA and KaSA
Rate 1/2	NRZ	Alternate I and Q bits (note 2)	NA	1 kbps - 3 Mbps (note 3)	1 kbps - 6 Mbps (note 3)	>10 Mbps - 75 Mbps (note 6)
		Alternate I and Q symbols		1 kbps - 300 kbps	1 kbps - 300 kbps	1 kbps - 10 Mbps
Rate 1/3	NRZ	Alternate I and Q bits (note 2)	NA	1 kbps - 2 Mbps (note 3)	1 kbps - 2 Mbps (note 3)	NA
Uncoded	NRZ	Alternate I and Q bits (note 2)	NA	Note 4	Note 4	1 kbps - 300 Mbps

Notes:

1. For SQPSK modulation, the I/Q (power) = 1:1 and
   the I channel data rate = Q channel data rate = 1/2 the source data rate.
2. For the alternate I and Q bit configuration, the data format must be NRZ-L. On each channel, the data bits are identically but independently differentially encoded and then convolutionally encoded (if desired) prior to transmission.
3. Periodic convolutional interleaving (PCI) recommended on SMA and SSA return service for baud rates > 300 kbps. When interleaving is not employed for baud rates > 300 kbps, SSA and SMA performance may not be guaranteed.
4. The SN is capable of supporting SMA and SSA uncoded return link signals; however, its use will be constrained and must be coordinated with the GSFC MSP.
5. Figure B-10 describes the convolutional encoders supported by the SN.
6. For rate 1/2 coding and source data rates greater than 20 Mbps (i.e., channel data rates greater than 10 Mbps), the customer transmitter must be configured to use N-parallel encoders, where N is the number of branch rate 1/2 encoders for each of the I and Q channels.
   N = channel data rate in bps/1x10^7, where N is rounded to the next higher integer if N is not an integer.

data source represents each of the I and Q channel sources separately for independent data conditioning operations. Figure B-10 describes the convolutional encoders supported by the SN.

e. Unbalanced Power Dual Data Sources. The I and Q channel consist of independent data that is independently formatted, convolutionally coded (if applicable), and symbol interleaved (if applicable). The signal is transmitted using unbalanced (I/Q power ratio is 4:1) QPSK or SQPSK modulation. Table B-7 lists the service configuration constraints, where the source data rate constraints apply to each channel separately. The data conditioning operations supported are shown in Figure B-8 for this configuration, where the channel data source represents each of the I and Q channel sources separately for independent data conditioning operations. Figure B-10 describes the convolutional encoders supported by the SN.

Table B-6. Data Configuration Constraints for DG2, BPSK

Coding (note 5)	Data Format	Source Data Rate Restrictions and Availability			
		MA	SMA	SSA	KuSA and KaSA
Rate 1/2	NRZ	NA	1 kbps - 1.5 Mbps (note 1)	1 kbps - 3 Mbps (note 1)	1 kbps - 75 Mbps (notes 4, 6)
	NRZ with Biϕ symbols	NA	1 kbps - 0.75 Mbps (notes 1, 2)	1 kbps - 1.5 Mbps (notes 1,2)	1 kbps - 5 Mbps
Uncoded	Biϕ	NA	Note 3	Note 3	1 kbps - 5 Mbps
	NRZ	NA	Note 3	Note 3	1 kbps - 150 Mbps (note 4)
Rate 1/3	NRZ	NA	1 kbps - 1 Mbps (note 1)	1 kbps - 2 Mbps (note 1)	NA
	NRZ with Biϕ symbols	NA	1 kbps - 0.5 Mbps (notes 1, 2)	1 kbps - 1 Mbps (notes 1,2)	NA

Notes: NA: Not Available

1. Periodic convolutional interleaving (PCI) recommended on SMA and SSA return service for baud rates > 300 kbps. When interleaving is not employed for baud rates > 300 kbps, SSA and SMA performance may not be guaranteed.
2. Biϕ symbol formats are not allowed with PCI.
3. The SN is capable of supporting SMA and SSA uncoded return link signals; however, its use will be constrained and must be coordinated with the GSFC MSP.
4. Higher KaSA return link data rates may be possible when the ground terminal is modified to receive 650 MHz bandwidth. A Ka-band IF service capable of supporting the 650 MHz bandwidth is currently under development. Please contact the GSFC MSP for further information.
5. Figure B-10 describes the convolutional encoders supported by the SN.
6. For a channel with rate 1/2 coding and data rates greater than 10 Mbps, the customer transmitter must be configured to use an N-parallel encoder, where N is the number of branch rate 1/2 encoders for the channel.
   N = channel data rate in bps/1x10^7, where N is rounded to the next higher integer if N is not an integer.

B.3.3.2 DG2 I-Q Channel Ambiguity

For the DG2 single data source SQPSK configurations (i.e., alternate I/Q data bit and alternate I/Q encoded symbols), I-Q channel ambiguity is resolved by the stagger between the I and Q channels.

For a DG2 single data source BPSK configuration, I-Q channel ambiguity does not exist because there is no quadrature component of the customer platform transmitted carrier signal.

Table B-7. Data Configuration Constraints for DG2, Dual Data Sources (QPSK, SQPSK)

Coding (note 7)	Data Format	Source Data Rate Restrictions and Availability (notes 5, 6) (data rates are for each channel separately)			
		MA	SMA	SSA	KuSA and KaSA
Rate 1/2 (Either Channel)	NRZ	NA	1 kbps - 1.5 Mbps (note 1)	1 kbps - 3 Mbps (note 1)	1 kbps - 75 Mbps (notes 4, 6)
	NRZ with Biϕ symbols	NA	1 kbps - 0.75 Mbps (notes 1, 2)	1 kbps - 1.5 Mbps (notes 1, 2)	1 kbps - 5 Mbps
Rate 1/3 (Either Channel)	NRZ	NA	1 kbps - 1 Mbps (note 1)	1 kbps - 2 Mbps (note 1)	NA
	NRZ with Biϕ symbols	NA	1 kbps - 0.5 Mbps (notes 1, 2)	1 kbps - 1 Mbps (notes 1,2)	NA
Uncoded (Either Channel)	NRZ	NA	Note 3	Note 3	1 kbps - 150 Mbps (note 4)
	Biϕ	NA	Note 3	Note 3	1 kbps - 5 Mbps

Notes: NA: Not Available

1. Periodic convolutional interleaving (PCI) recommended on SMA and SSA return service for baud rates > 300 kbps. When interleaving is not employed for baud rates > 300 kbps, SSA and SMA performance may not be guaranteed.
2. Biϕ symbol formats are not allowed with PCI.
3. The SN is capable of supporting SMA and SSA uncoded return link signals; however, its use will be constrained and must be coordinated with the GSFC MSP.
4. Higher KaSA return link data rates may be possible when the ground terminal is modified to receive 650 MHz bandwidth. A Ka-band IF service capable of supporting the 650 MHz bandwidth is currently under development. Please contact the GSFC MSP for further information.
5. For DG2 dual sources with identical symbol rates that are NRZ formatted on the I and Q channels, the I and Q channels must be offset relative to one another by one half symbol period (i.e., SQPSK modulation). Additionally, for DG2 dual sources that use biphase symbol formatting on either channel and the baud rate of the two channels are identical, SQPSK modulation is used and the transitions of one channel occur at the mid-point of adjacent transitions of the other channel.
6. For unbalanced QPSK, the I channel must contain the higher data rate and when the data rate on the I channel exceeds 70 percent of the maximum allowable data rate, the Q channel data rate must not exceed 40 percent of the maximum allowable data rate on that Q channel.
7. Figure B-10 describes the convolutional encoders supported by the SN.
8. For a channel with rate 1/2 coding and data rates greater than 10 Mbps, the customer transmitter must be configured to use N-parallel encoder, where N is the number of branch rate 1/2 encoders for the channel.
   N = channel data rate in bps/$1x10^7$, where N is rounded to the next higher integer if N is not an integer.

For the DG2 dual data source QPSK configuration, the WSC can resolve the I-Q channel ambiguity if at least one of the following conditions are met:

a. I/Q power ratio is 4:1.

b. One data channel is coded, the other channel is uncoded.

c. One channel is rate-1/3 coded and the other channel is rate-1/2 coded (SMA and SSA operation only).

d. One channel symbol rate differs by more than 25 percent from the other channel symbol rate and from a harmonic of that symbol rate.

For the DG2 dual data source SQPSK configuration, I-Q channel ambiguity is resolved when the I:Q power is 4:1. For this configuration with an I:Q power of 1:1, the I-Q ambiguity will exist at the WSC/SN data interface and it is the customer's responsibility to resolve this ambiguity.

B.3.3.3 DG2 Data Polarity Ambiguity

For NRZ-M, NRZ-S, Biphase-M, or Biphase-S customer data formats, the WSC resolves the data polarity ambiguity by differentially decoding the return service data to NRZ-L. For NRZ-L or Biphase-L customer data formats, data polarity ambiguity will exist at the WSC/SN data interface and it is the customer's responsibility to utilize other techniques, such as frame synchronization to an a priori data (sync) word or its complement, to resolve the data polarity ambiguity.

For a DG2 single data channel configuration with alternate I/Q encoded symbols (Rate 1/2), the Viterbi decoder in the WSC resolves the carrier phase ambiguity and provides a single output data signal. For a single data channel configuration with alternate I/Q data bits, convolutionally coded or uncoded, and independent differential encoding on the I and Q channel symbols, the independent differential decoding of the symbols received on the I and Q channel in the WSC prior to multiplexing of these data signals into a single data channel signal resolves the data polarity ambiguity.

NOTE

The DG2 single data channel configuration with alternate I/Q data bits requires that the I and Q channels be differentially encoded to either NRZ-M or NRZ-S in order to recover the single data source as well as resolve data polarity ambiguity. Without differential encoding, the single data source may have the alternate bits inverted.

Appendix C. Operational Aspects Of Signal And Autotrack Acquisition

C.1 General

C.1.1

This Appendix details the operational aspects associated with acquisition. A detailed description of both customer and TDRSS operations during acquisition is presented.

NOTE

> "Customer" is used in this Appendix as the general term. "Customer platform" or "customer MOC" is used where specificity is required.

C.1.2

The intent is to provide an understanding of the many processes that occur during acquisition. This will then indicate the operations which must be performed by the customer MOC and/or customer platform to acquire the scheduled TDRSS services.

C.1.3

Up to five distinct acquisition processes may be required by the combination of the customer MOC, the TDRSS, and the customer platform in acquiring a forward or return service signal. These are as follows:

a. Antenna acquisition
    1. Open-loop antenna pointing (MA, SSA, SSA cross-support, KuSA with autotrack inhibited, KaSA with autotrack inhibited).
    2. Autotracking (KuSA and KaSA).

b. PN code acquisition.

c. Carrier acquisition.

d. Symbol synchronization.

e. Deinterleaver (applicable only to certain SMA and SSA return service signals) and Viterbi decoder synchronization.

NOTE

> Not all of the above functions are required of every service or data group or mode. The detailed acquisition sequences to be presented discuss how and when these operations are accomplished in establishing the appropriate forward and/or return service.

C.1.4

Paragraph C.2 highlights the various parameters that impact the acquisition event sequence and/or the time to acquire (T_{acq}). Using a detailed timeline, paragraph C.3 describes the event sequence associated with acquisition. Paragraph C.4 concludes by addressing various issues related to reacquisition.

C.2 Key Parameters which Impact Acquisition Sequences and Times

C.2.1 Customer MOC Controllable Parameters

C.2.1.1 General

Table C-1 summarizes the parameters which impact acquisition and which the customer MOC can either schedule prior to (refer to paragraph 10.2) or initiate during (refer to paragraph 10.3) the scheduled service support period. The parameters are described in more detail in Sections 5 (MA), 6 (SSA), 7 (KuSA), and 8 (KaSA). Paragraphs C.2.1.2 through C.2.1.5 expand on certain aspects of these parameters.

C.2.1.2 Doppler Compensation

To aid in customer platform acquisition of both the forward service command and range channel PN codes and the forward service carrier, Doppler compensation should be scheduled. If Doppler compensation is not scheduled, the WSC will transmit the carrier frequency and the derived PN code chip rate as specified in the SHO. This fixed frequency forward service transmission may not allow acquisition and, therefore, it is recommended that the customer MOC schedule Doppler compensation at all times so that the forward service PN code clocks and the carrier are continuously compensated to account for changing customer platform dynamics. The MOC may choose to disable Doppler compensation during tracking services; however, valid tracking service data is available with or without Doppler compensation enabled.

C.2.1.3 Start of Forward Service Data

It is recommended that the customer MOC not initiate forward service data transmission to the NISN data transport system until sufficient time has elapsed after the scheduled service support period start time for the customer platform to have acquired the

Table C-1. Customer MOC Controllable Parameters Which Impact Acquisition

Parameter	Initiated or Scheduled by	Customer Services Affected	Impact on T_{acq}	Impact on Acquisition Sequence	Comments
Doppler Compensation	Customer MOC	All forward services	Decreased T_{acq}	None	Recommended. Not required if customer platform has capability to resolve Doppler by onboard processing.
Predicted Local Oscillator (LO) Frequency (f_o) (in SHO or reconfiguration OPM [Class 3])	Customer MOC	All forward services or noncoherent return services	Acquisition cannot be achieved unless the uncertainty of the predicted frequency and the unresolved Doppler are within the acquisition bandwidth of the receiver	Subsequent steps cannot be achieved	Crucial in establishing forward service and noncoherent return service OPM allows f_o reconfiguration if SHO f_o is outside of both the acquisition bandwidth of the receiver and the forward frequency sweep range (forward services) or the expanded frequency uncertatinty range (non-coherent) return service.
Forward Service Frequency Sweep	Customer MOC	All forward services	Increased T_{acq}	Sweep is scheduled and implemented	Employed when the customer MOC cannot define f_o accurately Independent of Doppler compensation
Expanded Frequency Uncertainty	Customer MOC	Return service non-coherent operation: DG1 mode 2 DG2 (noncoherent)	Increased T_{acq}	None	Employed when the customer MOC cannot define f_o accurately

Table C-1. Customer MOC Controllable Parameters Which Impact Acquisition (Cont'd)

Parameter	Initiated or Scheduled by	Customer Services Affected	Impact on T_{acq}	Impact on Acquisition Sequence	Comments
Start of Service	Customer MOC/DSMC	All forward and/or return services	Enhances T_{acq}	None	Scheduling to minimize impact of customer platform LO frequency uncertainties
Start of Forward Service Data (relative to start of forward service)	Customer MOC	All forward services	Enhances T_{acq}	Customer MOC initially sends no data until PN codes and carrier are acquired by customer platform	Enhances forward service T_{acq} and helps prevent false carrier lock by customer platform
Start of Return Signal Transmission (relative to start of return service)	Customer MOC/DSMC	All return services	Enhances T_{acq}	Customer platform transmits coherent carrier and PN codes prior to scheduled start of return service	Minimizes WSC PN code (if applicable) and carrier acquisition times For coherent operations, customer should allow time for forward service acquisition before starting return service. Typically start of return service equals start of forward service plus 30 seconds.
Start of Return Service Data (relative to start to return service)	Customer MOC	All return services	Enhances T_{acq}	Customer platform may initially transmit data preamble (pseudo-random bits recommended)	May prevent a potential WSC false lock condition and minimize WSC loss of data during acquisition
TDRS High Power Mode	Customer MOC	SSA and KuSA forward services	Decreases T_{acq} with power mode	None	

forward service PN codes (command and range channels) and the carrier, or until forward service lock is verified by return service data. This procedure will enhance the forward service T_{acq} and help to prevent false carrier lock. The specific acquisition events outlined in paragraph C.3 assume that commands are not sent by the customer MOC to its customer platform unless their receipt and/or implementation by that customer platform can be confirmed by the customer MOC via telemetry. For coherent turnaround services (i.e., return services using DG1 modes 1 or 3 or DG2 [coherent operations]), this implies that the start of forward service data transmission (by the customer MOC to the NISN data transport system) should not start until the return service acquisition process is complete.

C.2.1.4 Start of Return Service (Relative to the Start of the Corresponding Forward Service)

The start time of the scheduled return service support period, T_R, initiates the WSC return service acquisition sequence. For a customer platform in a coherent turnaround mode of operation, it is recommended that the forward service start time precede the return service start time by sufficient time to allow the customer platform acquire the forward service and provide the coherent return signal. Typically, the forward service start time precedes the return service start time by 30 seconds for coherent services.

C.2.1.5 Start of Return Service Data Transmission

a. The customer platform should be scheduled/commanded to initiate return service data transmission of desired customer platform data only after the WSC has completed all of its signal acquisition processes. This procedure helps prevent loss of desired customer platform data during this segment of the WSC acquisition process.

b. After WSC PN code and carrier lock has occurred, the next WSC processes involve symbol synchronizers, and (where applicable) Viterbi decoders and a deinterleaver. The number of symbols which must be processed by each of these devices for each to achieve lock depends on the P_{rec} and the symbol transition density of the individual customer spacecraft data channel. To avoid loss of data during these processes, it is advisable for the customer platform to transmit a preamble (e.g., a sequence of psuedo-random bits) before "real" data is sent. This may also reduce the synchronization time of this part of the return service acquisition process due to the high (50 percent) symbol transition density of such a preamble sequence.

C.2.2 Other Key Parameters

Table C-2 summarizes other key parameters which can impact the acquisition process, but which are a result of basic customer platform design decisions (e.g., G/T, EIRP) or are constrained by TDRSS characteristics.

Table C-2. Additional Items and Parameters Which Impact Acquisition

Item	Customer Services Affected	Impact on T_{acq}	Impact on Acquisition Sequence
Customer Platform Receive G/T	All forward services	T_{acq} varies inversely with customer spacecraft G/T	None
Customer Platform EIRP	All return services	T_{acq} varies inversely with customer Platform EIRP	None
KuSA Return Service Start-up for High Power Customer Platform	KuSA return service for P_{rec} values >-159.2 dBW	May increase T_{acq}	Acquisition process must limit instantaneous rate of change of P_{rec} $\leq$10 dB/sec

C.3 Acquisition Events

C.3.1

This paragraph presents a detailed description of both customer's and TDRSS operations during acquisition. Included are an acquisition timeline and table which are intended to present an accurate description of the many processes which must occur to establish service. Due to the large number of TDRSS services, only a normal support configuration has been included.

C.3.2

Table C-3 provides a step-by-step account from the customers point of view of the key events which must occur in establishing various services. The table assumes the TDRSS return service autotrack mode is enabled. If this mode is disabled, the table assumes that the customer platform orbital parameters, available to the TDRSS/WSC, are sufficiently accurate that program-track pointing of the TDRS SA antenna will provide the customer with satisfactory TDRSS KuSA/KaSA return service performance.

Wherever possible, specific T_{acq} values have been included to provide an estimate for the amount of acquisition overhead to be expected during scheduled service. However, these T_{acq} values are only estimates or predictions and should not be regarded as operational specifications.

Table C-3. Acquisition Events for TDRSS Services (Normal Forward and Return)

Event	Time	Equipment Status		Remarks
		Customer Platform	TDRS/WSC	
Service parameters defined by customer MOC	Up to 21 days prior to T_F or T_R depending on start time of first service, but at least T_F - 10 min or T_R –10 min depending on start time of first service	Not applicable	Not applicable	T_F is the scheduled start of forward service. T_R is the scheduled start of return service. For coherent services T_F must occur simultaneously with T_R or before $T_{R,}$ i.e., $T_R = T_F + \Delta$, $\Delta \geq 0$ (typically Δ=30 sec for coherent services). For non-coherent services, T_F and T_R are independent. Refer to paragraph C.2.1 for customer MOC controllable parameters applicable to acquisition.
TDRS and WSC configures for services	T_F-5 min to T_F, T_R-5 min to T_R [SA], or T_F-15 sec to T_F[MA]	Idle	TDRS SA antenna slewed towards platform under WSC control; WSC GCE initialized; TDRS configured	Up to 5 min required for slewing TDRS SA antenna; WSC commands TDRS configuration as required by SHO frequency, pin diodes, MA phase shifters, etc.
WSC performs pre-service testing if applicable	T_F - 3 min to T_F - 15 sec and T_R - 3 min to T_R - 15 sec	Not applicable	WSC performs pre-service testing	

Table C-3. Acquisition Events for TDRSS Services (Normal Forward and Return) (Cont'd)

Event	Time	Equipment Status		Remarks
		Customer Platform	TDRS/WSC	
Customer platform configured for forward service (note 1)	T_F - ε	Receiver configured; receiving antenna open-loop pointed toward TDRS; forward signal acquisition process enabled; autotrack process enabled (if applicable).	Continuing as above	Customer platform configured ε units of time prior to scheduled service start time (or prior to end of previous service support period); SHO must define customer platform receiver frequency to within ±700 Hz for S-band, and within ±5 kHz for Ku-band, and ±6 kHz (Ka-band).
Forward service begins	T_F	Continuing as above	WSC GCE activated; WSC transmits forward service signal	Recommended that customer MOC not transmit forward service data until sufficient time has elapsed for customer platform acquisition of command channel PN code, carrier, and range channel PN code, or until return service data stream, if available, indicates customer platform receiver carrier lock; recommended that Doppler compensation (carrier, PN code clocks) be scheduled during forward service signal acquisition (not automatic, must be in SHO). No command channel PN code modulation for forward service data rates >300 kbps.

Table C-3. Acquisition Events for TDRSS Services (Normal Forward and Return) (Cont'd)

Event	Time	Equipment Status		Remarks
		Customer Platform	TDRS/WSC	
Customer platform receives forward service signal	$T_1 = T_F + \tau_d$	Command channel PN code acquisition process starts; carrier acquisition process enabled. Autotrack acquisition process starts for Ku-band or Ka-band customers with autotrack enabled.	Continuing as above	τ_d reflects estimated propagation delay (approximately 240 msec): WSC $\rightarrow$TDRS$\rightarrow$customer platform For Ku-band and Ka-band customer platform and $T_R = T_F$, the customer platform autotrack process after T_R shall be at a rate which results in a instantaneous rate of change of $P_{rec} \leq 10$ dB/sec; customer platform autotrack of forward service signal not necessary if customer platform antenna can be open-loop pointed with sufficient accuracy to meet KuSA or KaSA forward and return service requirements
Command channel PN code acquired	$T_2 = T_1 + \tau_{cmd}$	Command channel PN code despreader synchronized; carrier acquisition process starts	Continuing as above	$\tau_{cmd} \leq 20$ sec (example value for NASA 4th generation transponder); τ_{cmd} represents the time required for the customer receiver to acquire the command channel PN code. Command channel is PN modulated only if data rate $\leq$ 300 kbps.

Table C-3. Acquisition Events for TDRSS Services (Normal Forward and Return) (Cont'd)

Event	Time	Equipment Status		Remarks
		Customer Platform	TDRS/WSC	
Carrier acquired	$T_3 = T_2 + \tau_{car}$	Carrier tracking loop locked; range channel PN code acquisition process enabled; command channel symbol synchronizer process enabled	Continuing as above	$\tau_{car} \leq 5$ sec (example value for NASA 4th generation transponder); τ_{car} represents the time required for the customer receiver to acquire the carrier
Range channel PN code acquired; coherent turnaround return service signal transmitted	$T_4 = T_3 + \tau_{rng} + \tau_m$	Range channel PN code despreader synchronized; return service carrier locked to forward service carrier; return service PN code generator locked (clock rate and PN code epoch) to range channel PN code	Continuing as above	$\tau_{rng} \leq 10$ sec (example value for NASA 4th generation transponder); $\tau_m \leq 1$ sec; τ_{rng} represents the time required for the customer receiver to acquire the range channel. τ_m represents the time required for the customer transponder to transition from noncoherent to coherent mode; a data preamble sequence may be desirable on each customer platform data channel during WSC return service signal acquisition to prevent real data (i.e., telemetry, scientific) loss and to aid in WSC symbol synchronization and Viterbi decoder acquisition (refer to paragraph C.2.1)
Customer platform autotrack acquisition complete, high accuracy tracking begins (if applicable and enabled)	$T_5 = T_1 + \tau_{auto}$	Autotrack locked; symbol synchronizer acquisition in progress; onboard computer searching for frame synch word in forward service data stream normal operation	Continuing as above	Autotrack acquisition may be complete before forward service signal is fully acquired or vice versa

Table C-3. Acquisition Events for TDRSS Services (Normal Forward and Return) (Cont'd)

Event	**Time**	**Equipment Status**		**Remarks**
		Customer Platform	**TDRS/WSC**	
Customer Platform configured for return service (note 1)	T_R - ε	Transmitter configured; coherent or non coherent mode enabled; transmitting antenna open-loop pointed toward TDRS	Continuing as above	Customer platform configured ε units of time prior to scheduled service start time (or prior to end of previous service support period)
Return service begins	τ_R	Continuing as above	WSC PN code and/or carrier acquisition process starts; symbol, Viterbi decoder, and deinterleaving synchronization and autotrack acquisition process enabled (as required)	For coherent services, τ_R is the start time of return service. τ_R is equal to the maximum of T_R or $T_F + \Delta$, where Δ is approximately $2\tau_d + \tau_{cmd} + \tau_{car} + \tau_{rng} + \tau_m$ For non-coherent services τ_R is independent of the T_F start time and if the local oscillator is not within the required values of ± 700 Hz (S-band), ± 5 kHz (Ku-band), ± 6 kHz (Ka-band), then OPM 07 (Expanded User Frequency Uncertainty Request) must be sent after T_R; A data preamble sequence may be desirable on each customer platform data channel during WSC return service signal acquisition to prevent real (i.e., telemetry, science) data loss and to aid in WSC symbol synchronization and decoder acquisition.

Table C-3. Acquisition Events for TDRSS Services (Normal Forward and Return) (Cont'd)

Event	Time	Equipment Status		Remarks
		Customer Platform	**TDRS/WSC**	
PN code (DG1 only) and carrier acquired	$T_5 = \tau_R + \tau_{acq}$	Continuing as above	PN code despreader and carrier acquired; symbol synchronizer and Viterbi decoder processes start	For coherent service, $\tau_{acq} \leq 1$ sec For non-coherent service, $\tau_{acq} \leq 1$ sec if customer platform transmitter frequency uncertainty is ≤ ± 700 Hz (S-band), ± 5 kHz (Ku-band), ± 6 kHz (Ka-band) and $\tau_{acq} \leq 3$ sec if customer platform transmitter frequency uncertainty is ± 3 kHz (S-band), ± 35 kHz (S-band), ± 20 kHz (Ku-band), ± 21 kHz (Ka-band)
Symbol and Viterbi decoder Synchronizers acquired; return service(s) established	$T_7 = T_5 + \tau_{syn}$	Continuing as above	Symbol and Viterbi decoder, and deinterleaver synchronizers (if applicable) locked	τ_{syn} (seconds) ≤ 1100 / (channel data rate in bps) for biphase symbols; τ_{syn} (seconds) ≤ 6500 / (channel data rate in bps) for NRZ symbols; For dual data channels, symbol and decoder synchronization must be achieved on each channel For DG2 services requiring channel ambiguity resolution by WSC, additional time is required for WSC to resolve the ambiguity.

Table C-3. Acquisition Events for TDRSS Services (Normal Forward and Return) (Cont'd)

Event	Time	Equipment Status		Remarks
		Customer Platform	TDRS/WSC	
TDRSS autotrack acquisition complete, high accuracy tracking begins; return service(s) established; return service channel data stream(s) transferred from WSC to NISN	$T_8 = \tau_R + \tau_{tauto}$	Continuing as above	Autotrack (if enabled) locked. Return service(s) established here	Signal acquisition will be completed before TDRSS autotrack (if enabled) acquisition is completed $\tau_{tauto} \leq 10$
Customer MOC receives return service data stream(s), begins forward service data transmission (e.g., preamble followed by commands)	$T_9 = T_8 + \tau_{has}$	Continuing as above	Normal operation	For τ_{has}; this acquisition sequence assumes that forward service data is sent by the customer MOC only after the return service acquisition is confirmed by the customer MOC via return service data (i.e., no forward return service data until successful return service acquisition); typical preamble consists of 128-bit alternating sequence followed by frame synchronization word to enable customer platform command processing

Table C-3. Acquisition Events for TDRSS Services (Normal Forward and Return) (Cont'd)

Event	Time	Equipment Status		Remarks
		Customer Platform	TDRS/WSC	
Forward service symbol synchronization achieved and frame synch word identified; forward service established; customer platform begins forward service data processing	$T_{10} = T_9 + \tau_{bit}$	Symbol synchronizer locked and frame synch word recognized; command processing enabled	Continuing as above	τ_{bit} is approximately 128 bit times (i.e., 128 bits after customer platform receives data modulated forward service signal

Note:

1. This can be achieved at the end of the previous forward service support period or by stored on-board commands. If coherent return service operations are scheduled later in this same service support period, the transponder can be set to permit automatic transition to coherent turnaround mode at, or prior to, the scheduled start of the coherent return service operations. This can also be achieved either via stored on-board commands or via commands imbedded in the forward service data once the forward service is established.

C.4 Reacquisition

C.4.1 Introduction

C.4.1.1

Once a service has been established, there are a number of conditions or events that can cause the service to be degraded or to be interrupted, in which case the service may need to be reestablished. Reacquisition refers to that part of reestablishing service which includes the following:

a. Reinitiating the customer platform initial acquisition process if it is a forward service reacquisition; recalculating new settings for the current circumstances and initializing acquisition circuits if it is a return service.

b. Executing the acquisition events (refer to paragraph C.3) as indicated for initial acquisition.

C.4.1.2

Reacquisition may also be required whenever there is a failure to establish service initially. In some cases of service interruption, additional WSC processing may be needed prior to initiation of the reacquisition process. This may include the need for the WSC to reconfigure the GCE and/or the TDRS and to calculate and implement new setup values. These two operations are referred to as TDRSS hardware reconfiguration and software resetup.

C.4.1.3

The events or conditions that initially trigger the need for a reacquisition may be categorized as arising from the customer MOC/DSMC or from the TDRSS as follows:

a. Customer MOC/DSMC Initiates Reacquisition. This may result indirectly from a customer MOC request to the DSMC to reconfigure a service parameter (resulting in a reconfiguration OPM [Class 03] from the DSMC to the WSC) or as a result of the customer MOC/DSMC directly requesting reacquisition via an OPM [Class 02].

b. TDRSS Initiates Reacquisition. Conditions that may cause the WSC to initiate reacquisition include a loss of carrier lock, service alarms, and hardware or software failures. Detailed and precise scenarios in this regard are beyond the scope of the current discussion. However, some general concepts are presented in paragraphs C.4.2 and C.4.3 to provide some additional insight into the reacquisition process.

C.4.1.4

The primary focus here will be on reacquisition initiated by the customer MOC/DSMC.

C.4.2 Customer MOC/DSMC Initiated Reacquisition

C.4.2.1

Table C-4 and Table C-5 summarize the parameters controlled by the customer MOC which may lead to service interruption for the forward and return services, respectively. The tables indicate the consequence of requesting each parameter in regard to both reacquisition and TDRSS reconfiguration.

C.4.2.2

As indicated in Table C-4 and Table C-5, the customer MOC may request, via the DSMC, a service reacquisition. Normally this request is initiated only after the customer MOC detects a problem and only if no TDRSS problems exist as indicated in the information conveyed from the WSC to the DSMC via an ODM[1]. In this case, the customer MOC may instead choose to simply terminate service or to change some operating condition or parameter as cited in paragraph C.4.1.

C.4.2.3

As seen in the tables, the customer MOC has the option to select forward and return service reacquisitions independently. However, for coherent turnaround operation, a forward service reacquisition will lead to a return service interruption and the WSC will automatically initiate return reacquisition after forward reacquisition. For noncoherent operation, forward and return service reacquisitions are independent so that the corresponding customer MOC-initiated reacquisition requests may also be invoked independently.

C.4.2.4

Figure C-1 and Figure C-2 provide an overview of some of the key elements that lead to the requirement for reacquisition of the forward and return service signals, respectively. Also included is some of the logic associated with the WSC regarding reacquisition. Normally, the customer MOC will detect a service fault whenever problems are detected by the WSC (refer to paragraph C.4.3). In this case, the WSC may automatically take the appropriate action, thereby perhaps alleviating the need for the customer MOC to request reacquisition.

C.4.2.5

The WSC monitors and reports on numerous elements of the WSC GCE and the TDRS, including performance data (such as loss of lock conditions) and equipment status (such as hardware faults). In addition, in some cases, the WSC automatically initiates reacquisition of the appropriate service. Consequently, with reference to the customer

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1 Transmission of ODMs from the DSMC to the customer MOC must be requested (in advance) by the customer MOC. They are not automatically transmitted to the customer MOC by the DSMC.

Table C-4. Parameters Which Impact Forward Service

Parameter or Operating Condition	Forward Service			Customer Platform Reacquisition Required	TDRSS Reconfiguration or Resetup Required
	MA	SSA	KuSA/ KaSA		
Forward Service Reacquisition	X	X	X	X	
Change in Customer Platform Receive Frequency	X	X	X	X	X
Doppler Compensation Inhibit (PN Codes and Carrier)	X	X	X	Note 4	Note 4
Reinitiation of Forward Service Doppler Compensation (PN Codes and Carrier)	X	X	X	Note 5	X
Forward Service Frequency Sweep (note 1)	X	X	X	X	X
Change in Customer Platform Receive Antenna Polarization		X	X	X	X
Initiation or Termination of the Command Channel PN Code		X	X	X	X
Forward Service EIRP (Normal and High Power)		X	X	Note 2	X
Change in Command Channel Data Rate	X	X	X	Note 3	X

Notes:
1. This request is normally used as an aid in customer platform acquisition of the TDRSS forward service signal.
2. Reacquisition by the customer platform of the forward service signal may or may not be required (usually depends on whether there is a loss of lock condition within the customer platform receiver as a result of the step change in received TDRSS forward service signal energy).
3. If the initial and final data rate are <300 kbps MOC only customer platform symbol resynchronization and frame synchronization search are required.
4. The WSC does not interrupt the TDRSS forward service signal if a Doppler compensation inhibit request OPM (Class 11) is used.
5. The WSC will minimize service interruptions due to Customer Reconfiguration OPMs. Customer platform reacquisition may be required.

Table C-5. Parameters Which Impact Return Service

Parameter or Operating Condition	Return Service			WSC Reconfiguration and Reacquisition Required
	MA	SSA	KuSA/KaSA	
Return Service Reacquisition	X	X	X	X
Expanded Customer Platform Frequency Uncertainty (note 1)	X	X	X	X
Change in I and/or Q Channel Data Rate	X	X	X	X
Change in Customer Platform Transmit Frequency	X	X	X	X
Redefinition of Maximum or Minimum Customer Platform EIRP	X	X	X	X
Change in I/Q (Power)	X	X	X	X
Change the I and/or Q Channel Data Bit Jitter	X	X	X	X
Change in DG1 Mode (1,2,3)	X	X	X (note 2)	X
Change in I and/or Q Channel Data Format	X	X	X	X
Change in Customer Platform Antenna Polarization		X	X	X
Change Between DG1 and DG2		X	X (note 2)	X
Change in DG2 Type (coherent/noncoherent)		X	X (note 2)	X
G_2 Inversion (I and/or Q Channel)	X	X	X	X

Notes:
1. This request is normally used as an aid in acquisition.
2. Not valid for KaSA service.

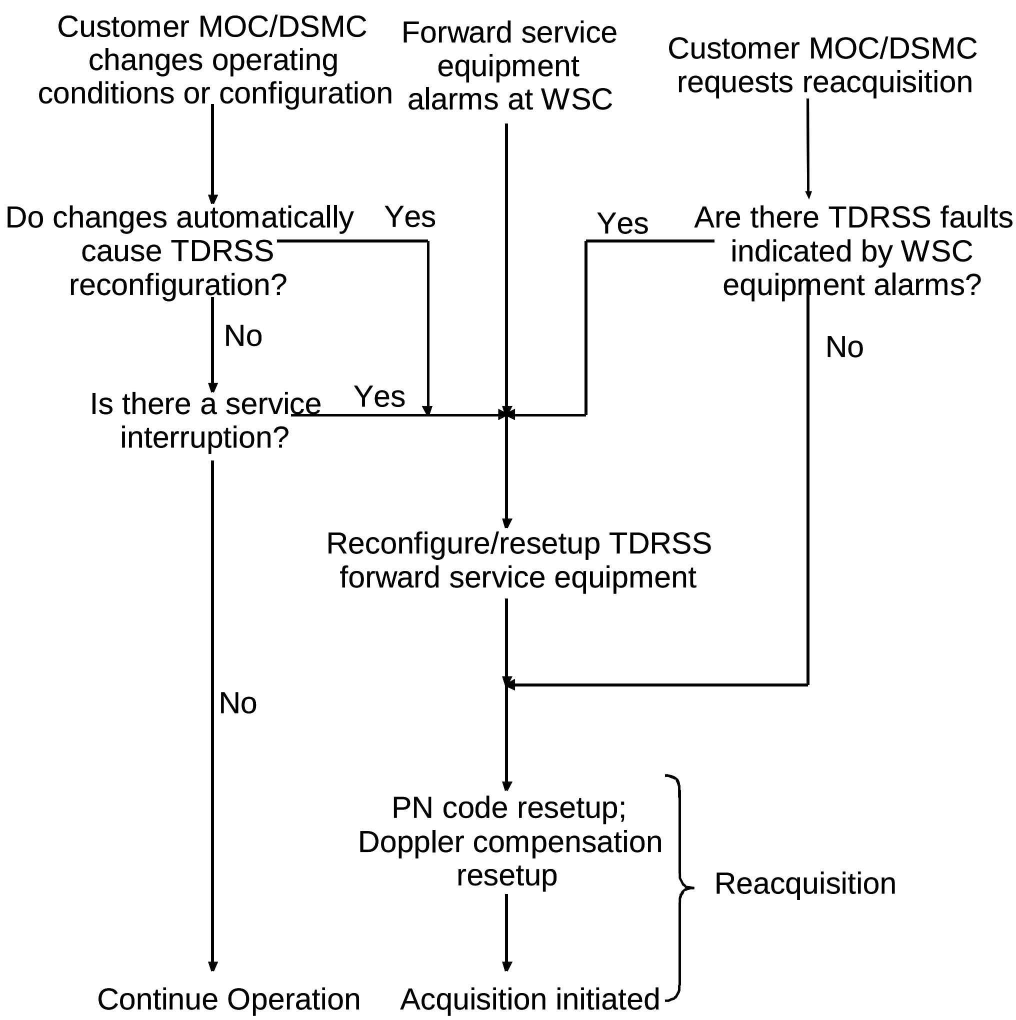


Figure C-1. Reacquisition Initiation Logic: Forward Service

MOC, acquisition contingencies need be developed primarily for those situations in which the WSC does not initiate reacquisition. Furthermore, these contingency procedures essentially consist of only those parameters listed in Table C-4 and Table C-5. The events which lead to customer MOC-initiated contingencies fall into four general classifications. These and possible customer MOC responses are as follows:

a. Initial acquisition not achieved (forward service).

   1. Forward service reacquisition.

   2. Forward service frequency sweep.

   3. TDRS high power mode.

   4. Reconfiguration of forward service parameters (refer to Table C-4).

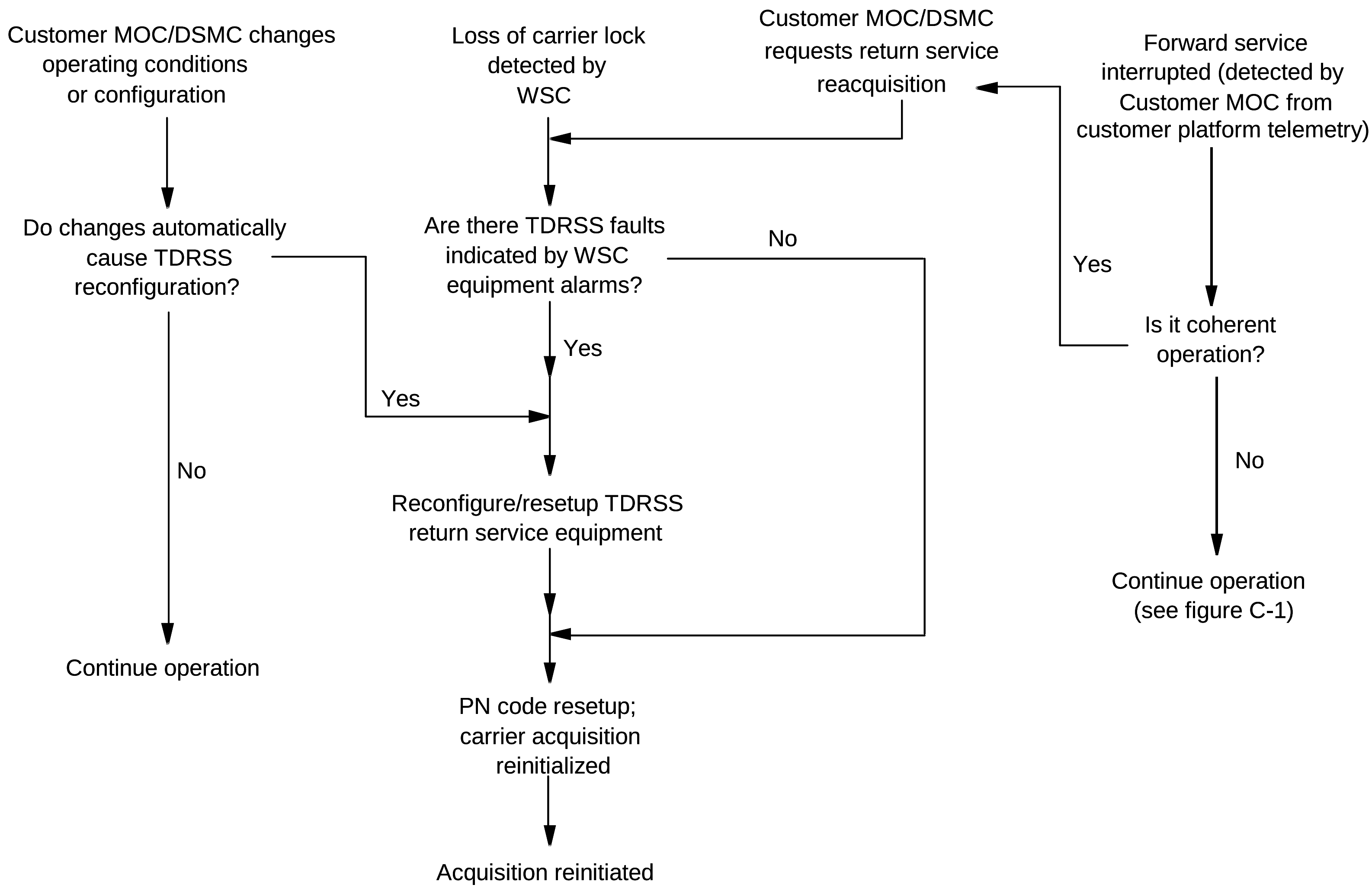


Figure C-2. Reacquisition Initiation Logic: Return Service

b. Initial acquisition not achieved (return service).

   1. Return service reacquisition.

   2. Expanded frequency uncertainty.

   3. Reconfiguration of forward and/or return service parameters (refer to Table C-4 and Table C-5).

NOTE

If in coherent turnaround operations, forward service reacquisition may be advised.

c. Loss or degradation of forward service.

   1. Forward service reacquisition.

   2. Reconfiguration of forward service parameters.

   3. Terminate forward service.

d. Loss or degradation of return service.

   1. Return service reacquisition (forward service reacquisition also if coherent turnaround).

   2. Reconfiguration of forward and/or return service parameters.

   3. Terminate return service.

C.4.3 WSC Initiated Reacquisition

As indicated earlier, there are a number of conditions whereby the WSC automatically initiates reacquisition. An exhaustive accounting of all conditions that lead to a WSC-initiated reacquisition is beyond the scope of this Appendix. Upon detection of a service degradation or interruption, the customer MOC should monitor the TDRSS status as conveyed from the DSMC via an ODM. Based on this information the customer MOC can infer whether the WSC has automatically initiated reacquisition. If the WSC has automatically initiated reacquisition, the WSC will not accept any OPMs applicable to this specific customer service during this reacquisition period. Finally, the customer MOC needs to decide if a customer MOC-initiated reacquisition request to the WSC by the DSMC is necessary or desirable.

Appendix D. Spectrum Considerations

D.1 Introduction

This Appendix describes some of the applicable treaty agreements on spectrum usage relevant to space missions utilizing the Space Network. Additionally, the GSFC Spectrum Allocation and Management Site (GSAMS) http://classwww.gsfc.nasa.gov/GSAMS/ web site provides regulatory background information and technical guidance for GSFC organizations involved in licensing RF equipment. In the event of a conflict between the GSAMS website and this appendix, please contact the GSFC Spectrum Manager for clarification.

The National Telecommunications Information Agency (NTIA) Manual of Regulations & Procedures for Federal Radio Frequency Management defines the regulations and policies pertaining to United States (US) Government agency use of RF spectrum in the United States and its possessions. (This manual is hereafter referred to as the NTIA manual.) The NTIA regulations are available from the following website: http://www.ntia.doc.gov/osmhome/osmhome.html.

The International Telecommunications Union Radiocommunication Sector (ITU-R) governs the use of the RF spectrum internationally. The ITU-R regulations are contained in the Radio Regulations (RR). Selected portions of the Radio Regulations are available from the GSAMS website with a user ID and password (See the GSAMS website).

Paragraph D.2 briefly provides guidance to projects that need to initiate RF equipment licensing. Paragraph D.3 describes the PFD limits, how they are calculated, and some of the operational implications to projects. Paragraph D.4 describes the limits for unwanted emissions. Paragraph D.5 describes the standards for frequency tolerance. Paragraph D.6 describes the regulations concerning cessation of emissions. Paragraph D.7 describes the protection afforded deep space Earth stations. Paragraph D.8 describes the preferred frequencies for launch vehicles. Paragraph D.9 provides additional ITU-R recommendations applicable to space-to-space links.

D.2 RF Equipment Licensing

All US space missions, including commercial space systems, that use the TDRSS system, must register frequency usage with the NTIA and are subject to all the NTIA regulations and procedures. Non US missions should register their frequency usage with their appropriate spectrum management agencies.

Early in the mission planning cycle, NASA projects should contact the appropriate center spectrum manager to get NTIA authorization to transmit. The NASA Center Spectrum Managers are responsible for management of the RF equipment licensing process, and are the final authority on the selection of the appropriate frequencies for all

NASA RF equipment. Amongst other duties, these center managers will facilitate the licensing of RF equipment by coordinating with national and international organizations in: 1) making frequency selections, 2) evaluating RF equipment against applicable national and international RF standards, 3) performing RF analyses, and 4) completing frequency authorization applications to the NTIA.

The Goddard Procedures and Guidelines (GPG) Policy 2570 provides GSFC missions with the requirements for Radio Frequency (RF) equipment licensing in accordance with National Policy Directive NPD 2570.5.

D.3 Power Flux Density (PFD) Considerations

Conformance with PFD limits is necessary to preclude harmful interference to terrestrial systems operating in the same frequency band. PFD levels should be calculated early on (during the mission planning and system design phase) in order to determine whether or not the PFD limits would impose any system requirements or operational constraints. For instance, many missions with high gain antennas opt to delay the start of transmissions until some period of time after the TDRS comes in view over the horizon in order to satisfy the PFD limits. Additionally, mission planners are strongly urged to consider that satellite subsystems and components often exceed specifications and this can result in PFD levels being exceeded.

The applicable PFD limits for the TDRSS S-Band, Ku-band, and Ka-band links are provided in Paragraph D.3.1. Paragraph D.3.2 describes the impact of not meeting the PFD limits. Paragraph D.3.3 provides the equations used to determine PFD levels. Paragraph D.3.4 provides an example application.

D.3.1 PFD Limits

Power Flux Density limits are imposed on NASA missions by both the NTIA and the ITU. Although largely similar, there are a number of differences in the requirements, which can result in a mission meeting one requirement but not the other. The consequences of failure to meet NTIA and ITU PFD limits are outlines in paragraph D.3.2. This section is intended to allow missions to determine the NTIA and ITU requirements applicable to them.

For most Space Network users, the applicable ITU and NTIA PFD limits for the TDRSS S-Band, Ku-band, and Ka-band links are shown in Table D-1. The international PFD limits were extracted from the ITU-R Radio Regulations Article S.21, Table S21-4. The national PFD limits were extracted from NTIA manual Table 8.2.36. In both cases, the PFD limit is defined at the Earth's surface as a function of the angle of arrival above the horizontal plane, α.

Table D-1. International and National PFD Limits Applicable to TDRSS Links

TDRSS Service	Frequency Band	Reference Bandwidth	Angle of Arrival α	ITU-R RR PFD Limit (dBW/m²)	NTIA PFD Limit (dBW/m²)
SSAF MAF SSAR MAR	2025 – 2110 MHz (note 1) 2200 – 2290 MHz	4 kHz	0° to 5°	-154	-154
			5° to 25°	-154 + $\frac{\alpha - 5}{2}$	-154 + $\frac{\alpha - 5}{2}$
			25° to 90°	-144	-144
KuSAF	13.4 – 14.05 GHz	4 kHz	0° to 90°	Not Applicable	-152
KuSAR	14.6 – 15.35 GHz	4 kHz	0° to 5°	Not Applicable	-152
			5° to 25°	Not Applicable	-152 + $\frac{\alpha - 5}{2}$
			25° to 90°	Not Applicable	-142
KaSAF KaSAR	22.55 – 23.55 GHz 25.25 – 27.5 GHz	1 MHz	0° to 5°	-115	-115
			5° to 25°	-115 + $\frac{\alpha - 5}{2}$	-115 + $\frac{\alpha - 5}{2}$
			25° to 90°	-105	-105

Note:
1. Nationally, the NTIA PFD limits can be exceeded by up to 3 dB in the 2025 – 2110 MHz band.

For S-band (and Ku-band links), these requirements are given in a 4 kHz reference bandwidth. The NTIA may on a case-by-case basis permit space-to-space links to exceed the PFD limits nationally in the 2200 – 2290 MHz band. The PFD limits can in some instances be more easily met with the 1 MHz reference bandwidth given in Recommendation ITU-R SA.1273 than with the 4 kHz reference bandwidth given in the ITU RRs and NTIA manual. The PFD limits given in ITU-R SA.1273 are provided in Table D-2.

Note that in Table D-1, there are no PFD limits in the ITU-R RR for the Ku-band links. Because the ITU-R RR only considers PFD limits for space stations in those bands for which the fixed and mobile services operate on a coequal basis relative to the space services, it includes no requirements for PFD limits for the TDRS Ku-band links, which operate on a secondary allocation (see explanation below). However, PFD limits applicable for the KuSAF and KuSAR services are contained in Recommendation ITU-R S.510, which are shown in Table D-3.

Table D-2. S-Band Space-to-Space PFD Limits Given in ITU-R SA.1273

TDRSS Service	Frequency Band	Reference Bandwidth	Angle of Arrival α	PFD Limit (dBW/m^2)
SSAF MAF	2025 – 2110 MHz	1 MHz	0° to 5°	-130
			5° to 25°	$-130 + \frac{\alpha - 5}{2}$
			25° to 90°	-120
SSAR MAR	2200 – 2290 MHz	1 MHz	0° to 5°	-127
			5° to 25°	$-127 + \frac{\alpha - 5}{2}$
			25° to 90°	-117

Table D-3. Ku-Band Space Research PFD Limits Given in ITU-R S.510

TDRSS Service	Frequency Band	Reference Bandwidth	Angle of Arrival α	PFD Limit (dBW/m^2)
KuSAF KuSAR	13.4 – 14.05 GHz, 14.6 – 15.35 GHz	4 kHz	0° to 5°	-148
			5° to 25°	$-148 + \frac{\alpha - 5}{2}$
			25° to 90°	-138

A primary allocation allows a particular class of users to operate in a band with full protection. New systems cannot be introduced into that frequency band if they will result in interference to a system operating with a primary allocation. A secondary allocation allows a class of users to operate in a band with protection from others operating with a secondary allocation; however, protection is not provided from interference caused by users operating with a primary allocation.

D.3.2 Consequences of Exceeding PFD Limits

If the PFD levels do not meet the PFD limits given in the NTIA manual, the NTIA will not grant frequency authorization except as noted in paragraph D.3.1.

If the PFD levels do not meet the PFD limits given in the ITU-R RR, then the mission is subject to the conditions given in Article S4.4. Article S4.4 states "Administrations of the Member States[‡] shall not assign to a station any frequency in derogation of either the Table of Frequency Allocations in this Chapter or the other provisions of these Regulations, except on the express condition that such a station, when using such a frequency assignment, shall not cause harmful interference to, and shall not claim protection from harmful interference caused by, a station operating in accordance with the provisions of the Constitution, the Convention and these Regulations."

D.3.3 Calculation of PFD Levels

The calculation of PFD levels requires the following data for the customer platform:

a. Peak transmitter power contained in the reference bandwidth (i.e., 4 kHz or 1 MHz), measured at the antenna input. Refer to paragraph D.3.3.1.

b. Transmitting antenna gain pattern.

c. Transmitting antenna mainbeam pointing characteristics, including any intentional or unintentional antenna mispointing.

d. Orbital altitude (nominally circular orbits are assumed in this analytical approach).

The PFD at an angle of arrival "α" is calculated as shown in Equation D-1 with R(α) found using Equation D-2 and Equation D-3. The geometry is shown in Figure D-1:

Equation D-1:

$$\text{PFD}(\alpha) = 10 \log \left[\frac{G_t(\theta) P_{tB}}{4\pi R^2(\alpha)} \right]$$

where:

PFD (α) = power flux density in dBW/m^2 at the surface of the Earth for an angle of arrival "α".

$G_t(\theta)$ = platform transmitting antenna gain in the direction of the point on the Earth's surface corresponding to an angle of arrival "α". θ = 0 refers to the antenna boresight direction.

P_{tB} = peak transmitter power in Watts in the reference bandwidth (i.e., 4 kHz or 1 MHz).

R(α) = slant range in meters from the customer platform to the earth for angles of arrival "α" (R is greater than or equal to the orbital altitude, depending on "α").

Equation D-2:

$$R(\alpha) = \sqrt{r_s^{\,2} + r_e^{\,2} - 2\, r_s\, r_e \cos[\phi(\alpha)]}$$

where

Equation D-3:

$$\phi(\alpha) = 90^\circ - \alpha - \sin^{-1}\left(\frac{r_e \cos(\alpha)}{r_s}\right)$$

As shown in Equation D-1, the calculation of PFD levels requires knowledge of the transmitting antenna gain pattern. A transmitting antenna gain pattern based on measured data may not be available. In this case, the antenna pattern for Earth stations given in the ITU-R RR Appendix S8, Annex III may be used to model platform high gain antennas. If measured data is available, the gain pattern of interest is an envelope containing at least 90 percent of the sidelobe peaks, which decreases monotonically with increasing off-axis angle.

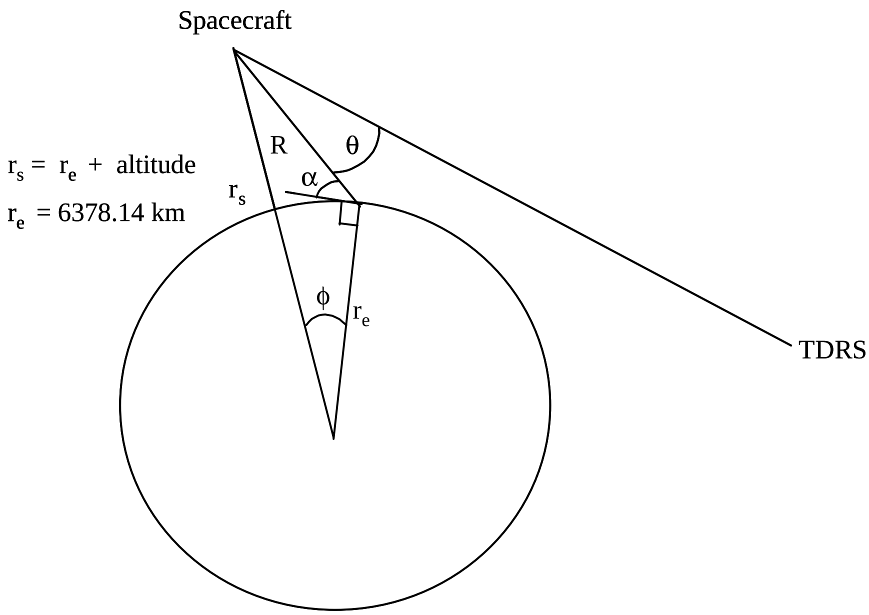


Figure D-1. Geometry for Determining PFD Conformance

Antenna pattern from ITU-R RR Appendix S8, Annex III is as follows:

a. for values of $\frac{D}{\lambda} \geq 100$ (maximum gain $\geq$ 48 dB approximately):

$$G(\theta) = G_{max} - 2.5 \times 10^{-3}\left(\frac{D}{\lambda}\theta\right)^2 \qquad \text{for } 0 < \theta < \varphi_m$$

$$G(\theta) = G_1 \qquad \text{for } \varphi_m \leq \theta < \varphi_r$$

$$G(\theta) = 32 - 25 \log \theta \qquad \text{for } \varphi_r \leq \theta < 48^\circ$$

$$G(\theta) = -10 \qquad \text{for } 48° \le \theta \le 180°$$

b. for values of $\frac{D}{\lambda} < 100$ (maximum gain < 48 dB approximately):

$$G(\theta) = G_{max} - 2.5 \times 10^{-3} \left(\frac{D}{\lambda}\theta\right)^2 \qquad \text{for } 0 < \theta < \varphi_m$$

$$G(\theta) = G_1 \qquad \text{for } \varphi_m \le \theta < 100\frac{\lambda}{D}$$

$$G(\varphi) = 52 - 10\log\frac{D}{\lambda} - 25\log\varphi \qquad \text{for } 100\frac{\lambda}{D} \le \varphi < 48°$$

$$G(\theta) = 10 - 10\log\frac{D}{\lambda} \qquad \text{for } 48° \le \theta \le 180°$$

where:

In cases where $\frac{D}{\lambda}$ is not given, it may be estimated from the expression $20\log\frac{D}{\lambda} \approx G_{max} - 7.7$, where G_{max} is the main lobe antenna gain (dB).

D: antenna diameter
λ: wavelength } expressed in the same unit

θ: off-axis angle of the antenna, in degrees

G_1: gain of the first sidelobe $= 2 + 15\log\frac{D}{\lambda}$

$$\varphi_m = \frac{20\lambda}{D}\sqrt{G_{max} - G_1} \quad \text{degrees}$$

$$\varphi_r = 15.85\left(\frac{D}{\lambda}\right)^{-0.6} \quad \text{degrees}$$

Paragraph D.3.3.1 shows how to calculate the peak transmitter power in the reference bandwidth, P_{tB}. Paragraph D.3.3.2 shows how Space-to-Space links with high gain transmitting antennas can meet PFD limits if they do not transmit when the TDRS spacecraft is just over the limb of the horizon.

D.3.3.1 Calculation of P_{tB}

The peak transmitter power in the reference bandwidth, $P_{tB,}$ depends on the number of data channels and the transmitted modulation and data formats. The standard TDRSS return links use suppressed carrier BPSK modulation, balanced or unbalanced QPSK modulation, balanced or unbalanced SQPSK modulation, or SQPN links. Channels are either in NRZ or Bi-phase format. For each channel, the transmitter Power Spectral Density (PSD) as a function of frequency offset from the carrier, f, is:

Equation D-4:

$$\text{PSD}(f) = P\,T\frac{\sin^2(x)}{x^2},\quad \textit{where } x = \pi f T \quad \textit{for NRZ and PN spread links}$$

Equation D-5:

$$\text{PSD}(f) = P\,T\frac{\sin^4(x)}{x^2},\quad \textit{where } x = \pi f T/2 \quad \textit{for Bi-phase formatted links}$$

where:

P = total power (measured in Watts) for the channel. Represents the power delivered to the transmitting antenna, taking into account transmitter-to-antenna line losses and the I/Q channel ratio, where applicable.

T = 1/R_s = channel symbol period.

R_s = symbol rate. The symbol rate includes PN spreading and convolutional encoding as appropriate, but excludes bi-phase encoding. PN spread links have a symbol rate of 3.08 Mcps. The symbol rate for a non-spread channel is equal to the data rate times the coding rate (if applicable). For instance a 256 kbps channel with rate ½ convolutional coding has a symbol rate of 512 ksps.

For signals with two channels, the total PSD(f) is found by summing the PSD(f) from both channels. The peak PSD(f) is not affected by whether or not the Q channel is delayed with respect to the I channel.

Most TDRSS links operate with a symbol rate much greater than the reference bandwidth. In this case, the PSD(f) for a given channel is seen to be relatively constant over the reference bandwidth. The resulting P_{tB} for NRZ and PN spread signals is given by Equation D-6. The resulting P_{tB} for bi-phase formatted signals is given by Equation D-7:

Equation D-6:

PtB (dBW/Bref) = 10 LOG10(P Bref /Rs)   for NRZ signals with Rs>>Bref

Equation D-7:

PtB (dBW/Bref) = 10 LOG10(P Bref /Rs) –2.8 dB for Bi-phase signals with Rs>>Bref

where:

Bref = reference bandwidth in Hz (4000 or 1000000)

D.3.3.2 Special Case: Satisfying PFD Limits for High Gain Space-to-Space Links By Ceasing Transmissions as the TDRS spacecraft is near the horizon

In many cases, the PFD limits are difficult to meet when a customer platform high gain antenna is pointed towards the Earth's horizon (i.e. when the TDRS is just entering or leaving the platform field of view.) In this case, many missions opt to delay the start of transmissions until the high gain antenna is pointed sufficiently far away from the Earth's horizon. Similarly, the missions cease transmissions a few minutes prior to the time that the TDRS is beyond the horizon. This section describes how to calculate the minimum angle between the line-of-sight (LOS) vector to TDRS and the pointing vector to the horizon that is just sufficient to ensure that the PFD limits are met for all angles of arrival, α. The geometry is shown in Figure D-2.

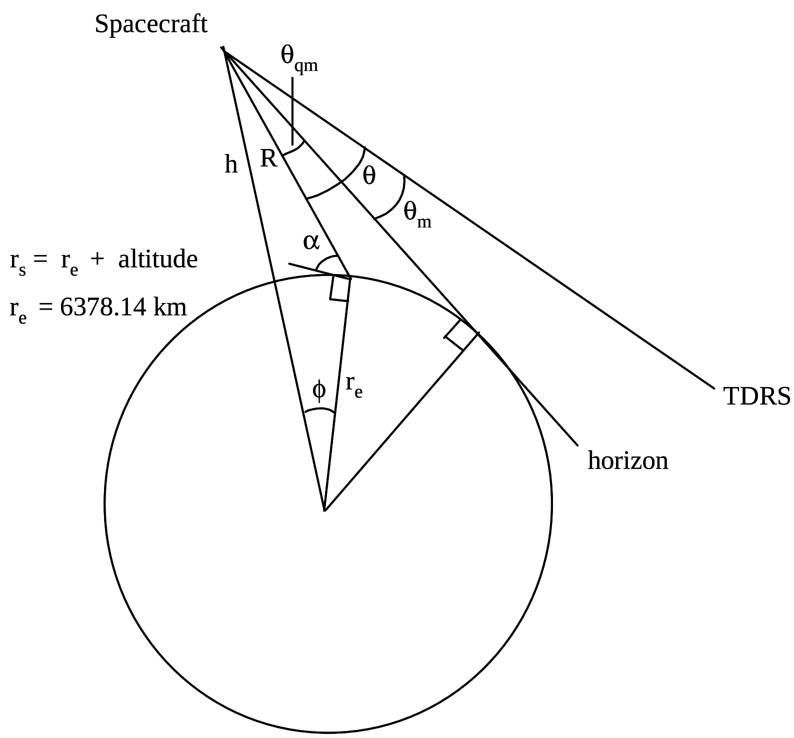


Figure D-2. Geometry for the Minimum Angle between the Pointing Vectors Towards the Horizon and the TDRS

The minimum angle between the line of sight vector to TDRS and the horizon, $\theta_{m,}$ is found at each value of α by calculating:

a. ϕ(α) and R(α) found from Equation D-2 and Equation D-3.

b. θ_{qm}(α), the angle between horizon vector and the Earth's surface for a given α, from equation Equation D-8.

Equation D-8:

$$\theta_{qm}(\alpha) = \sin^{-1}\left(\frac{r_e}{r_s}\right) - \sin^{-1}\left(\frac{r_e \cos(\alpha)}{r_s}\right)$$

c. the maximum gain at the offpointing angle, θ, which is just sufficient to ensure that the PFD limit is met. This is accomplished by setting the PFD(α) in Equation D-1 to the PFD limit at α and solving for G(θ).

d. the minimum offpointing angle, θ, that yields the G(θ) found in step C. (Use the platform transmitting antenna gain pattern, if available.)

e. θ_m by subtracting θ_{qm} from θ. (θ_m is the minimum angle between the LOS vector to TDRS and the pointing vector to the horizon that satisfies the NTIA PFD threshold at the Earth's surface for a given angle of arrival, α.)

The minimum angle between the LOS vector to TDRS and the pointing vector to the horizon needed to satisfy the PFD limits is simply the largest value of θ_m taken over all values of α. This angle is denoted as MAX[θ_m(α)].

A geometrical analysis can be used to bound the time required for a platform to travel from the point where $\theta_m = 0$ to the point where θ_m = MAX[θ_m(α)]. This bound represents a bound on the time period for which the transmission should be ceased to meet PFD limits as the platform comes around the limb of the horizon.

D.3.4 An Example Application

The minimum angle between the LOS vector to TDRS and the pointing vector to the horizon was calculated for a representative platform. The link is an uncoded 50 Mbps data stream that is BPSK/NRZ modulated onto the carrier. The peak transmitter power is 12.6 Watts. The peak transmitter power in the 4 kHz reference bandwidth is found to be –30 dBW using Equation D-4. The antenna gain was modeled with a peak gain of 46 dBi and the pattern given in Annex III to RR Appendix S8. The calculations, which are shown in Figure D-3, indicate that the minimum angle between the LOS vector to TDRS and the pointing vector to the horizon is 5.4°. A geometrical analysis indicates that with an altitude of 400 km and an inclination of 51.6°, θ_m will exceed 5.4° approximately 2.5 minutes after the TDRS is visible over the horizon.

flux = PtGt/4piR^2										
Spacecraft Altitude		400	km							
Narrowband RF Transmit Power		12.60	Watts maximum							
Narrowband RF Transmit Power		11.00	dBW max							
Carrier Symbol Rate		5.00E+07	bps x 2							
Peak PSD		-65.99	dBW/Hz							
PSD in 4 kHz Bandwidth		-29.99	dBW							
Spacecraft Cable Loss		0	dB							
					Power Flux Density at Earth's Surface					
RGT Elevation Angle	Spacecraft Look Angle	Earth Central Angle	Spacecraft Range	Spacecraft Antenna Gain	Peak Received PSD on Earth (assuming 0 dBi Antenna Gain)	PFD Limit	Margin to PFD Limit = Max Antenna Gain	Minimum Antenna Offpointing Angle Needed	Thetaqm	Minimum Antenna Offpointing
[degrees]	[degrees]	[degrees]	[km]	[dB]	[dBW/m^2/4 kHz]	[dBW/m^2/4 kHz]	[dB]			
0.00	70.22	19.78	2293.99	0	-168.17	-152.00	16.17	4.80	0.00	4.80
5.00	69.62	15.38	1804.50	0	-166.08	-152.00	14.08	6.00	0.60	5.40
10.00	67.92	12.08	1439.83	0	-164.12	-149.50	14.62	5.80	2.29	3.51
15.00	65.36	9.64	1175.45	0	-162.36	-147.00	15.36	5.40	4.86	0.54
20.00	62.16	7.84	984.18	0	-160.82	-144.50	16.32	5.00	8.06	NA
25.00	58.52	6.48	844.02	0	-159.48	-142.00	17.48	4.50	11.70	NA
30.00	54.58	5.42	739.37	0	-158.33	-142.00	16.33	5.10	15.64	NA
35.00	50.43	4.57	659.75	0	-157.35	-142.00	15.35	5.60	19.79	NA
40.00	46.12	3.88	598.17	0	-156.49	-142.00	14.49	6.00	24.09	NA
45.00	41.71	3.29	549.90	0	-155.76	-142.00	13.76	6.40	28.51	NA
50.00	37.22	2.78	511.74	0	-155.14	-142.00	13.14	6.80	33.00	NA
55.00	32.67	2.33	481.44	0	-154.61	-142.00	12.61	7.20	37.55	NA
60.00	28.07	1.93	457.42	0	-154.16	-142.00	12.16	7.40	42.15	NA
65.00	23.43	1.57	438.55	0	-153.80	-142.00	11.80	7.80	46.78	NA
70.00	18.77	1.23	424.02	0	-153.51	-142.00	11.51	8.00	51.44	NA
75.00	14.10	0.90	413.24	0	-153.28	-142.00	11.28	8.20	56.12	NA
80.00	9.40	0.60	405.80	0	-153.12	-142.00	11.12	8.20	60.81	NA
85.00	4.70	0.30	401.44	0	-153.03	-142.00	11.03	8.30	65.51	NA
90.00	0.00	0.00	400.00	0	-153.00	-142.00	11.00	8.30	70.22	NA
									MaxAngle	5.40

Figure D-3. Calculation of the Minimum Antenna Angle Between the Pointing Vector to the Horizon and the Pointing Vector to TDRS

D.4 Unwanted Emissions

This section describes the regulations and recommendations concerning unwanted emissions. Unwanted emissions is defined as all emissions outside the necessary bandwidth and includes both out-of-band continuous spectrum components and spurious emissions.

The necessary bandwidth is a two-sided bandwidth and is defined as follows: "For a given *class of emission*, the width of the frequency band which is just sufficient to ensure the transmission of information at the rate and with the quality required under specified conditions." For space telecommunication links, GSFC missions generally record the necessary bandwidth as the bandwidth that is just sufficient to contain the mainlobe of the signal spectrum. For TDRSS links, the necessary bandwidth is twice the highest baud rate on either channel.

Paragraph D.4.1 describes the unwanted emission regulations given in the NTIA manual. Paragraph D.4.2 provides examples for the calculation of NTIA emission masks. Paragraph D.4.3 describes the ITU-R recommendations on unwanted emissions.

D.4.1 NTIA Emission Mask

Figure D-4 shows the unwanted emission mask given in Section 5.6.3 of the NTIA Manual. Figure D-5 shows the same mask plotted on a log frequency scale. This emission mask is applicable for all Earth and space stations operating above 960 MHz. The NTIA emission mask is defined relative to the in-band peak PSD and is based on a 1 Hz reference bandwidth. It applies to all discrete spectral lines, including spurious outputs and harmonics.

The NTIA mask is calculated relative to the actual signal attenuation measured at the edge of the necessary bandwidth. From this point, the NTIA mask requires an additional attenuation of 40 dB per decade until a maximum required attenuation of 60 dB (relative to the peak measured spectral power density) is reached. Obviously, the determination of the exact attenuation at the edge of the necessary bandwidth for a real system is complicated by the variability of a typical PSD waveform. Therefore, in practice, NTIA estimates this attenuation by plotting a line intersecting the measured 3 dB and 20 dB attenuation points on the log scale PSD plots. The starting point for the NTIA mask is then assumed to be the attenuation at which this line intersects the necessary bandwidth.

The NTIA mask applies for all unwanted emissions; the NTIA does not define separate regions for out-of-band emissions and spurious emissions. Missions that do not meet this standard fall subject to Section 5.1.2 of the NTIA Manual. This section states, "In any instance of harmful interference caused by nonconformance with the provisions of this chapter, the responsibility for eliminating the harmful interference normally shall rest with the agency operating in nonconformance."

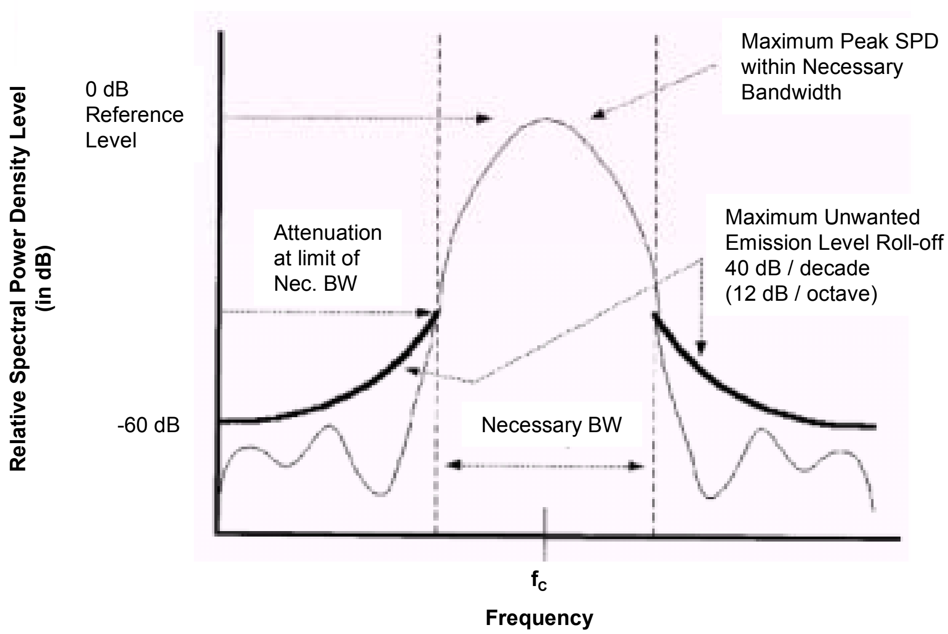


Figure D-4. NTIA OOB Emission Mask for Space Services

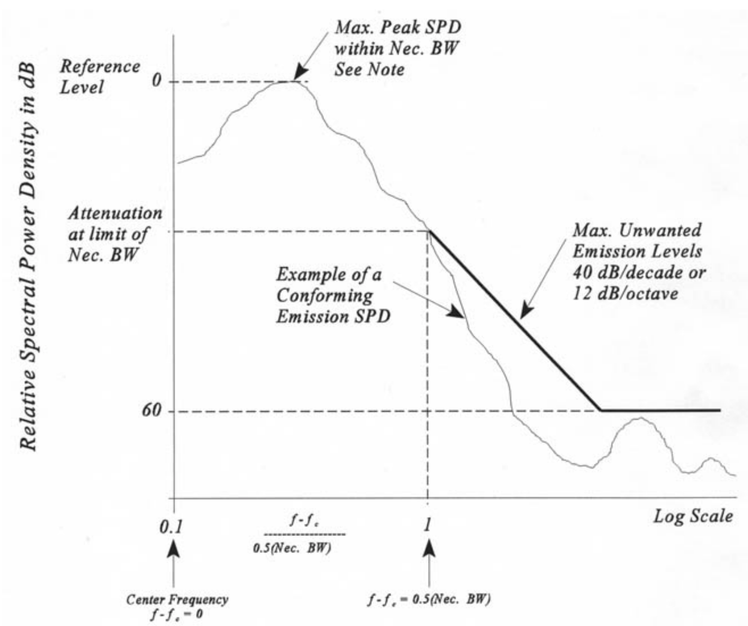


Figure D-5. Log Scale NTIA OOB Emission Mask for Space Services

D.4.2 NTIA Emissions Mask Examples

This section will present example NTIA emissions masks for several power spectral density waveforms: an ideal unfiltered 150 kbps OQPSK signal, an ideal unfiltered 3.082 Mcps SQPN signal, a simulated filtered phase-modulated 150 kbps OQPSK signal, and a simulated filtered 3.082 SQPN signal. In both the simulated cases, various hardware distortions have been incorporated in determining the resultant PSDs. In Figure D-6, both the 150 kbps OQPSK waveforms are plotted versus frequency offset (F – Fc) on the upper X-axis and as a function of necessary bandwidth on the lower X-axis.

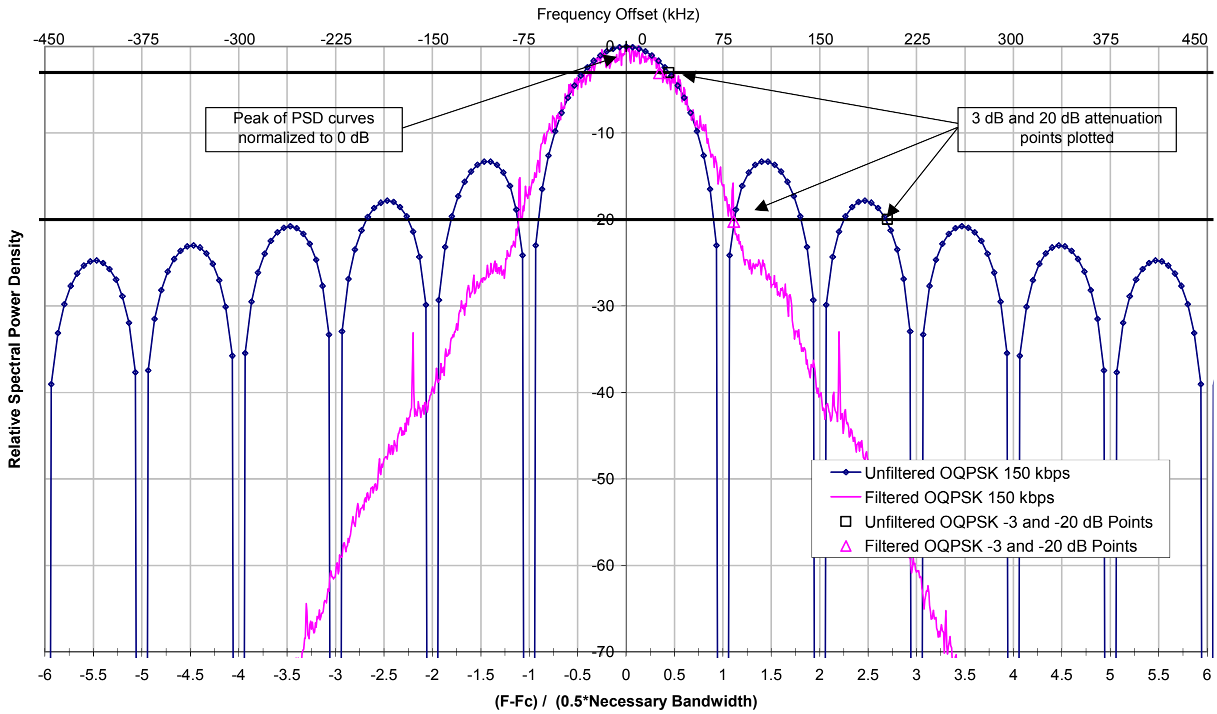


Figure D-6. Example Unfiltered and Filtered OQPSK PSDs

Note that for a 150 kbps QPSK signal, the necessary bandwidth (2 sided) is just the bandwidth required to pass the main lobe, or 150 kHz. Thus the NTIA mask will start at the actual calculated/simulated attenuation at the necessary bandwidth edge of +/- 75 kHz and extend at a rate of 40 dB per decade until the 60 dB attenuation point.

From the PSD plot in Figure D-6, the frequencies corresponding to the 3 dB and 20 dB attenuation points on both PSDs can be determined. These points are plotted along with the PSDs on a log frequency scale in Figure D-7. Note that lines connecting the 3 dB and 20 dB attenuation points are also included on this figure. The points at which these lines intersect the necessary bandwidth edge (10*log(75) on this figure) are the starting points for the NTIA masks depicted.

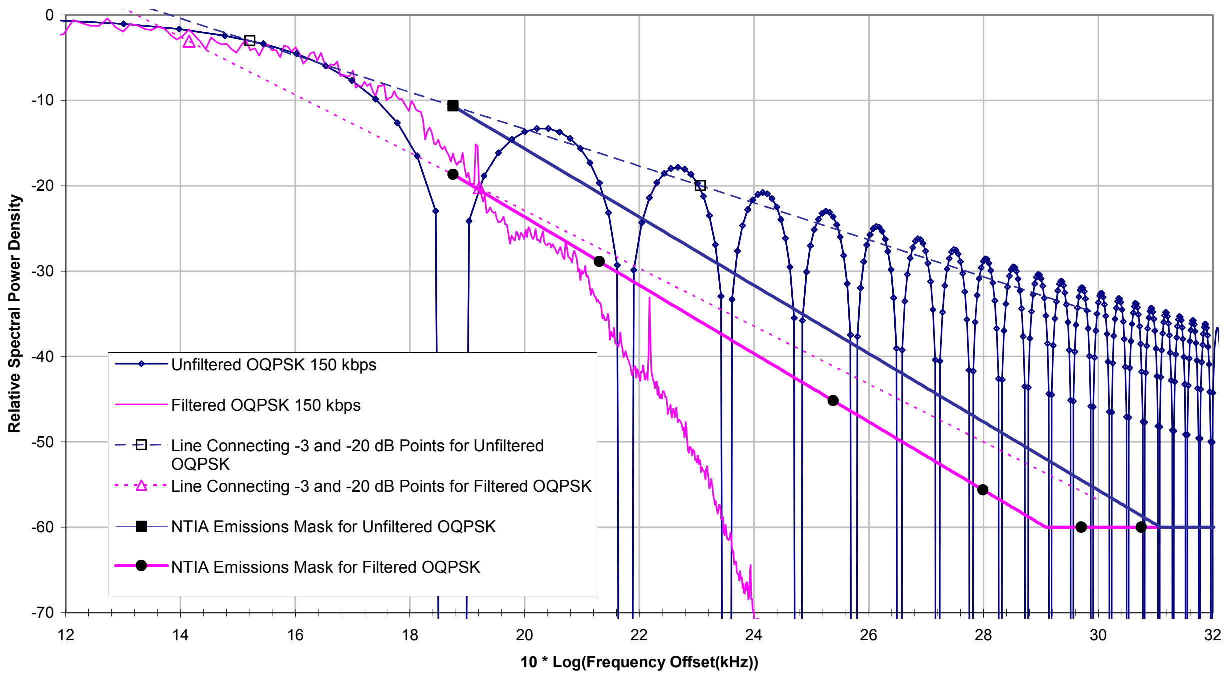


Figure D-7. Example Log Scale OQPSK PSDs with NTIA Masks

From Figure D-7, it can be seen that the Filtered OQPSK power spectral density meets the requirements of the NTIA mask over most of the applicable frequency range. (The PSD in the vicinity of the necessary bandwidth is slightly above the mask). However, the unfiltered OQPSK exceeds the mask throughout the entire frequency range by a significant margin. The PSDs and emission masks are plotted on a linear frequency offset axis in Figure D-8.

Figure D-9 through Figure D-11 provide the same type of graphs for the filtered and unfiltered 3.082 Mcps SQPN signal. Similar to the OQPSK case, the unfiltered SQPN PSD does not meet the NTIA emission mask; however, the filtered SQPN PSD does meet the NTIA emission mask.

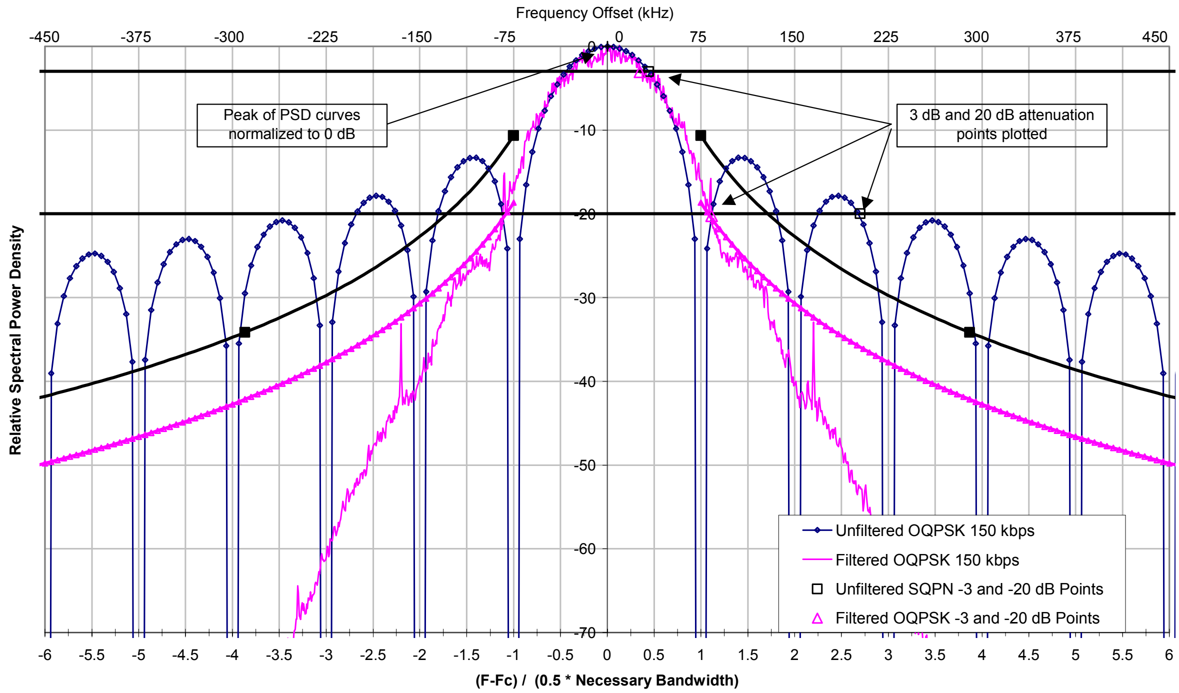


Figure D-8. Example OQPSK Power Spectral Densities and NTIA Emission Masks

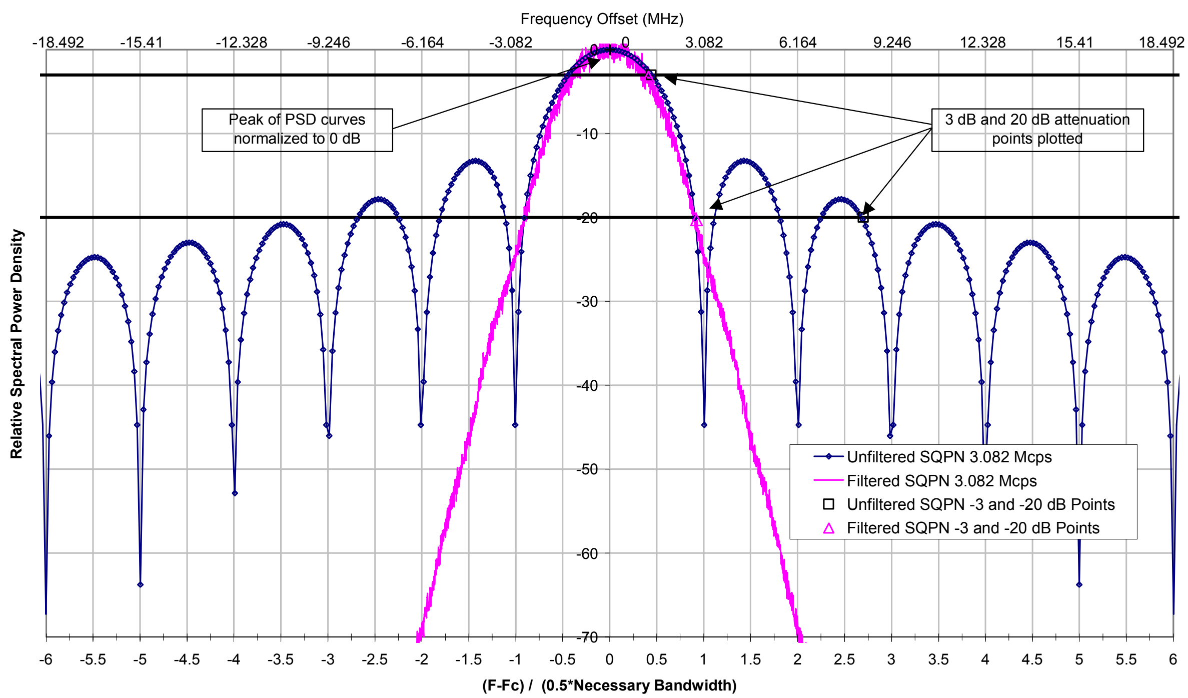


Figure D-9. Example Unfiltered and Filtered SQPN PSDs

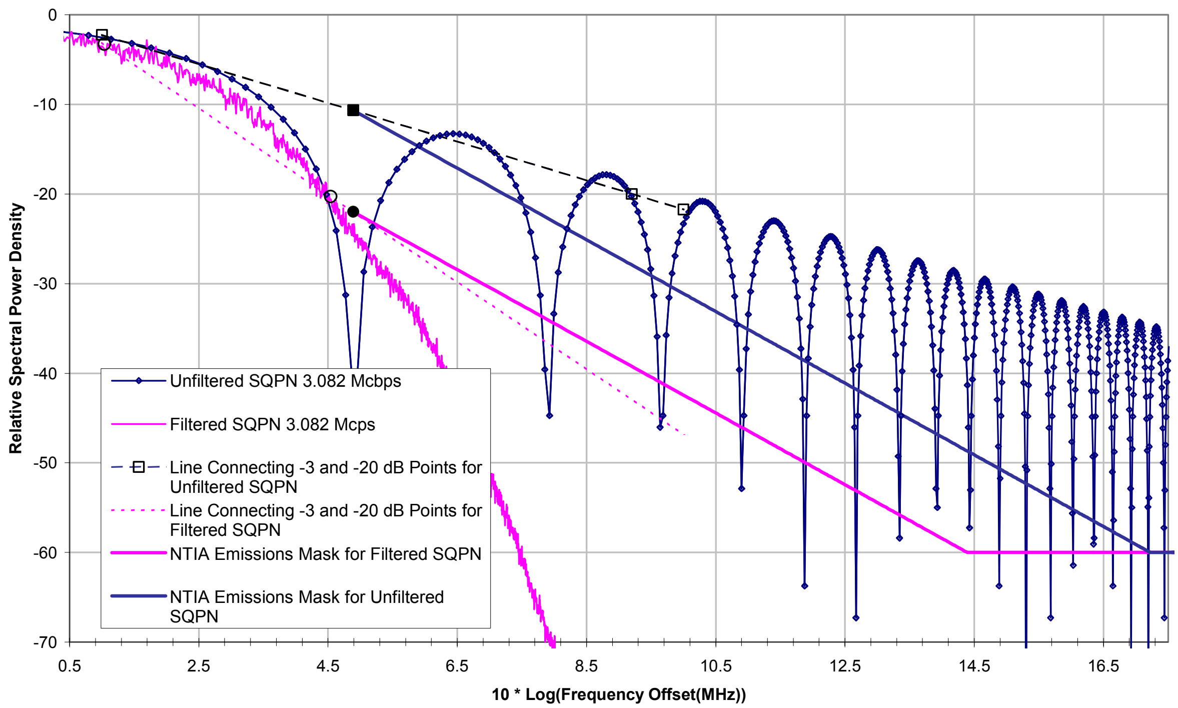


Figure D-10. Example Log Scale SQPN PSDs with NTIA Masks

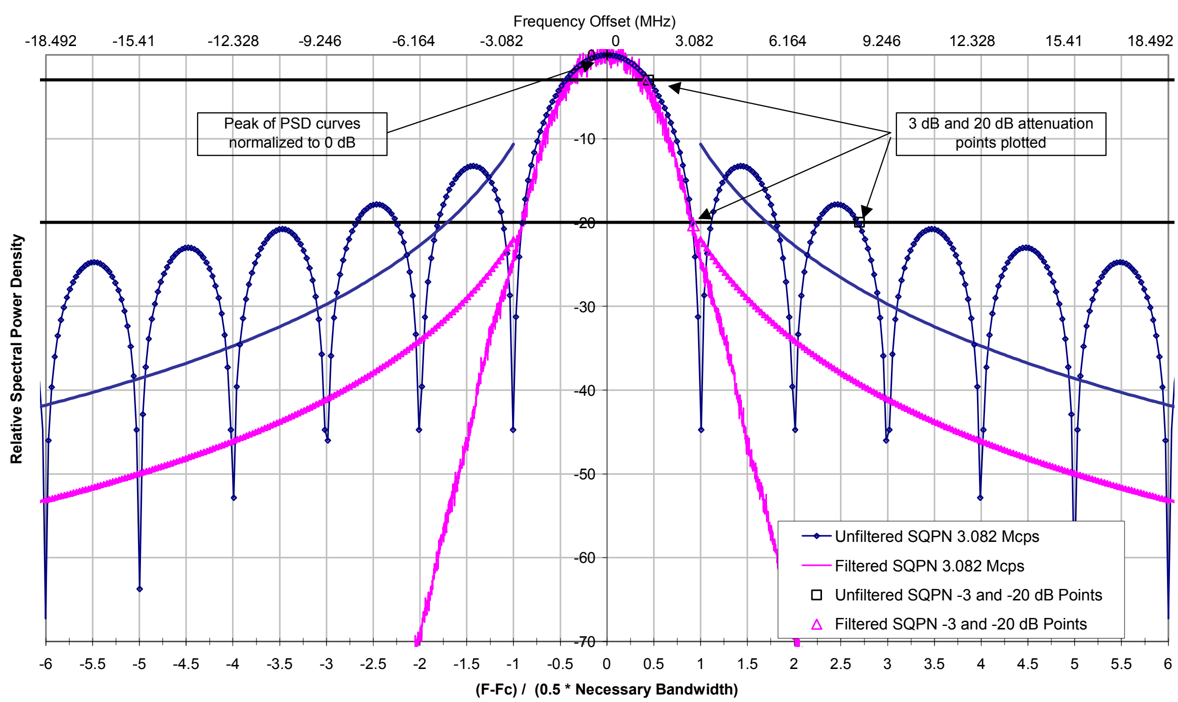


Figure D-11. Example SQPN Power Spectral Densities and NTIA Emission Masks

D.4.3 ITU Unwanted Emission Limits

Unlike the NTIA, the ITU-R defines unwanted emissions in two separate regions. The region just outside the necessary bandwidth is the out-of-band region; the region farther out is the region of spurious emissions. Recommendation ITU-R SM.1539 defines the boundary region. In general, the boundary between the out-of band emissions and the spurious emissions is 250% of the necessary bandwidth, but there are some exceptions.

Recommendation ITU-R SM.1541 defines limits on unwanted emissions in the out-of-band region. The out-of-band emission mask for space services is defined in Annex 5 of Recommendation ITU-R SM.1541. However, there is currently no ITU mask applicable for space services operating space-to-space links in the out-of-band region.

Recommendation ITU-R SM.329 defines limits on spurious emissions. Table 2 of the ITU SM.329-9 shows that for space services, the peak attenuation in the spurious emission region is 43 + 10 log *P*, or 60 dBc, whichever is less stringent. P is defined to be the power (in Watts) supplied to the antenna transmission line.

D.5 Frequency Tolerance

Section 5.2.1 of the NTIA manual indicates that the frequency tolerance for space services is 20 parts per million (ppm). Missions that do not meet this standard fall subject to Section 5.1.2 of the NTIA Manual. This section states, “In any instance of harmful interference caused by nonconformance with the provisions of this chapter, the responsibility for eliminating the harmful interference normally shall rest with the agency operating in nonconformance.”

D.6 Cessation Of Transmissions

Article S22.1 of the ITU Radio Regulations states that, “space stations shall be fitted with devices to ensure immediate cessation of their radio emissions by telecommand, whenever such cessation is required under the provisions of the ITU Regulations.”

The NTIA has a similar requirement. Section 8.2.32 of the NTIA manual indicates that the “use of space stations will be authorized only in those cases where such stations are equipped so as to ensure the ability to turn on or to provide immediate cessation of emissions by telecommand.”

D.7 Protection Of Deep Space Earth Stations

TDRSS S-band links operating in the upper portion of the 2200 – 2290 MHz band have the potential to cause unacceptable interference to deep space missions operating in the 2290 – 2300 MHz band. Recommendation ITU-R SA.1157 defines protection criteria for deep space operations in the 2 GHz band. This recommendation indicates that the protection criteria for deep space Earth stations operating near 2 GHz is -222 dBW/Hz. This protection threshold is measured at the deep space Earth station after accounting for the receiving antenna gain. Platforms operating in the upper portion of the 2200 – 2290 MHz band need very stringent filtering to meet the deep space protection criteria. In particular, a platform using the 2287.5 MHz TDRSS return links with a necessary bandwidth of 5 MHz or higher will easily violate the deep space protection criteria when it transmits sufficiently close to the beam of a DSN 70 meter or 34 meter antenna. In such case, transmission must be terminated per the NTIA frequency certification guideline. Such operations will be expensive to plan, coordinate and execute. This is practical only for those spacecraft whose flight paths rarely come close to a DSN antenna beam, such as a satellite with low inclination. Other platforms need to filter out sideband emissions on board in order to minimize the need for operational avoidance. In either case, the mission should coordinate with the Deep Space Network through the GSFC, JSC, and JPL Spectrum Managers.

There are approximately 10 deep space Earth stations worldwide. The three NASA deep space Earth stations are located at Goldstone, CA; Madrid, Spain; and Canberra, Australia. Additional information on the deep space Earth stations can be found in the CCSDS 411.0-G Green Handbook on RF Frequency and Modulation Systems, Part 1, Earth Stations. This handbook is available at the following website: http://www.ccsds.org/green_books.html.

D.8 Preferred Frequencies for Launch Vehicles

NASA has agreements with other administrations to use the following preferred frequencies to support launch vehicles:

a. 2211 MHz +/- 4 MHz

b. 2215 MHz +/- 4 MHz

c. 2272.5 MHz +/- 2 MHz

d. 2285 – 2300 MHz

Frequencies outside the preferred frequencies are acceptable, but frequency coordination may be more difficult.

D.9 Additional Applicable Recommendations

The following ITU-R Recommendations are of particular interest to missions utilizing the Space Network.

a. **SA.1154** Provisions to protect the space research (SR), space operations (SO) and Earth-exploration satellite services (EES) and to facilitate sharing with the mobile service in the 2025-2110 and 2200-2290 MHz bands

b. **SA.1155** Protection criteria related to the operation of data relay satellite systems.

Appendix E. Customer Platform and TDRS Signal Parameter Definitions

E.1 General

This Appendix defines the salient characteristics of the TDRSS forward service to a customer platform and the parameters which constrain the customer platform transmitted signal. The specifications of these parameters are given in Tables 5-3 (MAF), 6-4 (SSAF), 7-3 (KuSAF), 8-3 (KaSAF), 5-11 (MAR), 6-12 (SSAR), 7-9 (KuSAR), and 8-9 (KaSAR), respectively.

E.2 Symbol (Data) Asymmetry

a. For the NRZ signal format, symbol (data) asymmetry is defined as follows:

$$\frac{\text{length of long symbol - length of short symbol}}{\text{length of long symbol + length of short symbol}} \times 100\%$$

b. For the Bi∅ format signal, data asymmetry applies to both the entire symbol and to each half-symbol pulse. Therefore, for Bi∅, symbol (data) asymmetry is defined as follows:

1. For the entire symbol:

$$\frac{\text{length of long symbol - length of short symbol}}{\text{length of long symbol + length of short symbol}} \times 100\%$$

2. For the half-symbol pulse:

$$\frac{\text{length of long half symbol pulse - length of short half symbol pulse}}{\text{length of long half symbol pulse + length of short half symbol pulse}} \times 100\%$$

E.3 Symbol (Data) Rise Time

Symbol (data) rise time is the time required to switch from 90 percent of the initial data state to 90 percent of the final data state as a percentage of symbol duration. Symbol (data) rise time is illustrated in Figure E-1.

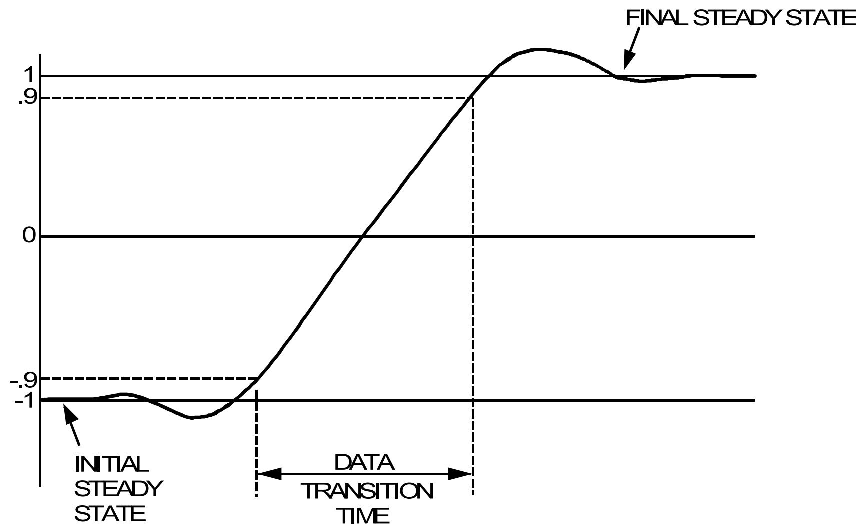


Figure E-1. Symbol (Data) Rise Time

E.4 Symbol (Data Bit) Jitter and Jitter Rate

Symbol (data bit) jitter is defined as the peak frequency deviation from the desired symbol clock frequency expressed as a percentage of the symbol clock frequency. A mathematical description of this definition follows.

A symbol clock with symbol jitter can be expressed as follows:

$$c(t) = \mathrm{sgn}\left[\cos(2\pi f_S t + \phi(t)\right]$$

where

$f_S =$ desired symbol rate

$\phi(t) =$ symbol clock <u>phase</u> jitter

$2\pi f_S t + \phi(t) = \theta(t) =$ symbol clock phase in radians

The frequency of the symbol clock is as follows:

$$f_C = \frac{d\theta(t)}{dt} \cdot \frac{1}{2\pi} = f_S + \frac{d\phi(t)}{dt} \cdot \frac{1}{2\pi} \quad \text{Hz}$$

It can be seen that the clock frequency is comprised of a constant component and a time-varying component. Symbol jitter is defined as the peak absolute value of the time-varying portion of the symbol clock <u>frequency</u>:

$$\Delta f = \left[\max\left(abs\left(\frac{d\phi(t)}{dt} \cdot \frac{1}{2\pi} \right) \right) \right] = \text{symbol jitter in Hz}$$

Symbol jitter expressed as a percentage of the symbol clock rate can be computed as follows:

$$\Delta f \cdot \frac{1}{f_S} \cdot 100\% = \left[\max\left(abs\left(\frac{d\phi(t)}{dt} \cdot \frac{1}{2\pi} \right)\right)\right] \cdot \frac{1}{f_S} \cdot 100\%$$ = symbol jitter as a % of the symbol clock rate

If the jitter is random, the 3σ value of the symbol clock frequency jitter may be used in the above expression.

The symbol jitter rate is defined as the maximum frequency component, f_m, in the symbol clock frequency jitter power spectral density (i.e., the symbol clock frequency jitter spectral distribution is from 0 to f_m Hz).

For KuSAR special constraints apply. These constraints are as follows:

a. The WSC will be provided with scheduling parameters from the DSMC which categorize the input jitter for each channel into one of six ranges: None, 0.01%, 0.1%, 0.5%, 1.0%, and 2.0%. The last three of these are valid only for Shuttle. The constraints governing each of the first three cases are detailed below:

1. Jitter = None (Coded or Uncoded Data). When the scheduled jitter parameter for a data channel is "None" and the data is either coded or uncoded, then $\Delta f = f_m = 0$.

2. Jitter = 0.01% (Coded or Uncoded Data). When the scheduled jitter parameter for a data channel is "0.01%" and the data is either coded or uncoded, Δf and f_m will lie as shown in Figure E-2 for all symbol rates up to and including 150 Msps.

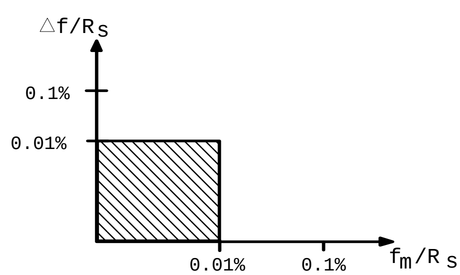


Figure E-2. Coded and Uncoded Data at 0.01% Jitter

3. Jitter = 0.1% (Coded or Uncoded Data). When the scheduled jitter parameter for a data channel is "0.1%" and the data is uncoded, Δf and f_m will lie as shown in Figure E-3 through Figure E-6, as appropriate, depending on symbol rate. When the data is coded, Δf and f_m will lie as shown in Figure E-6, independent of symbol rate.

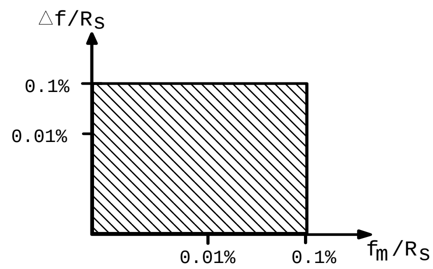


Figure E-3. Uncoded Data at 0.1% Jitter for $R_S \leq 20$ MSPS

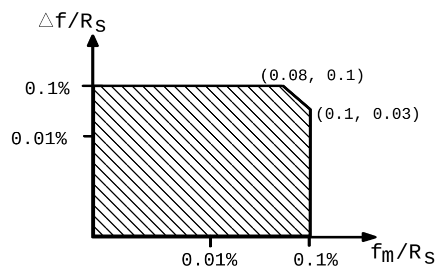


Figure E-4. Uncoded Data at 0.1% Jitter for ($20 < R_S \leq 40$) MSPS

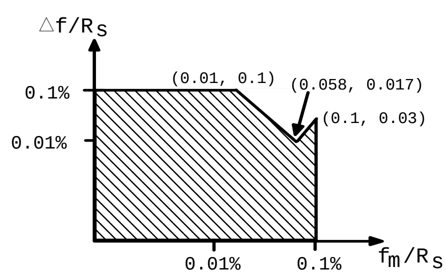


Figure E-5. Uncoded Data at 0.1% Jitter for (40 < Rs < 75) MSPS

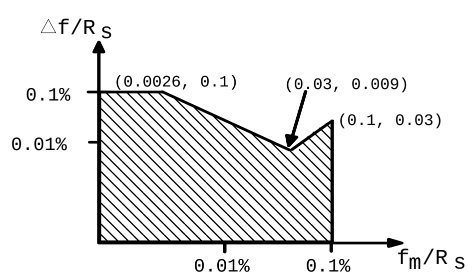


Figure E-6. Uncoded Data at 0.1% Jitter for ($75 < R_S \leq 150$) MSPS
Coded Data at 0.1% Jitter for ($R_S \leq 150$) MSPS

E.5 Phase Imbalance

E.5.1 Suppressed Carrier

E.5.1.1 BPSK

BPSK phase imbalance is defined as, $\phi = 180 - \psi$, where ϕ is the phase imbalance and ψ is the value of the phase angle between the two BPSK signal vectors; as shown in Figure E-7.

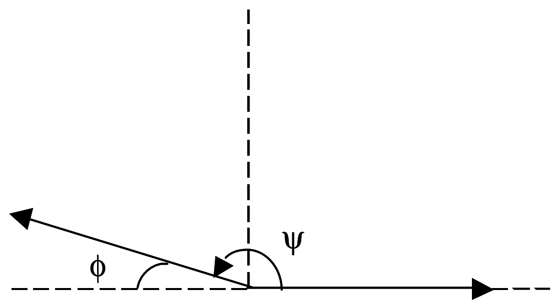


Figure E-7. BPSK Phase Imbalance

E.5.1.2 QPSK

QPSK phase imbalance is defined as $\phi = \max |\psi_i - \psi_{ideal}|$ where ϕ is the phase imbalance and the four actual phase angles $\{\psi_i\}$ are as shown in Figure E-8.

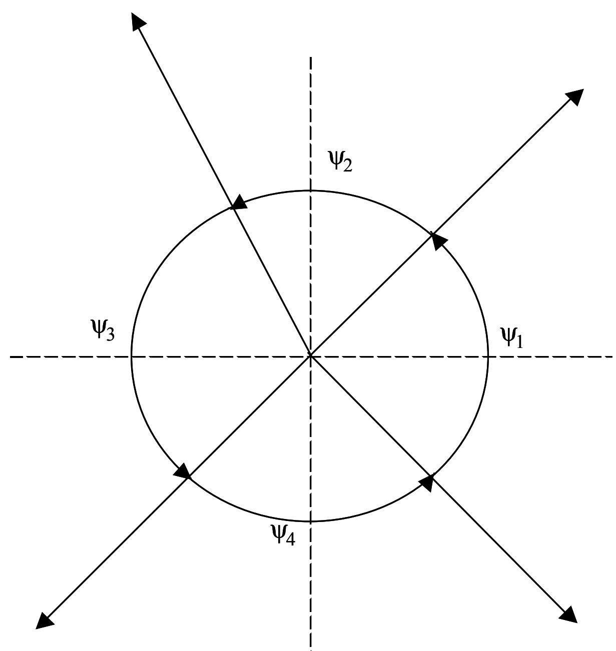


Figure E-8. QPSK Phase Imbalance

ψ_{ideal} is the value of each illustrated phase under distortion-free conditions and, for example, is given by:

ψ_{ideal} = 90 degrees; Q/I (power) = 0 dB

= 126.87 degrees or 53.13 degrees; Q/I (power) = 6 dB

E.5.2 Residual Carrier

For residual carrier modes of operation, a phase imbalance constraint is not specified because the modulation index tolerance constraint supersedes this constraint.

E.6 Gain Imbalance

E.6.1 Suppressed Carrier

Gain imbalance, G, is defined by the following relationship:

$G = 20 \log_{10} [\max (R_i/R_j)]$ at customer platform HPA output.

where R_i and R_j are the magnitudes of the signal modulation vectors at the customer platform HPA output in the absence of incidental AM and varying modulation. Figure E-9 and Figure E-10 show BPSK and QPSK gain imbalance, respectively.

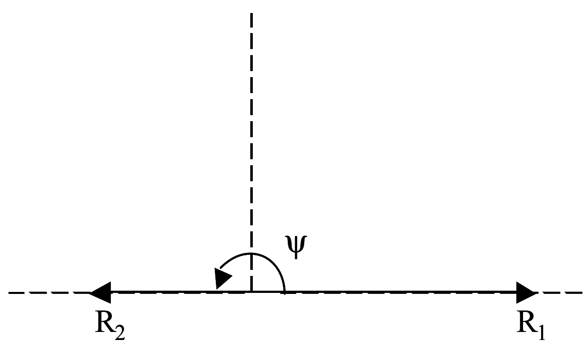


Figure E-9. BPSK Gain Imbalance

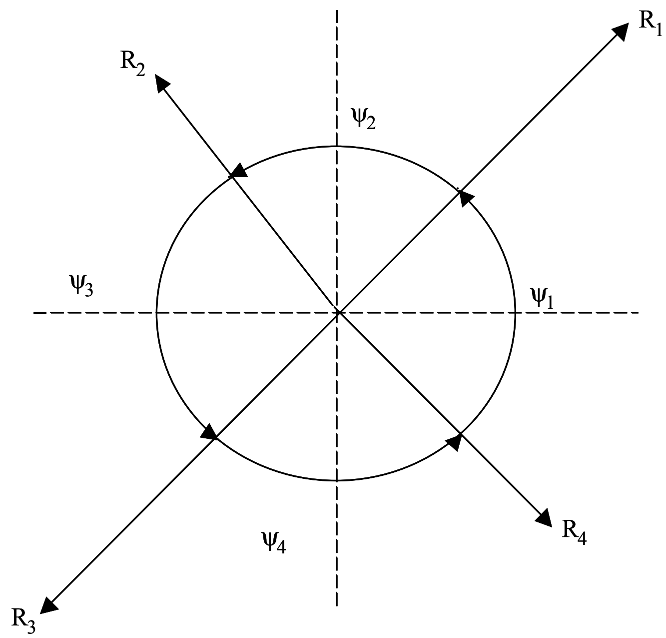


Figure E-10. QPSK Gain Imbalance

E.6.2 Residual Carrier

For residual carrier case, gain imbalance is defined as follows:

$$G = 20 \log_{10} [\max (R_{ideal}/(R_{max} \text{ or } R_{min}))]$$

Gain imbalance is illustrated in Figure E-11.

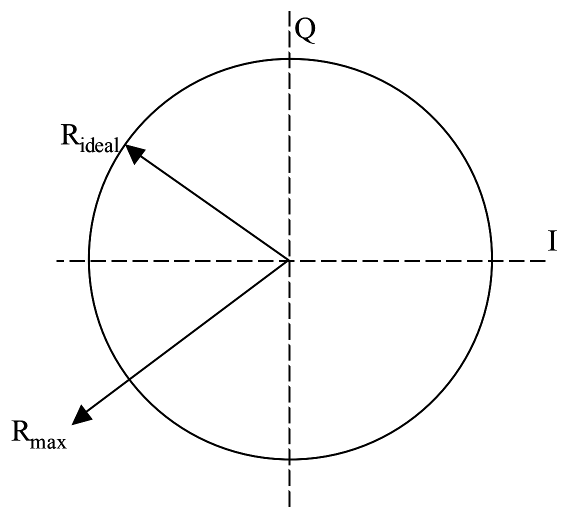


Figure E-11. Residual Carrier Gain Imbalance

E.7 Phase Nonlinearity

Phase nonlinearity is defined as the peak deviation of the phase from the best linear fit to the phase response over the bandwidth of interest, as illustrated in Figure E-12.

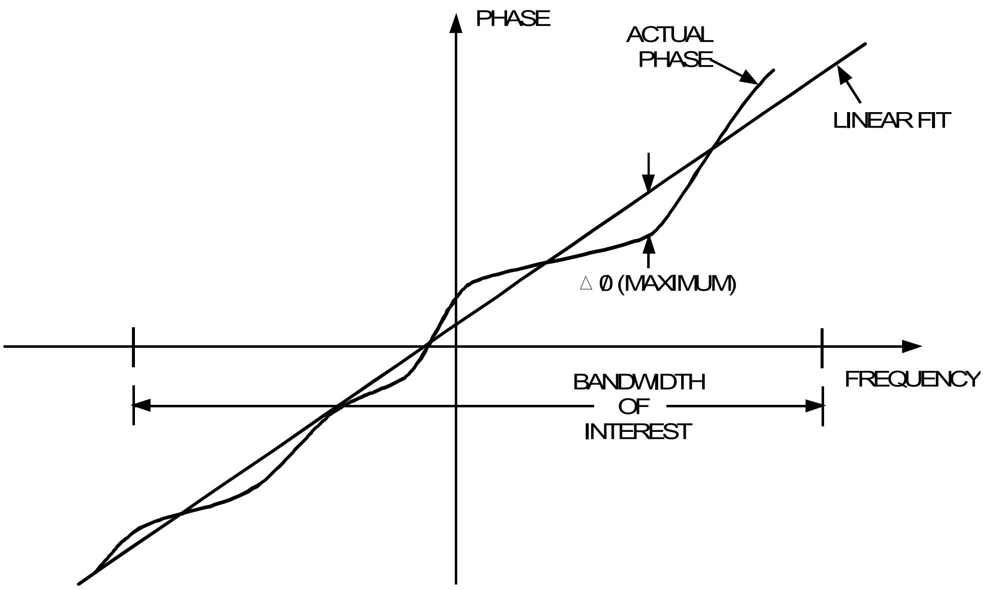


Figure E-12. Phase Nonlinearity

E.8 Gain Flatness

Gain flatness is defined as the peak deviation of the gain from the best horizontal fit to the gain response over the bandwidth of interest, as illustrated in Figure E-13.

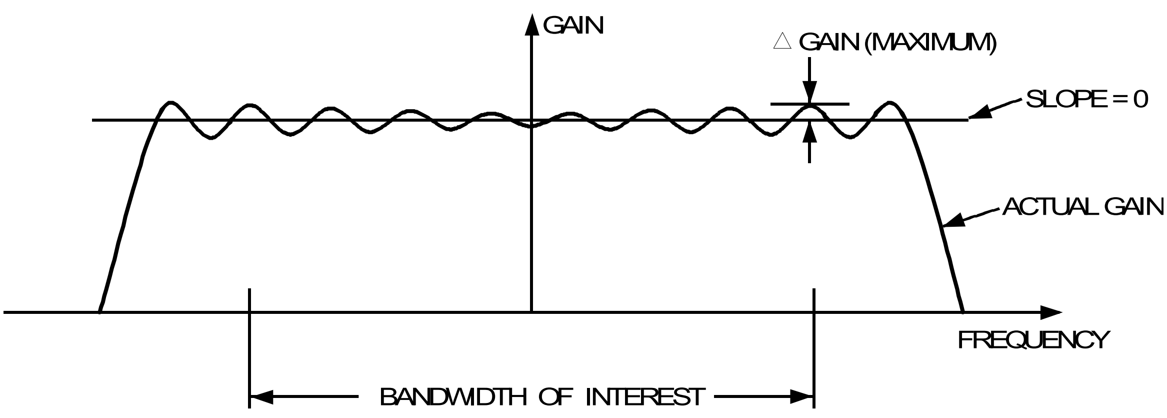


Figure E-13. Gain Flatness

E.9 Gain Slope

Gain slope is defined as the peak absolute value of the derivative of the gain response (relative to the frequency) over the bandwidth of interest, as illustrated in Figure E-14.

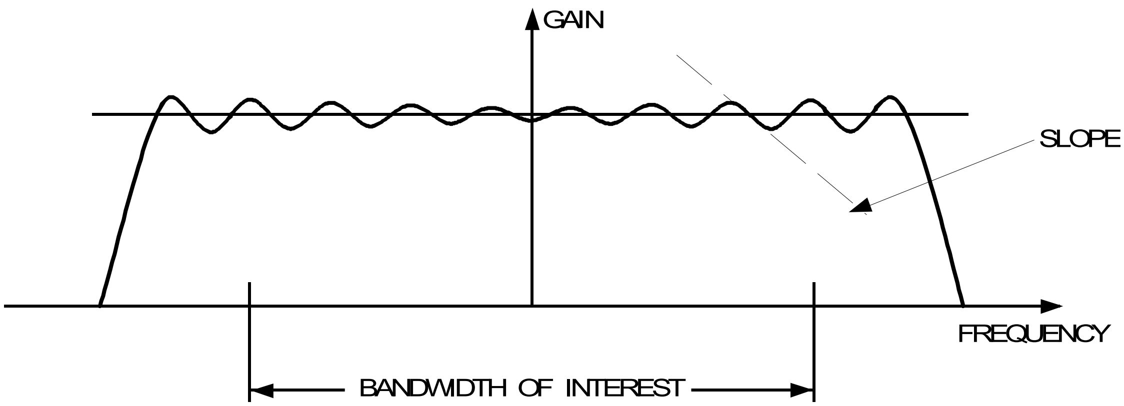


Figure E-14. Gain Slope

E.10 AM/PM

AM/PM is defined as the peak absolute value of the derivative of the amplifier output phase (relative to the input power) over the operating range of the RF output stages, as described by the following equation and as illustrated in Figure E-15.

AM/PM = worst-case $\frac{d\phi_{out}}{dP_{in}}$ over the range of operating points

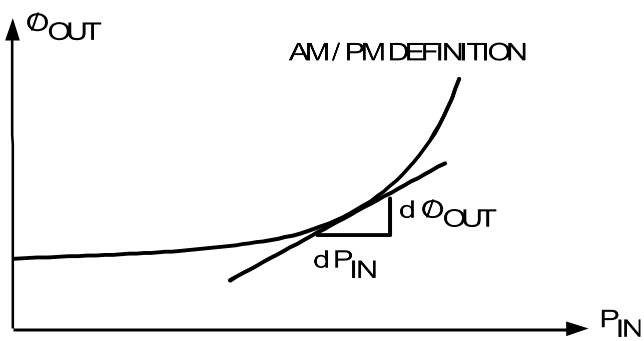


Figure E-15. AM/PM Definition

For forward service:

P_{in} = RF power input in dBW to cascaded WSC and TDRS HPAs.

ϕ_{out} = RF phase output in degrees from cascaded WSC and TDRS HPAs.

For return service:

P_{in} = RF power input in dBW to user transmitter HPA.

ϕ_{out} = RF phase output in degrees from user transmitter HPA.

E.11 Frequency Stability

Frequency stability is the peak instantaneous carrier frequency deviation from the nominal carrier frequency normalized by the nominal carrier frequency as observed over the specified time interval of interest. This includes frequency deviation due to all sources including deviations induced by environmental changes. (This parameter only applies to the noncoherent return mode of operation).

E.12 Incidental AM

Incidental AM is the undesired amplitude modulation superimposed on the carrier and present at the HPA output. This parameter is expressed as a modulation percentage relative to the carrier amplitude. This distortion can be shown mathematically on a continuous wave signal as follows:

$$A\left[1+\sum_i m_i \cos(\omega_i t+\varphi_i)\right]\cos\left[\omega_c t+\theta\right]$$

where m_i represents the amplitude of the i^{th} AM component, ω_i represents the frequency of the i^{th} component, ϕ_i represents the phase of the i^{th} component, ω_c represents the carrier frequency, and θ represents the arbitrary phase of the carrier. The power of the i^{th} component is $\frac{1}{2}m_i^2$.

The incidental AM (peak) is defined by:

$$\sum_i m_i \text{ x } 100 \text{ percent}$$

E.13 Spurious PM

Spurious PM is the residual or unwanted phase modulation at the HPA output, in the absence of data modulation, that is characterized by a discrete spectrum. This distortion can be shown mathematically on a continuous wave signal as follows:

$$A\cdot\cos\left[\omega_c t+\theta+\sum_i a_i \cos\left[(\omega_C+\omega_i)t+\phi_{Di}\right]\right]$$

where ω_C represents the carrier frequency, θ represents the arbitrary phase of the carrier, a_i represents the amplitude of the i^{th} component, ω_i represents the frequency of the i^{th} component, and ϕ_{Di} represents the phase of the i^{th} component. The power of the i^{th} component is $\frac{1}{2} a_i^2$.

Spurious PM is generally specified as a limit on total spurious PM power (in degrees rms). Total spurious PM can be computed as follows:

$$\sigma_{\varphi_D} = \frac{180}{\pi} \cdot \sqrt{\frac{1}{2} \sum_i a_i^2} \text{ deg rms}$$

E.14 Phase Noise

Phase noise is residual or unwanted phase modulation that is characterized by a continuous spectrum. This distortion can be shown mathematically on a continuous wave signal as follows:

$$A \cdot \cos\left[\omega_c t + \theta + \phi_n(t)\right]$$

where ω_c represents the carrier frequency, θ represents the arbitrary phase of the carrier, and $\phi_n(t)$ is the undesired phase modulation having a one-sided continuous spectrum, $S_{\phi_n}(t)$ rad^2. Phase noise is generally specified as a collection of phase noise limits (in degrees rms) over various frequency ranges offset from the carrier frequency. Phase noise in the frequency range f_a to f_b (offset from the carrier frequency) can be computed as follows:

$$\sigma_{\phi_n} = \frac{180}{\pi} \sqrt{\int_{f_a}^{f_b} S_{\phi_n}(f) \cdot df} \text{ deg rms}$$

For the coherent turnaround mode, constraint values assume no phase noise on the signal received by the customer platform; it, therefore, represents the phase noise added by the customer platform, including a contribution due to forward link carrier recovery. Values indicated for the coherent mode represent total output phase noise of the customer platform.

E.15 In-band Spurious Outputs

In-band spurious outputs is the sum of the power of all in-band spurs measured relative to the total signal power (dBc indicates dB below total signal power); where in-band is defined as 2x the maximum channel baud rate.

E.16 Out-of-Band Emissions

Out-of-band emissions are defined as emissions outside of the allocated band of operation. See Appendix D for a further description of out-of-band emissions.

E.17 I/Q Symbol (Data) Skew

For QPSK, the ideal time delay between the symbol (data) transitions on the I channel and the symbol (data) transitions on the Q channel is zero. For SQPSK, the ideal time delay between the symbol (data) transitions on the I channel and the symbol (data) transitions on the Q channel is $0.5T_s$ (where T_s is the channel symbol duration). I/Q symbol (data) skew is the deviation from this ideal relative time delay – measured as a percent of the symbol (bit) time. I/Q symbol (data) skew is defined mathematically as follows:

$$\text{I/Q symbol (data) skew} = \frac{\alpha}{Ts} \times 100\%$$

Where α is as defined in Figure E-16 for the QPSK case. For SQPSK, α is relative to the ideal $0.5T_s$ interval between symbol (data) transitions on the I and Q channels.

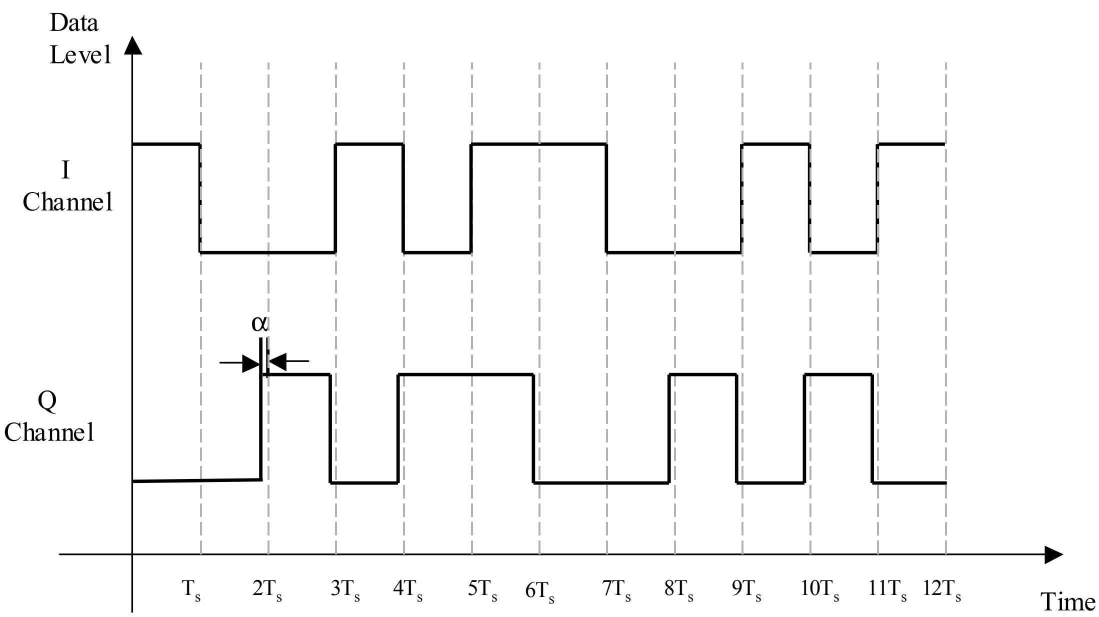


Figure E-16. Description of I/Q Data Skew Assuming QPSK Modulation

E.18 PN Chip Skew

PN chip skew is the deviation of the chip transitions between the I (or command channel for forward) and the Q (or range channel for return) from the ideal time delay.

E.18.1 Return I/Q PN Chip Skew

The ideal time delay between the chip transitions on the I channel and the chip transitions on the Q channel is $0.5T_c$ (where T_c is the PN code chip duration). I/Q chip skew is the deviation from this ideal time delay. I/Q PN chip skew is defined in Figure E-17.

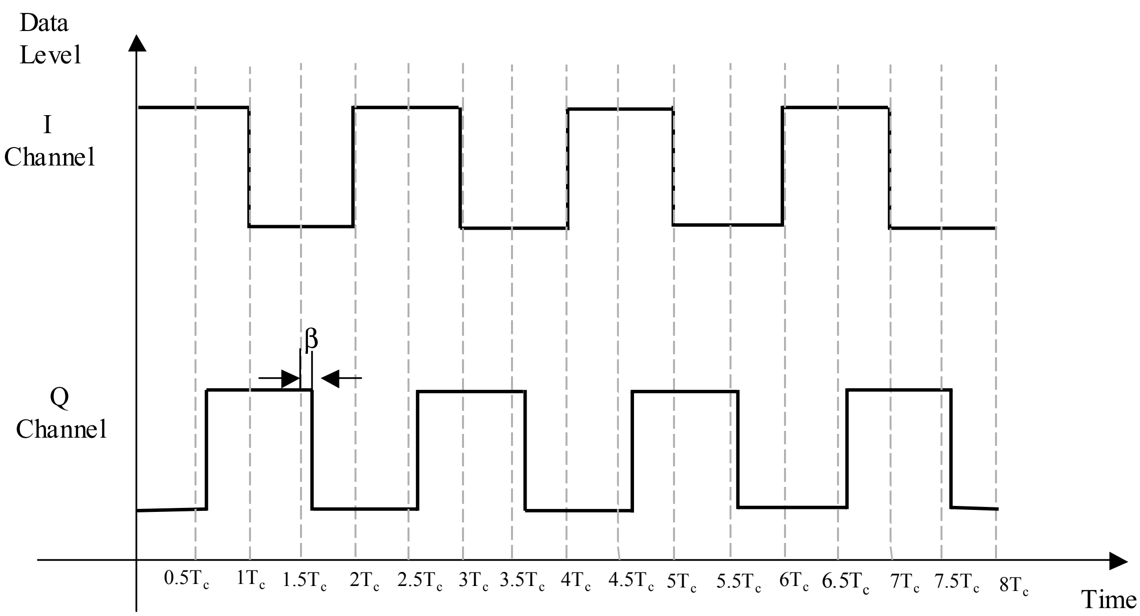


Figure E-17. Definition of I/Q PN Code Chip Skew

E.18.2 Command/Range Channel PN Chip Skew

The ideal time delay between the chip transitions on the command channel and the chip transitions on the range channel is zero. The command/range channel PN chip skew is the deviation from this ideal time delay.

E.19 PN Chip Asymmetry

PN chip asymmetry is defined as follows:

$$\frac{\text{length of long chip - length of short chip}}{\text{length of long chip + length of short chip}} \times 100\%$$

E.20 PN Chip Jitter

PN code chip jitter is defined as the unwanted phase variations of the PN code chip clock measured in degrees rms. A PN code chip clock with PN code chip jitter can be expressed as follows:

$$c(t) = \text{sgn}\left[\cos(2\pi f_{pn} t + \phi(t)\right]$$

where

$f_{pn} =$ desired PN code chip rate in Hz

$\phi(t) =$ PN code chip clock phase jitter in radians

The PN code chip jitter is the rms value of $\phi(t)$ expressed in degrees.

E.21 PN Chip Rate

PN code chip rate is defined as the peak deviation of the actual PN chip rate from the desired PN chip rate (where the desired PN chip rate is defined as the PN chip rate which results in absolute coherence with the carrier rate).

E.22 Noncoherent and Coherent Turnaround PN Power Suppression

PN power suppression is the effective reduction in despread signal power due to the presence of timing imperfections (asymmetry and jitter) in the customer platform transmitter PN clock. Under noncoherent conditions, jitter will be solely due to the transmitter's oscillator. Under coherent turnaround conditions, it will also reflect forward link PN tracking in the absence of PN jitter on the signal received by the customer platform.

E.23 Antenna-Induced AM

Antenna-induced AM is amplitude modulation inadvertently induced on the transmit signal by the antenna. This distortion is generally caused by the slight, unavoidable movements of the antenna during transmission.

E.24 Antenna-Induced PM

Antenna-induced PM is phase modulation inadvertently induced on the transmit signal by the antenna.

E.25 Axial Ratio

For circularly polarized antennas, the electrical field vector usually produced describes an ellipse instead of a circle. The axial ratio is a measure of ellipticity of the customer platform transmitting antenna and is the ratio of the major axis of the ellipse to the minor axis.

E.26 Data Rate Tolerance

Data rate tolerance is the allowable difference between the actual data rate and the desired data rate – measured as a percentage of the desired data rate.

E.27 Power Ratio Tolerance

Power ratio tolerance is the ratio of the actual I/Q channel power ratio to the desired I/Q channel power ratio.

E.28 Permissible EIRP Variation

Permissible EIRP variation is the range over which the customer platform EIRP, measured along the customer platform/TDRS line-of-sight, may vary without requiring customer platform reconfiguration. Performance is determined from customer platform transmitter power variation, transmit antenna pattern, worst case customer platform orientation, and maximum variation in range between the customer platform and the TDRS over the duration of a pass.

E.29 Rate of EIRP Variation

Rate of EIRP variation is the time derivative of the customer platform EIRP.

E.30 Maximum User EIRP

Maximum user EIRP is the maximum allowable user EIRP transmitted toward a TDRS.

E.31 Modulation Index Accuracy

Modulation index accuracy is the peak deviation of the modulation index from the desired modulation index as a percentage of the desired modulation index. Modulation index accuracy is defined as follows:

$$\frac{\text{peak deviation from the desired mod index}}{\text{desired mod index}} \times 100\%$$

E.32 Subcarrier Frequency Accuracy

Subcarrier frequency accuracy is the maximum deviation of the subcarrier frequency from the desired subcarrier frequency.

E.33 Data Transition and Subcarrier Coherency

Coherency between the data transition and the subcarrier zero-crossing – measured in degrees of the subcarrier cycle.

E.34 Subcarrier Phase Noise

Unwanted phase modulation to the subcarrier. See paragraph E.14 for a general description of phase noise.

E.35 Maximum Frequency Error of 8.5 MHz Subcarrier

The peak instantaneous subcarrier frequency deviation from the nominal subcarrier frequency normalized by the nominal subcarrier frequency.

E.36 Minimum EIRP for TDRSS Ku-Band Autotrack

Minimum EIRP required to ensure nominal autotrack acquisition and performance.

E.37 Short Term EIRP Stability

Peak variation in user EIRP over a time duration as described by the specification.

Appendix F. Periodic Convolutional Interleaving with a Cover Sequence for Synchronization

F.1 General

This Appendix describes (n, m) Periodic Convolutional Interleaving (PCI) which, when used with the appropriate periodic convolutional deinterleaving, guarantees separation of any two symbols within n of each other in the interleaved symbol sequence to be at least nm/(n-1) symbols between each other in the deinterleaved sequence. PCI is recommended on S-band DG1 mode 3 and DG2 return services for channel baud rates > 300 kbps. At these higher data rates, any single RFI pulse affects multiple adjacent transmitted symbols. The effectiveness of the WSC Viterbi decoding process decreases as the number of adjacent symbols overlapped increases. The purpose of the periodic convolutional interleaving (and associated WSC deinterleaving) is to break up or spread out these corrupted symbols so that they appear at the Viterbi decoder input to be random in their occurrence just as if they arose from a channel without memory. When interleaving is not employed for DG1 mode 3 and DG2 channel baud rates > 300 kbps, S-band return performance may not be guaranteed. Deinterleaving is not supported for baud rates $\leq$ 300 kbps. Additionally, biphase symbol formats are not allowed with PCI. Use of biphase symbol formats on S-band services at baud rates > 300 kbps should be coordinated with the GSFC MSP.

F.2 (30,116) Periodic Convolutional Interleaving

F.2.1 Interleaving

The encoded symbol sequence interleaving is shown in Figure F-1 as commutated delay elements. The input and output commutators are slaved, advance for each encoded symbol, and recycle every 30 symbols. The input to the zero delay element of the interleaver is always a G_1 encoder symbol modulo-2 added to the initial cover sequence state (refer to paragraph F.2.2).

F.2.2 Cover Sequence

The cover sequence is modulo-2 added bit-by-bit to the preinterleaved symbols to provide for perfect deinterleaving synchronization. The cover sequence is:

first bit → 000001110010001010111101101001 ← last bit

where the first bit is for the zero delay element and the last bit is for the 116 delay element of the interleaving.

F.2.3 Synchronization

F.2.3.1 Cover Sequence

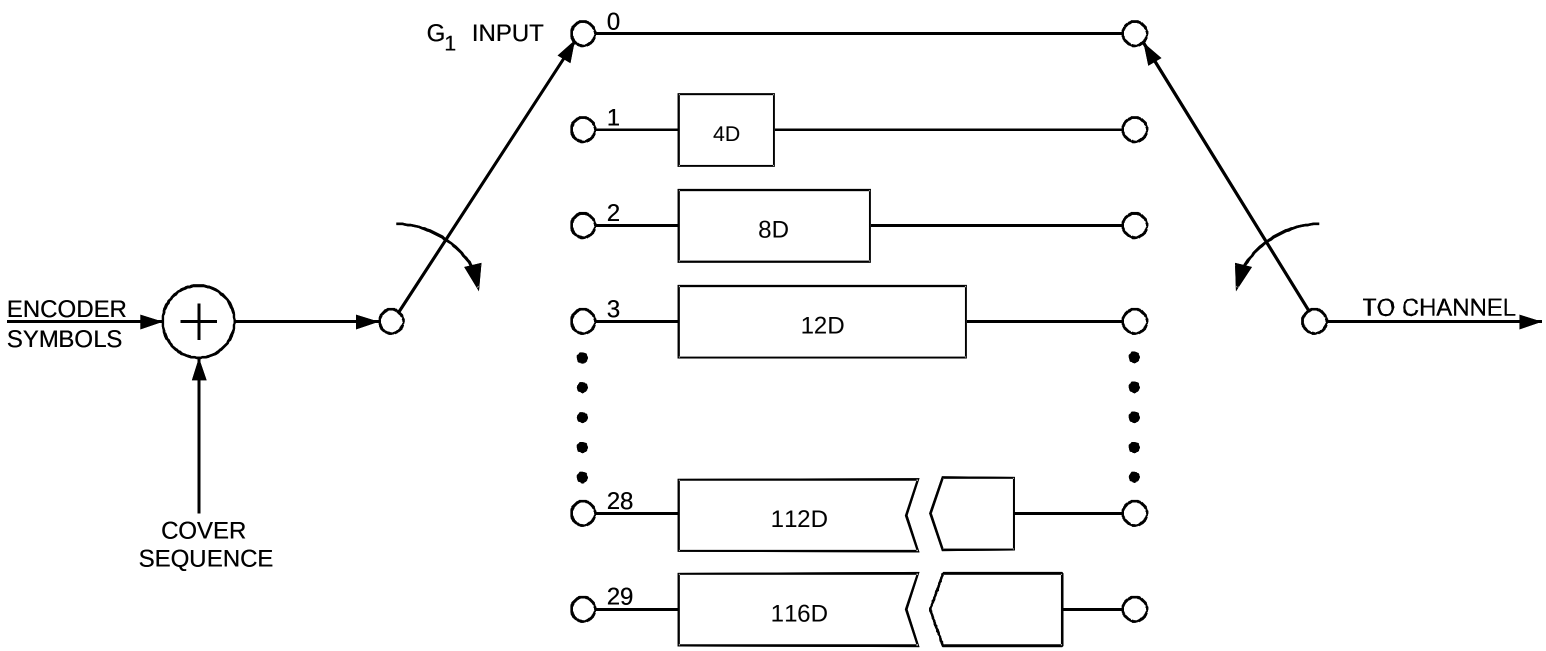
The cover sequence is synchronized with the interleaving delay selection so that the first bit occurs during the zero delay selection by the interleaving commutation (commutator positions as shown in Figure F-1).

F.2.3.2 Convolutional Encoding

The convolutional encoding is synchronized with the interleaving delay selection so that the symbol from the G_1 generator of the convolutional encoding occurs during the zero delay selection by the interleaving commutation (commutator positions as shown in Figure F-1).

F.2.3.3 Timing Synchronization

The encoding, cover sequence generation, modulo-2 addition, and interleaving (commutation and delay) will be time synchronous.



Note

D = Delay element

Figure F-1. Periodic Convolutional Interleaving

Appendix G. Predicted Performance Degradations Due to RFI

G.1 General

G.1.1

Certain portions of the RF spectrum used by TDRSS are also occupied by independent ground-based transmitters, which may introduce RFI. Although RFI may be present at S-, Ku-, and Ka-band frequencies, current indications and performance evaluations suggest that only S-band RFI warrants concern at this time. The interference environment and any associated RFI model is constantly changing and RFI should be dealt with on a case-by-case basis for each customer. The customer community will, however, be kept abreast of significant changes if they occur. Please contact the GSFC MSP for further information.

G.1.2

Both forward and return service performance may be affected by RFI, with the return service impact of most potential significance. The RFI impact on forward service performance is heavily dependent on the customer platform orbit and varies rapidly with time; therefore, forward service RFI must be treated on a customer-unique basis. On the other hand, the effects of return service RFI change much more gradually with time and an assessment may be developed which has broad applicability to virtually all TDRSS customers.

G.1.3

The major RFI problem to which this Appendix is devoted concerns S-band RFI emitters, which are expected to degrade the performances of the SSA and MA return service. These degradations are treated as increased required P_{rec} or, equivalently, as additional customer platform EIRP required above the value which would suffice in an RFI-free environment. As will be described, there are many variables and uncertainties associated with these degradation estimates, so that customers are urged to include additional margins in their customer platform EIRP specifications within: economic constraints, the maximum P_{rec} restrictions of Section 5 (MA) and Section 6 (SSA), and the allowable excess margin.

The Final Acts of the World Administrative Radio Conference-92 (WARC-92) re-allocated portions of S-band frequencies to fixed service users. As more fixed service users move into this band, this re-allocation may have an RFI impact on SN operations in S-band. Each customer should coordinate with the GSFC MSP to determine the RFI levels and mitigation techniques for their specific mission.

Two systems are available to customers for predicting possible interference. The Automated Conflict Resolution System (ACRS) predicts mutual interference between two or more customer platforms scheduled on the same TDRS at the same time. Customer MOCs receive ACRS output and may alter their schedules based upon the interference mitigation techniques provided by ACRS. The TDRS Look Angle System (TLAS) plots the TDRS look angles as it tracks the customer platform and predicts periods of ground based RFI and earth multipath. Both systems use TDRS and customer orbital data as inputs as well as customer schedules received directly at the DSMC.

G.2 Factors Influencing Degradation

G.2.1

A number of factors or parameters determine the degree of performance degradation from RFI on any particular service. Different RFI environments are expected at the TDRSs (such as more RFI for TDRS-East than for TDRS-West). Intentional offpointing of the TDRS SA antenna away from the geographic zone containing the RFI emitters will serve as a direct means of RFI mitigation. Customer platform signal parameters are significant, particularly the return service used (MA or SSA), the convolutional code rate (rate 1/3 is optional for some SSA and SMA applications), and the degree of compliance with the signal quality customer platform constraints.

G.2.2

The largest element of uncertainty in determining RFI degradation estimates concerns the RFI environment itself. The environment is constantly changing and the GSFC MSP will be kept informed of the changes in the environments in which the SN operates.

G.3 Need For Channel Coding and Periodic Convolutional Interleaving

G.3.1

Forward error control coding not only provides a performance improvement against thermal noise, but it also makes the service performance less sensitive to RFI degradations. Clearly, even very occasional bursts of interference drive the BER up to an unacceptable value on an uncoded system. These same errors on the encoded symbols of a coded system are unlikely to result in output errors after the decoding process. For this reason, convolutional encoding should be used on all MA and SSA return services, using the code formats and rates given in Appendix B.

G.3.2

At SSA return service data rates in which the encoded baud rate exceeds 300,000 symbols per second, the use of periodic convolutional interleaving (PCI) is required for the current estimated RFI environments. At these higher data rates, any single RFI pulse affects multiple adjacent transmitted symbols. The effectiveness of the WSC

Viterbi decoding process decreases as the number of adjacent symbols overlapped increases. The purpose of the periodic convolutional interleaving (and associated WSC deinterleaving) is to break up or spread out these corrupted symbols so that they appear at the Viterbi decoder input to be random in their occurrence just as if they arose from a channel without memory.

G.3.3

If the RFI environment becomes more severe in the future than currently estimated, return service periodic convolutional interleaving may be necessary below 300,000 symbols per second. This will be ascertained during the mission planning and RF ICD development activities between the customer project and the GSFC MSP.

G.4 SSA RFI Degradation Estimates

G.4.1

Prior to the fixed service re-allocation into the S-band, a detailed evaluation of the SSA return service RFI impact has been performed. This evaluation involved a rigorous BER analysis based on the use of analytical models of the customer platform communications terminal, the TDRSS channel, the RFI environment (both noiselike and sinusoidal pulses), and the WSC Viterbi decoding process. Corresponding RFI degradation results for the SSA maximum data rate (the worst case) and for the appropriate convolutional code rate and/or data group are shown in Table G-1. Assumptions used in determining these values are that all customer platform constraints are met and the EIRP offers no margin to offset RFI degradation. RFI degradation estimates for 0º offpointing (i.e., the TDRS SSA antenna beam is pointing directly at the location of the RFI sources) for TDRS-East are not included in the table due to the severe RFI degradation incurred ($\geq$5 dB) and the impracticality of operating under such conditions.

G.4.2

When an SSA customer has refined his return service communications system design sufficiently, the Communications Link Analysis and Simulation System (CLASS) is used to predict return service performance. During the RF ICD process, the RFI degradation to SSA return service performance will be determined for each customer platform return service based on the customer platform transmit signal parameters (including code and data rates) and characteristics (customer platform constraints), operating frequency, and orbital parameters. These results also include the effect of any interaction between the RFI and the customer platform design partial compliance with the customer platform constraints. This degradation will then be incorporated into RF ICD link calculations.

Table G-1. Estimates of RFI Degradations on SSA Return Services

Conditions (note 2)	Customer Platform EIRP Increase to Offset RFI (dB) (notes 1 & 3)		
	Rate 1/2 Convolutional Encoding		Rate 1/3 Convolutional Encoding
	DG1	DG2	DG2
TDRS-East			
1.5-degree Offpointing	2.7	3.3	1.5
4-degree Offpointing	1.0	1.2	0.5
TDRS-West			
0-degree Offpointing	2.3	2.6	1.0
1.5-degree Offpointing	1.0	1.2	0.6
4-degree Offpointing	0.5	$\leq$ 0.5	0.5

Notes:

1. EIRP increase is determined for the maximum data rate applicable to the particular data group and code rate.
2. Offpointing is the number of degrees the TDRS SA antenna is pointed away from the location of the ground-based RFI sources.
3. RFI degradations are worst-case estimates based upon maximum data rate and will be determined during the customer platform RF ICD process. Link calculations will consider the customer's characteristics to determine the RFI degradation.

G.5 MA RFI Degradation Estimates

G.5.1

Prior to the fixed service re-allocation into the S-band, a detailed evaluation of the MA return service RFI impact has been performed as described in paragraph G.4. Using the estimate of the RFI environment in the MA return service band as seen by TDRS-East, the estimate of RFI degradation is $\leq$0.5 dB for all data rates between 1 and 300 kbps. The analysis assumes no MA antenna beam offpointing, that all customer platform constraints are met, and that the EIRP offers no margin to offset RFI degradation. Contact the Mission Services Program Office, for MA RFI degradation values for data rates greater than 300 kbps (SMA only). During the RF ICD process, the RFI degradation to MA return service performance will be determined and incorporated into the RF ICD link calculations.

G.5.2

CLASS is also used to predict MA return service performance as described for the SSA customer platform in paragraph G.4.

G.6 SSA and MA Forward Service RFI Degradation

As briefly indicated in paragraph G.1, the RFI impact on forward service operation is extremely sensitive to customer platform orbit and is a rapidly varying function of time. Accordingly, forward service RFI considerations are treated on a customer-unique basis.

Appendix H. Demand Access System (DAS)

H.1 Overview and Purpose

H.1.1 Overview

The existing F1-F7 Tracking and Data Relay Satellites (TDRSs) provide communication services to customers by using ground-based electronics to process signals emanating from customer emitters that are relayed by the F1-F7 TDRS MA on-board phased array antenna systems (refer to SNUG Section 3.2.1, MA Service Overview). The Demand Access System (DAS) allows the Tracking and Data Relay Satellite System (TDRSS) F1-F7 MA Return (MAR) capability to be scheduled for extended duration or in a 'near real time' manner. DAS provides DG1 mode 2 return services only. DAS will be operated as a part of the SN using the first-generation satellites (F1-F7) only. DAS is not capable of operations with the second-generation satellites (F8-F10). As of December 2001, the DAS is still under development and specific capabilities may be subject to change. Please contact the GSFC MSP or check the DAS web site at http://stelwscpo.gsfc.nasa.gov/Das/index_ie.htm for the latest information.

H.1.2 Purpose

The purpose of DAS is to:

a. Provide a capability to support continuous or intermittent, conflict-free, MAR link services 24 hours per day, 7 days per week upon demand from customers.

b. Provide an automated capability to transition customer services between TDRSs/SGLTs.

c. Provide a capability to support multiple, DAS MA return links per TDRS/SGLT/Ground Station.

d. Meet or exceed current communications performance and capabilities of the existing TDRS F1-F7/WSC MAR DG1 Mode 2 link services (refer to MAR telecommunications services in SNUG Section 5 and tracking and clock calibration services in SNUG Section 9) with the exceptions of the functions not possible due to the lack of tie-ins with the MA forward link (coherent turnaround support, cross support, two-way ranging, and two-way Doppler). DAS provides both QPSK and BPSK modulation for PN spread signals. Return Channel Time Delay or any other measuring service is not available from DAS since signal delay is variable (output from DAS to NISN to the Customer is TCP/IP) depending on loading and the extent of DAS processing desired.

e. Provide beamforming, demodulating, data distributing and short term storage capabilities for each service.

f. Automate the operation of all DAS resources.

g. Provide resource allocation accounting.

h. Provide commercial off-the-shelf (COTS) data and control interfaces for DAS customers with the flexibility of accommodating non-standard/customer-unique telemetry interfaces (e.g. use of dedicated T1s and/or fiber).

i. Provide simple, modular beamforming, demodulating, routing and storage expansion functions, which can be modularly expanded to add DAS return link channels as needs change.

j. Provide customers with the capability of obtaining dedicated DAS services as defined below.

H.2 Obtaining DAS Services

Potential customer service requirements will be subjected to a system loading analysis and an RF compatibility analysis prior to approval to use DAS. If the loading analysis determines that the availability of shared resources cannot support additional customers, the GSFC MSP will determine if additional resources must be procured. A Project Service Level Agreement will be negotiated with the customer. Planning activities are shown in Table H-1 and ideally take place a minimum of 18 months prior to commencement of services.

H.3 Customer Interface with the DAS

H.3.1 General

DAS will communicate scheduling and status information to and from the customer via the SN Web Services Interface (SWSI) (refer to SNUG paragraph 10.2.4 for further information on SWSI or the web site at: http://msp.gsfc.nasa.gov/swsi/). The SWSI interface with DAS allows the customer insight into available resources, allows the customer to submit requests for DAS services, and permits monitoring DAS service performance. Table H-2 lists information exchanged between DAS and the customer via SWSI.

Table H-1. Planning Sequence

<table>
<tr><th>1½ to 2 Years Prior to Operations</th><th>Customer Operations Begin</th></tr>
<tr><td>• Identification of DAS as Service Provider
• RF Compatibility Analysis
• Loading Analyses
• Identification of Additional DAS equipment (if needed)
• PSLA generation</td><td><u>Dedicated Customers</u>
1. DAS configured for support

<u>Non-Dedicated Customers</u>
2. Available resources configured for support</td></tr>
<tr><td colspan="2">Notes:
1. The following two classes of DAS customers will be supported:
a. Dedicated Customers – Guaranteed support from the shared set of DAS resources
b. Non-Dedicated Customers – Customers receiving first come, first serve support from the remaining set of DAS resources after allocations have been made to support dedicated customers.
2. A Spacecraft Identification Code (SIC) based processing list will be used for establishing and/or restoring services in the event of equipment failures or resource conflicts.
3. Orbiting DAS customers are required to provide customer platform mass, cross-sectional area, and drag coefficient values. These platform-specific values are needed for accurate orbit modeling which allows DAS to determine visibility and service schedules up to five days into the future. In the event these values are not provided, baseline values will be substituted which will impact orbit modeling accuracy, especially for platforms with orbits less than 750km in altitude. DAS Customers with orbit altitudes below 750 km should update the mass value whenever it varies more than 10% from the previously submitted value in order to maintain accuracy of their DAS 5-day orbit predictions.</td></tr>
</table>

H.3.2 DAS Planning/Scheduling Sequence

DAS service support begins with planning sequences. Planning sequences include interaction between DAS and the customer (via SWSI) to setup a resource allocation request within the context of the available DAS MAR resource times and the resource utilization objectives. This customer interaction will provide DAS with the time window(s) in which the customer requests DAS resources. DAS will then provide the customer with the time that service is available within that time window and the associated TDRS(s) available for the support. The customer can then vary parameters of their request derived from this information.

NOTE

> If a dedicated customer preempts a non-dedicated customer, DAS will attempt to reschedule the non-dedicated customer's preempted support at another time within the requested window.

Table H-2. DAS/Customer Interaction via SWSI

DAS will receive the following information from the customer:	DAS will provide the following information to the customer:
<u>Resource Requests:</u> • Customer location and identification • TDRS ID • Type of Service • Period of Service • Signal Characteristics (to set up demodulation and other DAS components) • Archive Requests • Data routing • Emitter ephemeris data: a. Emitter type b. Epoch Time c. Emitter Position (X, Y, Z at epoch in meters) d. Emitter Velocity (X, Y, Z at epoch in meters/seconds) e. Mass of Satellite f. Average Cross-sectional Area of Platform g. Drag Coefficient h. Solar Reflectivity Coefficient • Reconfiguration Requests • Reacquisition Requests • Status Requests	• Acknowledgement and status of requests • Resource allocation assignments • Resource availability • Emitter visibility information • Real-time service status and performance

The customer will send a request via SWSI for the resources desired, including customer identification and location (ephemeris), identification of the TDRS(s) requested, parameters of resources requested, period of the request, demodulator parameters, archive and retrieval requests, and data forwarding requirements. DAS will interact with the Customer via SWSI to establish and confirm a customer request.

Upon receipt of a specific request for resources, DAS will examine the parameters required to set up the request and determine if they are feasible. If DAS determines that the request is not within the capability of the system, DAS will notify the customer to this effect.

Upon determining that the request is feasible, DAS will allocate and reserve appropriate resources. If there are no resources available for allocation during the time frame requested, DAS will notify the customer.

DAS will notify the customer via SWSI if updated ephemeris data for the service is needed.

H.3.3 During Real-Time Events

The customer will be notified via a SWSI alert that the requested service has commenced. DAS will command archive and routing equipment for telemetry data capture before the service begins. DAS beamforming and demodulating elements will be commanded before the signal acquisition sequence is to commence. During the service, the Customer will be allowed to modify some parameters of the service. Regular status will be reported to the customer while the service is ongoing, upon request. Data will be archived and routed in accordance with the customer request. DAS will interface directly to the closed IONet and to the open IONet via the NISN gateway.

H.3.4 Archived Data Retrieval

Data that has been archived will be made available for retrieval upon request by the customer. Data that has been archived will be retained for up to 30 days. The customer can request via SWSI that DAS retrieve and route this data to the customer for use. This request must include the identification of the data to be retrieved, the parameters for routing, and the time retrieval and routing is to occur.

Appendix I. NISN Services

I.1 General

NISN provides several facilities of networked data services. This Appendix discusses only those services that pertain to the direct utilization of the SN. Please note, NASA's current policy is that commanding spacecraft over Internet segments or domains is not permitted.

I.2 Services Available

In conformance with Agency direction, the Internet Protocol (IP) has been adopted as the standard for NISN's routed data services. The legacy SN interface was built on serial clock and data interface using the 4800 bit block format (see paragraph I.2.5). However, the data service has been transitioned to an IP routed data service requiring the use of conversion devices. New SN projects should design their interfaces to be consistent with IP interfaces without serial interfaces and 4800 bit block formats.

For further information, please contact the Information Services and Advanced Technology Division, NASA/GSFC Code 290 and/or refer to the NASA Integrated Services Network (NISN) Services Document, (NISN/001-001) and the Space Operations Management Office Services Catalog.

I.2.1 IP Routed Data Services

The NISN provides Wide Area Network (WAN) voice and data communications services between the Space Network and Space Network customers using the Mission Critical and Real Time Critical IP routed Data Service. NISN has implemented a WAN to support operational data transfer between hosts and external projects called the IP Operational Network (IOnet). IOnet supports missions on a 24-hour basis transferring real-time data (attitude, orbit, ephemeris, telemetry, state vectors), as well as non-real-time data (data products, quick-look image data, and other data sets associated with small Explorer projects). The Network is monitored electronically 24 hours per day, 7 days per week. All project connections to the IOnet must be authorized via an application process defined in the Internet Protocol Operational Network (IOnet) Access Protection Policy and Requirements.

I.2.1.1 Types of IOnet

The IOnet is divided into two parts: the more secure Closed segment (Closed IOnet) and the less secure Open Segment (Open IOnet). Access between the two domains is strictly controlled via the IOnet Secure Gateway at GSFC. Customers may apply for connection to either domain as NISN requirements analysis determine and the IOnet Access Protection Policy and Requirements dictate.

I.2.1.2 Legacy MDM/4800 Bit Block

The legacy interface is targeted for End of Life in the near future and as such, it is not recommended that any new project interfaces be implemented on it. Currently, the replacement interface has not been specified at this document's time of publishing.

The legacy interface delivers and accepts data via IP multicast packets with 4800 bit block formatted data units. Customers who use this interface must be connected via the IP multicast enabled part of IOnet, which is also the most secured domain of the IOnet (see Figure I-1). Project interfaces are rigidly controlled and audited for this service, according to the IOnet Access Protection Policy and Requirements.

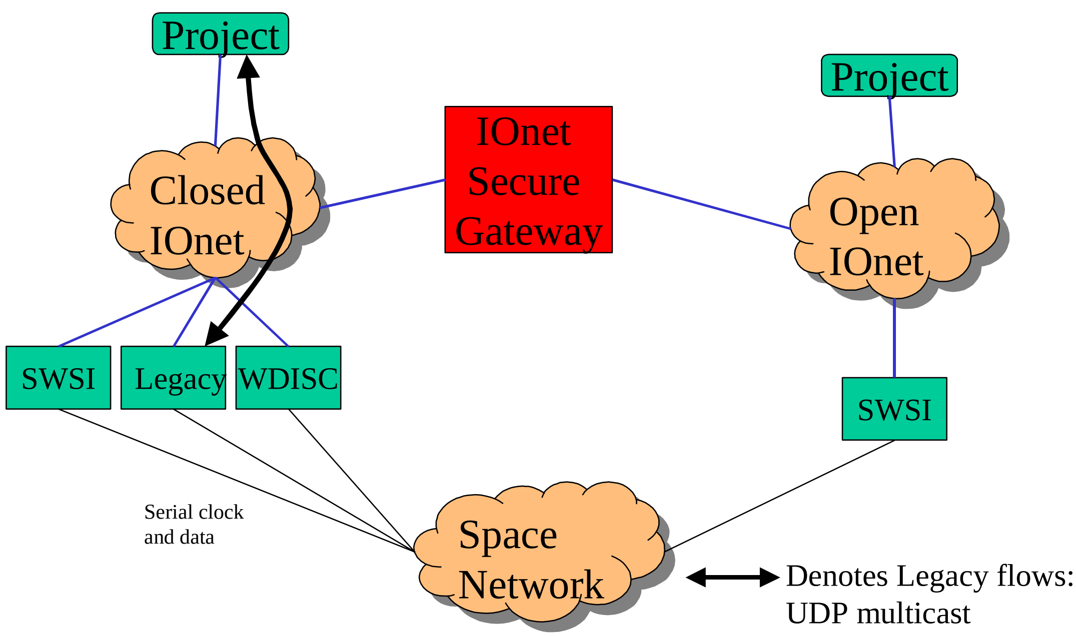


Figure I-1. NISN/SN Legacy Interfaces

I.2.1.3 WDISC IP

The WDISC IP interface is supported via Closed IOnet interface (see Figure I-2 and the IOnet Access Protection Policy and Requirements). Because this interface is Unicast IP, it is possible to interface to it via the IOnet Secure Gateway System, from the Open IOnet or beyond, as permitted in the IOnet Access Protection Policy and Requirements.

I.2.1.4 Space Network Web Services Interface (SWSI)

The SWSI is designed to be accessed from the NISN Closed IOnet or Open IOnet (see Figure I-3). NISN's Open IOnet allows access from the NASA Science Internet and the public Internet, thus allowing cooperation with NASA's university, enterprise, and inter/intra-agency partners.

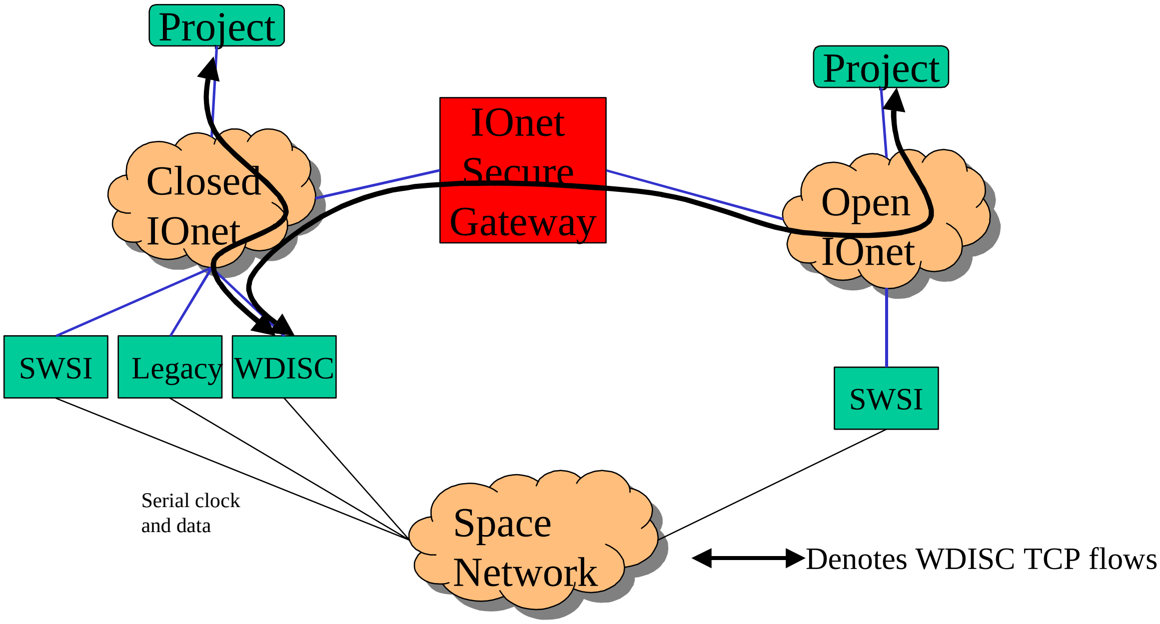


Figure I-2. NISN/SN WDISC Interfaces

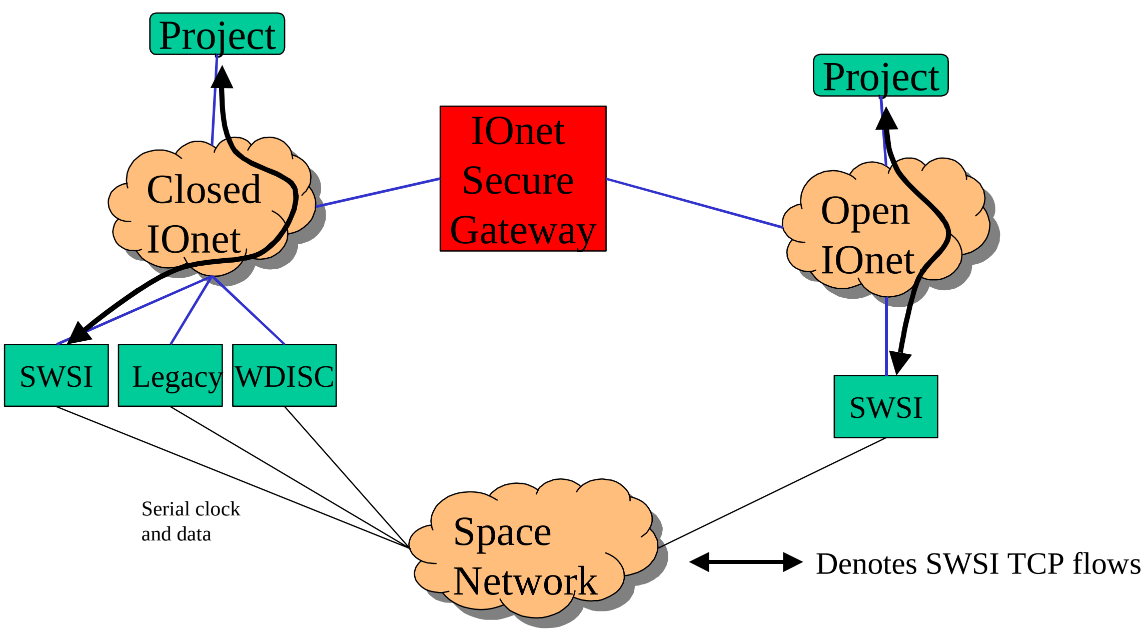


Figure I-3. NISN/SN SWSI Interfaces

I.2.2 Non-IP Routed Data Services

NISN will continue to support those legacy protocols currently in use until they can be phased out. Requirements entailing the use of protocols other than those associated with the IP protocol suite will be processed on a case-by-case basis. However, the customer is well advised to be developing or implementing plans for the modification of the supported information system(s) to interface the network using the IP protocol suite. If NISN assistance in this regard is desired, NISN engineering support is available.

I.2.2.1 High Rate Data System

The High Rate Data System is a one-way, multi-mode/multi-channel system designed for operation over a full C-band (36 MHz) domestic communications satellite transponder. Specifically, it is used to provide the ground communications path between WSC and customers at JSC (see Figure I-4). This service provides a medium for transport of a TDRSS customer's digital baseband return link when the rates are 2 Mbps or higher. The system has an upper limit for the customer's data of 48 Mbps. The satellite, when not used for data, may be used for the transmission of video information in a customer's TDRSS Ku-band return link from the WSC to JSC.

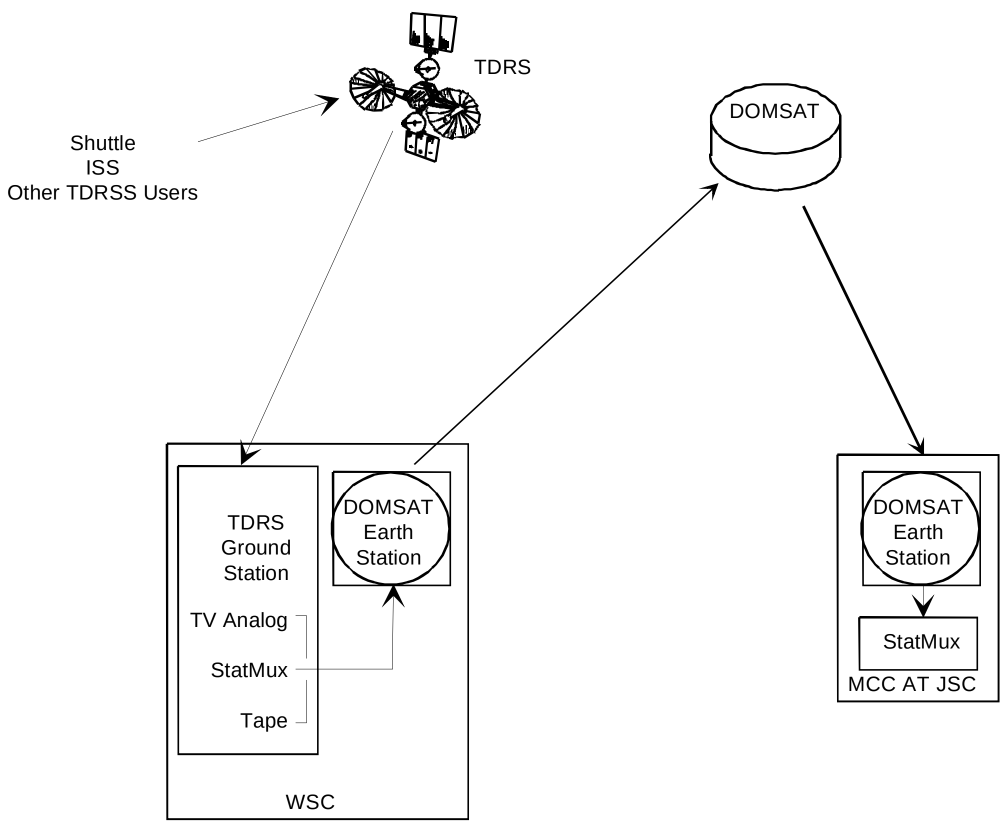


Figure I-4. Functional Configuration of High Data Rate System Block Format Description

I.2.3 Network Consulting Services

Whether a customer's requirement is as small as a simple data link between two points or as complex as a dedicated subnetwork for a specific project, consulting and integration services are available to provide the customer with one-stop shopping for the satisfaction of communication and network requirements. If the requirement is unique or does not easily fall within standard service offerings, consulting staff is offered to work with the customer to provide a tailored solution to the unique needs of a project. Examples of available services include:

a. Requirements Analysis

b. Subnetwork Engineering & Design

c. Implementation Coordination

d. Prototyping Activities

e. Network Traffic Modeling

I.2.4 Dedicated Voice Services

Dedicated Voice Services encompass a wide range of service complexity. At the simplest, it can be a dedicated point-to-point "shout down" circuit with no signaling. The majority of Dedicated Voice Services consists of a system of highly reliable, dedicated four wire voice circuits working in conjunction with switching and conferencing systems to create Mission type voice loops. These voice loops interconnect the different voice distribution systems that support the diverse Mission Control Centers within NASA. It should be noted the customer is responsible for the procurement of the unique four-wire end equipments required for their termination and local distribution of the procured four-wire Dedicated Voice Services.

I.2.5 Block Format Description

For customers electing the blocked data format option of the MDM data system, the MDM data system will return telemetry data and forward command data in the NISN (legacy NASCOM) TDRSS 4800-bit block format. The option for telemetry and command data may be independently selected. A description of the 4800-bit block is as follows:

a. General. The 4800-bit block for TDRSS-relayed telemetry and command data consists of the following elements (see Figure I-5 for an illustration of the forward command and return telemetry block format):

   1. Network header.

   2. Customer header.

   3. Time.

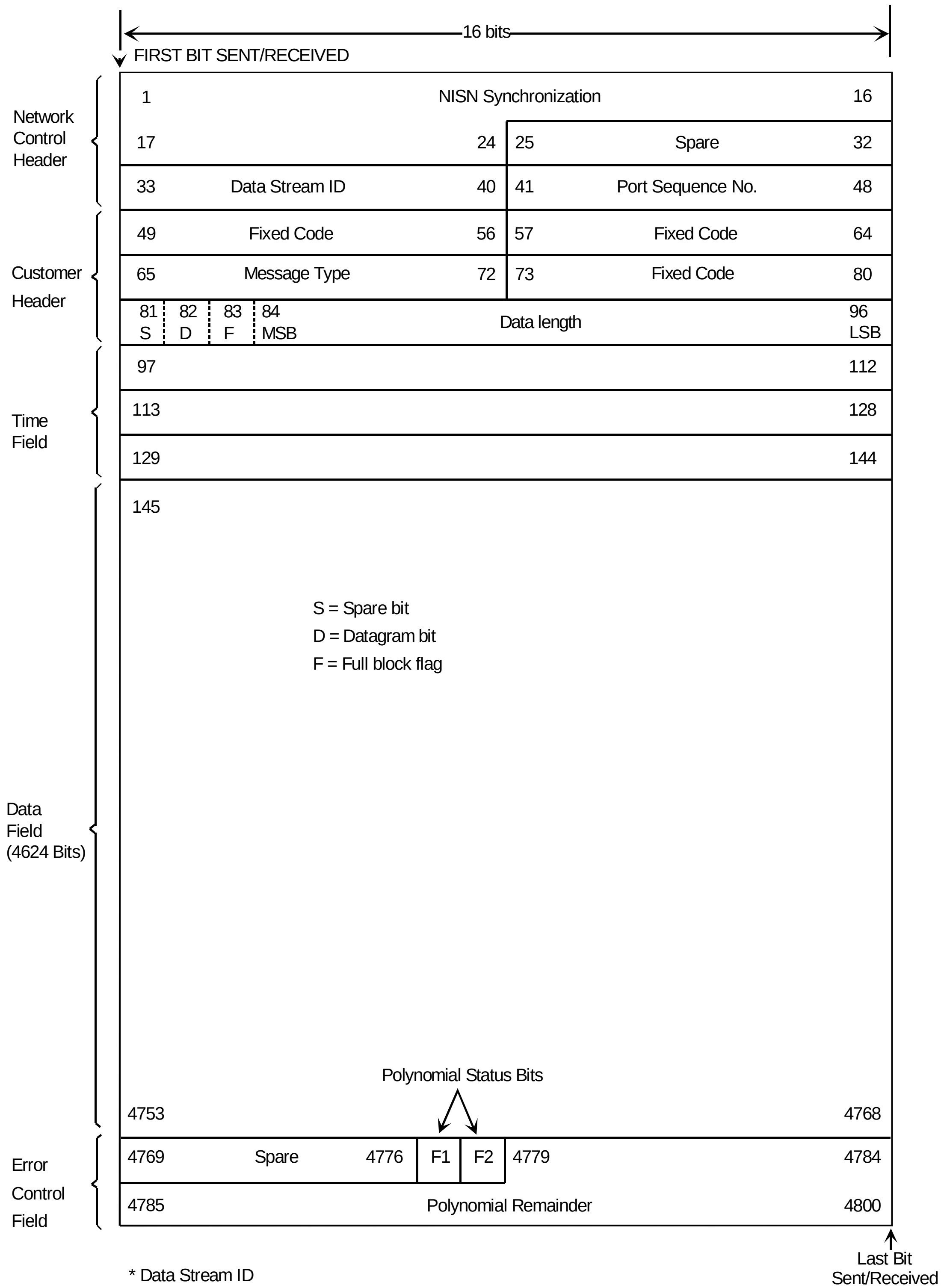


Figure I-5. NISN/TDRSS Forward Channel Command and Return Telemetry Transmission 4800 Bit Block Format

4. Data.

5. Block error control.

b. Bits 1-48: Network Header. The network header is the first 48 bits in the 4800-bit block format and contains the NISN sync code and information that may be needed by NISN for routing and accounting purposes. In the MDM forward channel application for command data via the TDRSS, its use is confined to block sync code detection.

   1. Bits 1-24: NISN Sync. The 24-bit NISN sync code is a fixed code used to determine the beginning of the 4800-bit block (627627 Hex MSB first).

   2. Bits 25-32: Spare. For telemetry data, the MDM sets this field to all binary 1's. For command data, the convention is open to the command originator. There is no requirement for the MDM.

   3. Bits 33-40: Data Stream ID. For telemetry data, the project data ID is assigned by the DSMC in scheduling coordination with the customer. Operationally, it is inserted by the MDM data system for a scheduled data flow event in accordance with the required use of the MDM channel as provided in a schedule furnished to NISN by the DSMC. For command data, the convention is open to the command originators. There is no requirement for the MDM data system.

   4. Bits 41-48: Port Sequence Number. For telemetry, this is an 8-bit binary count incrementing number (sequentially assigned to the block) and is generated by the MDM data system on a port basis at the first transmitting multiplexer. It is used for block accounting. For command data, the convention is open to the command originator. There is no requirement for the MDM data system.

c. Bits 49-96: Customer Header. The 48-bit customer header is normally reserved for information required by customer ground facilities to route and process the data contained in the block. In the MDM forward channel TDRSS application, its functional use is limited to information necessary for NISN to strip the command data out of the block and maintain a bit-contiguous serial data stream to the WSC. In the TDRSS return channel application, use of the header is similar, but the data stripping function may be performed either in the MDM data system or by the customer ground facility. For return channels, fields other than the data length and full block flags are predetermined in MDM firmware. There are other differences in forward and return channels. Applications are as follows:

   1. Bits 49-56: Fixed Code For Telemetry Data. This field contains a fixed code which is the ASCII null character (binary bit pattern 00000001). For command data, the convention is open to the command originator. There is no requirement for the MDM data system.

2. Bits 57-64: Fixed Code. Same as bits 49-56.

3. Bits 65-72: Message Type Code. For telemetry, this field contains a fixed code identifying the block as one which originated at the WSC. The codes are 16(hex) for STGT, 15(hex) for WSGT and 13(hex) for JSC. For command data, the convention is open to the command originator. There is no requirement for the MDM data system.

4. Bits 73-80: Fixed Code. Same as bits 49-56.

5. Bit 81: Spare. This bit is always set to binary 0.

6. Bit 82: Single Block Command Flag. This bit is set to binary 0 when a command message exceeds 4624 bits; i.e., a multiblock command transmission. This bit is set to binary 1 when a command message is contained within a single block. For telemetry data, this bit is always set to binary 0.

NOTE

A block with bit 82 set to binary 0 is held in the MDM terminal in the WSC until five blocks have been accumulated, until a block is received with the single block flag set, or after 200 milliseconds have elapsed.

7. Bit 83: Full Block Flag. This bit contains a flag which indicates whether the block contains fill bits in the data field. A binary 1 represents a full block condition.

8. Bits 84-96: Data Length. The last 13 bits of the customer header contain a binary count of the number of bits of data, exclusive of fill, contained in the block. This field is used by the WSC MDM terminal (command data) and by the customer ground facility (telemetry data) to assist in removal of fill data in processing the data block. The binary count equals 4624 (decimal) for the full block condition.

d. Bits 97-144: Time. For telemetry, the 48-bit time field is reserved for a time code which is in UTC having a resolution of 1 μsec. The format is NASA PB4. The time in the block represents the time that the WSC MDM terminal received the first data bit in the data field. For command data, the convention is open to the command originator. There is no requirement for the MDM data system.

e. Bits 145-4768: Data Field. The 4624-bit data field is used to transmit customer data. When the data field contains fill bits, they follow the customers data and complete the data field. A specific fill data pattern code 311 (octal) is used (binary bit pattern 11001001).

f. Bits 4769-4800: Block Error Control. The block error control field is 32 bits in length and is reserved for information used to determine if bit errors have occurred during transmission of the block. For command data, the originator is expected to insert the polynomial computed for the data content of the block at his location using an MDM-compatible algorithm. For telemetry data, this field is computed and inserted by the transmitting MDM terminal, decoded and passed to the customer by the receiving MDM terminal.

1. Bits 4769-4776: Spare. These eight bits are not used and are set to all binary 1's.

2. Bits 4777-4778: F1 and F2 Polynomial Status Flags. These bits are reserved for flags which indicate that a block either passed or failed a polynomial check when it was decoded. These bits are set to binary 1 by the customer ground facility or the NISN MDM terminal originating (encoding) the block. For telemetry data, one of these (bit 4778) is set to binary 0 by the NISN MDM terminal decoder to indicate that the block passed the polynomial check or is left as a binary 1 if an error is detected in the block. The other bit (4777) may be used for second decode process at the customer ground facility.

3. Bits 4779-4800: Polynomial Remainder: The last 22 bits of the block are reserved for the polynomial remainder which results from the originator or the NISN MDM terminal encoding the entire content of the block (excluding the NISN sync code and block error control fields). The decoding process of the NISN MDM terminal for telemetry data does not remove or alter this field. It is passed on to the customer ground facility where a second decode process may be used [refer to paragraph (2)].

Appendix J. Customer Constraints for the Expendable Launch Vehicle Class of TDRSS Customers

J.1 General

This Appendix contains the customer constraints for the S-band DG2 non-coherent Expendable Launch Vehicle (ELV) class of TDRSS customers. In general, an S-band ELV customer typically uses DG2 non-coherent service (noncoherent, non-PN coded service) with BPSK or QPSK modulation, a baud rate limit of 1024 ksps per channel, rate 1/2 convolutional coding and requires 1-way Doppler tracking.

Compliance with the customer constraints of this Appendix is expected to ensure the performance described in this Appendix; however, compatibility testing with the SN must still be performed to confirm this performance.

J.2 Customer Constraints

Table J-1 provides a summary of the customer constraints for the S-band ELV class of TDRSS customers.

Table J-1. Customer Constraints for the S-Band ELV Class of TDRSS Customers

Parameter		Specification Value
Spurious Outputs	In-band	≥23 dBc
	Out-of-band	≥15 dBc (between data bw and 2x channel bw) ≥30 dBc (outside of 2x channel bw)
Frequency Stability (peak)	Short-Term Stability	≤ ±26 x 10^{-9} for a 1 second average time (notes 1 and 2)
	Long-Term Stability	≤ ±3.77 ppm for a 5 hour observation time (notes 1 and 2) ≤ ±11.3 ppm for a 48 hour observation time (notes 1 and 2)
	Temperature Stability	≤ ±11.3 ppm over the temperature range expected during the mission (note 3)
Phase Noise (note 3)	With a Doppler tracking requirement	1 Hz – 10 Hz: ≤2.0° rms 10 Hz – 100 Hz: ≤1.0° rms 100 Hz – 1 kHz: ≤1.0° rms 1 kHz – 3 MHz: ≤1.0° rms (SMA) 1 kHz – 6 MHz: ≤1.0° rms (SSA)
	Without a Doppler tracking requirement (note 5)	1 Hz – 10 Hz: ≤50.0° rms 10 Hz – 100 Hz: ≤5.5° rms 100 Hz – 1 kHz: ≤2.5° rms 1 kHz – 3 MHz: ≤2.5° rms (SMA) 1 kHz – 6 MHz: ≤2.5° rms (SSA)
Gain Imbalance	BPSK	±1.0 dB
	QPSK	±0.5 dB

Table J-1. Customer Constraints for the S-Band ELV Class of TDRSS Customers (cont'd)

Parameter		Specification Value
Phase Imbalance	BPSK	±9°
	QPSK	±5°
Gain Flatness		≤ ±0.4 dB over ±0.7 MHz
Gain Slope		Not specified
Phase Nonlinearity		≤ ±4° over ±0.7 MHz
Spurious PM		≤ 2° rms
AM/PM		≤ 15°/dB
AM/AM		Not specified
Incidental AM		≤ 5%
Symbol Asymmetry		≤ ±3%
Symbol Rise Time		≤ 5% of symbol duration but > 35 nsec for SMA and > 17 nsec for SSA
Symbol Jitter		≤ 0.1%
I/Q Symbol Skew		≤ ±3%
Minimum 3-dB bandwidth prior to power amplifier		≥ 2 x maximum baud rate

Notes:

1. The short-term and long-term frequency stabilities determine the required stability over the time period specified and at any constant temperature (±0.5° C) in the range expected during the mission. At a minimum, a mission temperature range of -10° C to +55° C shall be considered.
2. Transmitter oscillator required to be characterized ≤ 48 hours prior to the scheduled service and the SHO be updated. Expanded customer frequency uncertainty request required in SHO, which allows a customer oscillator uncertainty of up to ±35 kHz for S-band DG2 BPSK and non-staggered QPSK signals.
3. At a minimum, a mission temperature range of -10° C to +55° C shall be considered.
4. Derivation of the phase noise requirements involved making assumptions about the distribution of the phase noise power in each frequency region. Since no phase noise PSD will exactly match the phase noise power distribution assumed for this derivation, phase noise PSDs which are close to violating the phase noise limits or phase noise PSDs which do violate the phase noise limits should be evaluated on a case-by-case basis to determine their acceptability.
5. Or can accept a total Doppler tracking error greater than the 0.2 rad/sec, perhaps as high as 3.79 rad/sec.

J.3 Acquisition

For S-band DG2 non-coherent return service, the total acquisition time is the sum of the following:

a. Carrier acquisition time

b. Symbol/Decoder synchronization time or Symbol/Deinterleaver/Decoder synchronization time (if deinterleaving is applicable)

The carrier acquisition time is discussed in paragraph J.3.1 (SMA) and paragraph J.3.2 (SSA). The synchronization time and associated requirements are given in Table 5-8 (SMA) and Table 6-9 (SSA).

J.3.1 SMA

TDRSS will achieve customer carrier acquisition within 3 seconds with a probability of 90% or greater ($P_{acq} \geq 90\%$) for customers who meet the customer constraints of Table J-1 and provide a total $(I+Q)P_{rec}$ consistent with the required P_{rec} in note 3 of Table 5-8.

J.3.2 SSA

TDRSS will achieve customer carrier acquisition within 3 seconds with a probability of 90% or greater ($P_{acq} \geq 90\%$) for customers who meet the customer constraints of Table J-1 and provide a total $(I+Q)P_{rec} \geq -190.9$ dBW or a P_{rec} consistent with paragraph J.5, whichever is greater.

J.4 Signal Tracking

J.4.1 SMA

TDRSS will provide SMA return signal tracking (carrier, symbol synchronization, convolutional deinterleaver synchronization, Viterbi decoder synchronization) as given in paragraph 5.3.3.3.

J.4.2 SSA

TDRSS will provide SSA return signal tracking (carrier, symbol synchronization, convolutional deinterleaver synchronization, Viterbi decoder synchronization) as given in paragraph 6.3.3.3.

J.5 BER Performance

TDRSS will provide 10^{-5} BER service for customers who meet the customer constraints of Table J-1 and the adjusted P_{rec} requirements as defined by Table J-2.

Table J-2. P_{rec} Adjustment for TDRSS ELV Customers

ELV Configuration		**P_{rec} Ajustment** (notes 1, 2 & 4)
		SMA/SSA
Minimum Customer Bandwidth	BPSK	-0.8 dB
	QPSK	+0.4 dB
Nominal Customer Bandwidth (note 3)	BPSK	-1.4 dB
	QPSK	-0.6 dB

Notes:

1. P_{rec} adjustment relative to the 10^{-5} BER P_{rec} requirements for DG2 channel data rates $\leq$ 1 Mbps of Table 5-8 (SMA) and Table 6-9 (SSA). The P_{rec} requirements for DG2 channel data rates $\leq$ 1 Mbps of Table 5-8 (SMA) and Table 6-9 (SSA) are based upon WSC specified implementation loss amounts of 2.6 dB and the adjustment indicated here effectively reduces the required P_{rec} by the value shown for negative numbers and increases the required P_{rec} by the value shown for positive numbers.
2. The P_{rec} amounts indicated by this table are expected to result in a 0 dB link margin; however, compatibility testing with the SN must be performed to confirm this performance. Customers are expected to take the necessary precautions to ensure an appropriate margin is maintained during the mission.
3. The nominal and minimum bandwidths are the double-sided 3 dB bandwidth introduced by the transmitter's filter. Nominal bandwidth is defined as 8x the I or Q channel baud rate, whichever is greater. Minimum bandwidth is defined as 2x the I or Q channel baud rate, whichever is greater.
4. The P_{rec} adjustment values are based upon analysis of the combined effect of all constraint parameters at their maximum values. The P_{rec} adjustment value may be improved for customers operating with constraints at less than the maximum values. Customers should contact the GSFC MSP for compatibility testing and further analysis.

Appendix K. Use of Reed-Solomon Coding in Conjunction with SN User Services

K.1 General

This Appendix describes the use of Reed-Solomon (R-S) coding, both alone and combined with convolutional coding. The SN supports R-S decoding for WDISC customers only; however, the data rates supported by the WDISC are limited (refer to Section 3.6 for further information). Although the SN does not presently support R-S coding for all data rates, the customer MOC may perform R-S decoding for improved performance.

The Consultative Committee for Space Data Systems (CCSDS) has recommended the following telemetry coding standards for space communications [1]:

a. Rate-1/2 convolutional coding.

b. (255, 223) R-S coding.

c. Concatenated coding: a rate-1/2 convolutional inner code with a (255, 223) R-S outer code.

d. Turbo coding (not discussed in this Appendix).

In the discussion that follows, all operating points (BER vs E_b/N_o) are based on the theoretical (best-possible) performance of the forward error correction code. Thus, all operating points discussed are illustrated by the theoretical curves in Figure K-1. In practice, the actual E_b/N_o required for any SN-specified operating point is the theoretical value plus the SN's allowable implementation loss for the service type, configuration, data rate, and channel coding. The P_{rec} values in the main body of this document include this implementation loss. The P_{rec} reduction values given in section K.4 below assume the customer is compliant with all constraint parameters.

K.2 Concatenated Coding: A (255, 223) Reed-Solomon Outer Code with a Rate 1/2 Convolutional Inner Code

K.2.1

Throughout the SNUG, the customer's P_{rec} has been specified to maintain a 10^{-5} BER in an AWGN channel. At this BER, rate-1/2 coding allows customers to reduce their required P_{rec} by 5.4 dB relative to an uncoded signal. Concatenated coding – the use of R-S coding as an outer code with a rate-1/2 convolutional inner code – can further improve BER performance. Customers planning to operate at a BER worse than 10^{-5} at the output of the WSC convolutional decoder are required to negotiate support with the GSFC MSP.

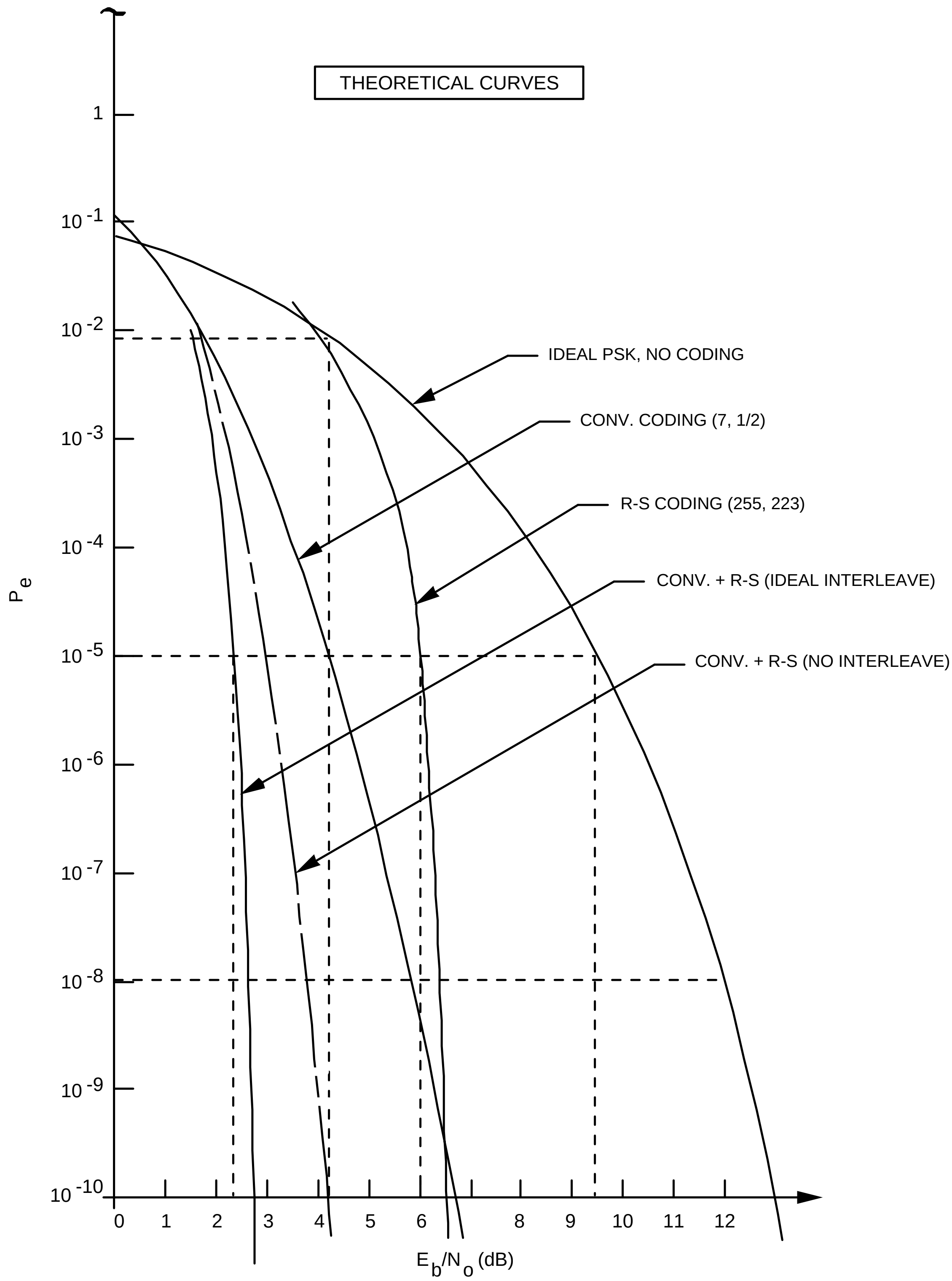


Figure K-1. Theoretical Performance of Concatenated, R-S, and Convolutional Coding (from [2])

NOTE

> Throughout this document, the coding gain achieved by using rate 1/2 convolutional coding is already included in the equations for determining the return link minimum required Prec for a 10^{-5} BER.

K.2.2

Figure K-1 shows the theoretical performance of concatenated coding. Customers with an E_b/N_o of 4.2 dB (referenced to the data rate of the convolutional code) can achieve a BER of 10^{-5} at the output of the convolutional decoder at the WSC, and a BER of 10^{-10} at the output of the R-S decoder (without interleaving).

K.2.3

Although the CCSDS recommendation for telemetry coding does not include periodic convolutional interleaving (PCI) of the convolutional encoder output symbols, PCI is recommended for S-band customers with concatenated coding and channel baud rates > 300 kbps. When interleaving is not employed for channel baud rates > 300 kbps, S-band performance may not be guaranteed.

K.3 (255, 223) Reed-Solomon Coding (Without Convolutional Coding)

K.3.1

Since all S-band return services (SSAR, MAR, and SMAR) require convolutional encoding, R-S coding alone (without the convolutional inner code) applies only to the KuSA and KaSA return services. Uncoded signals must maintain an E_b/N_o of 9.6 dB in an AWGN channel in order to achieve a 10^{-5} BER at the WSC. R-S encoding alone, in conjunction with KuSAR or KaSAR service, allows the customer to reduce their P_{rec} by up to 3.0 dB and still achieve a BER better than 10^{-7} at the output of the R-S decoder.

K.3.2

When transmitting at a reduced P_{rec} with an E_b/N_o less than 9.6 dB, the customer will be operating at a BER worse than 10^{-5} at the input of the R-S decoder.

K.4 Summary

K.4.1

The resultant P_{rec} reductions and BER performance with R-S encoding are summarized in Table K-1. R-S decoding is performed either by the SN for WDISC customers or at the customer MOC.

Table K-1. Performance of R-S Encoding in Conjunction with SN Services

Coding Scheme	Reference Point (notes 3 and 4)		Resultant P_{rec} Reduction for BER
	Input to R-S Decoder (note 1)	**Output of R-S Decoder (WSC or MOC)**	
Concatenated Coding (note 5)	E_b/N_o = 4.2 dB BER = 10^{-5}	BER ~ 10^{-10}	None; better BER at R-S decoder
(255, 223) R-S Coding Only	E_b/N_o = 9.6 dB BER = 10^{-5}	BER much better than 10^{-10}	None; better BER at R-S decoder
	E_b/N_o = 6.6 dB BER worse than 10^{-5} (note 2)	BER better than 10^{-7}	3 dB

Notes:

1. E_b prior to R-S decoding is referenced to the customer data rate at the input to the R-S decoder (that is, the information rate multiplied by 255/223).
2. Support for signals with BERs worse than 10^{-5} must be negotiated with the GSFC MSP.
3. BERs assume ideal R-S performance as well as an ideal communications channel between the WSC and the MOC.
4. Customers must also comply with the P_{rec} requirements for signal acquisition and antenna autotrack acquisition, if applicable.
5. This Appendix uses the term concatenated coding to represent a rate-1/2 convolutional inner code with a (255, 223) R-S outer code.

K.4.2

The reduction in P_{rec} applies only to the P_{rec} required for BER performance. Customers must also comply with the P_{rec} requirements for signal acquisition and antenna autotrack acquisition, if applicable. Support for signals with a BER worse than 10^{-5} must be negotiated with the GSFC MSP.

K.4.3

Customers operating in an RFI environment will experience additional losses that have not been characterized at this time. Such customers should coordinate with GSFC MSP to determine performance.

References

1. "Telemetry Channel Coding," Recommendation for Data System Standards, CCSDS 101.0-B-4, Blue Book, Issue 4, Consultative Committee for Space Data Systems, May 1999.
2. Advanced Orbiting Systems, Networks and Data Links: Summary of Concept, Rationale, and Performance," Recommendation CCSDS 700.0-G-3, Green Book, Issue 3, Consultative Committee for Space Data Systems, November 1992.

Appendix L. McMurdo TDRSS Relay System (MTRS)

L.1 General

The MTRS consists of two TDRS relay ground systems, known as MTRS-1 and MTRS-2, which are within the National Science Foundation's (NSF) McMurdo facilities in the Antarctic. The Wallops managed McMurdo Ground Station (MGS) receives S-band and X-band data from orbiting missions. The X-band data can be connected to the MTRS to provide a method for near real-time or stored high rate scientific data through TDRS to WSC for delivery to end users. The MTRS can be used to relay up to 300 Mbps. Please contact the GSFC MSP for the latest information and potential support.

L.2 Operational Overview

Figure L-1 depicts an overview of the MTRS data flow from orbiting missions to the WSC. The prime MTRS-1 system is located on Black Island about 35 km southeast of McMurdo and provides greater than 20 hours of daily TDRS view for relaying data from McMurdo (using TDRSS located at both 171° and 174° west longitude). The backup MTRS-2 system is located on Ross Island near the MGS and provides approximately 10 hours of daily TDRS view for data relay (using the TDRS at 171° west longitude). Only one MTRS relay is used at a time depending upon their availability and status.

Both MTRS-1 and MRTS-2 are interfaced to the MGS system and can be remotely operated at MGS for data transfer via TDRS (174° W/171° W) to WSC. The MTRS transmits the data via the TDRSS KuSA return service at total data rates up to 300 Mbps. At this time, planning is ongoing to support polar missions on a "demonstration capability basis" for high rate relay of data from the MGS thru MTRS to WSC. Currently, MTRS is not considered to be an "operational asset", but may be in the near future. Please refer to the Operations Interface Procedures for the McMurdo TDRS Relay System, 532-OIP-NCC/MTRS, for additional information. Additionally, scheduling coordination needs to be performed between all elements to ensure successful relay of data.

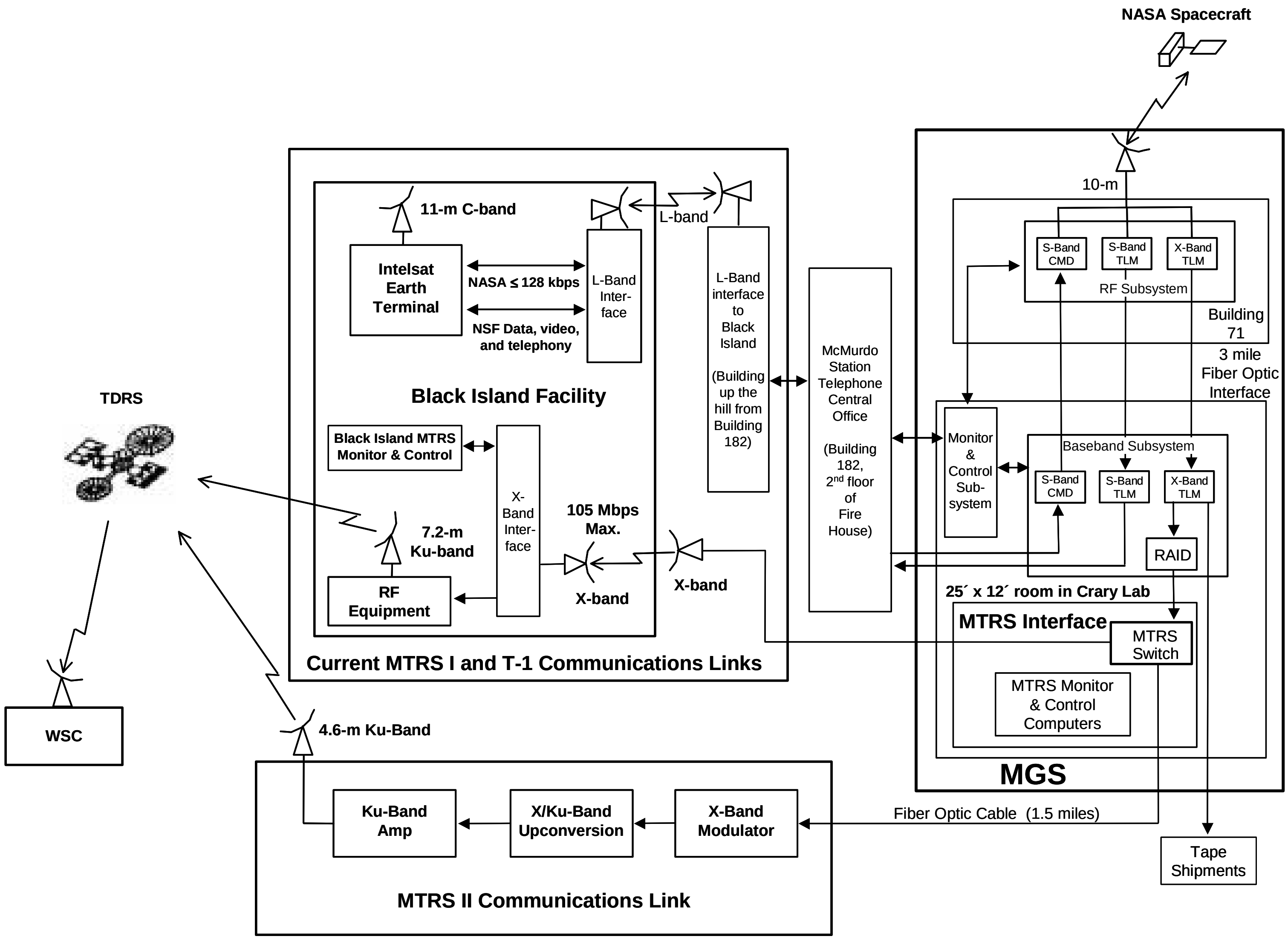


Figure L-1. MTRS Data Flow

Appendix M. South Pole TDRSS Relay (SPTR) and WSC Alternative Resource Terminal (WART)

M.1 General

M.1.1 South Pole TDRSS Relay (SPTR)

The SPTR, located at the Amundsen-Scott South Pole Station, Antarctica, provides connectivity to the South Pole science LAN enabling Internet connectivity via the TDRSS SSAR and high rate FTP via the TDRSS KuSAR.

M.1.2 WSC Alternative Resource Terminal (WART)

The WART provides dedicated support to the NSF operations at the South Pole (primarily to the SPTR that is located at the true South Pole) and control of the F-1 TDRS. This will be a limited capability in that it will only provide the functionality listed below:

a. TT&C for F1

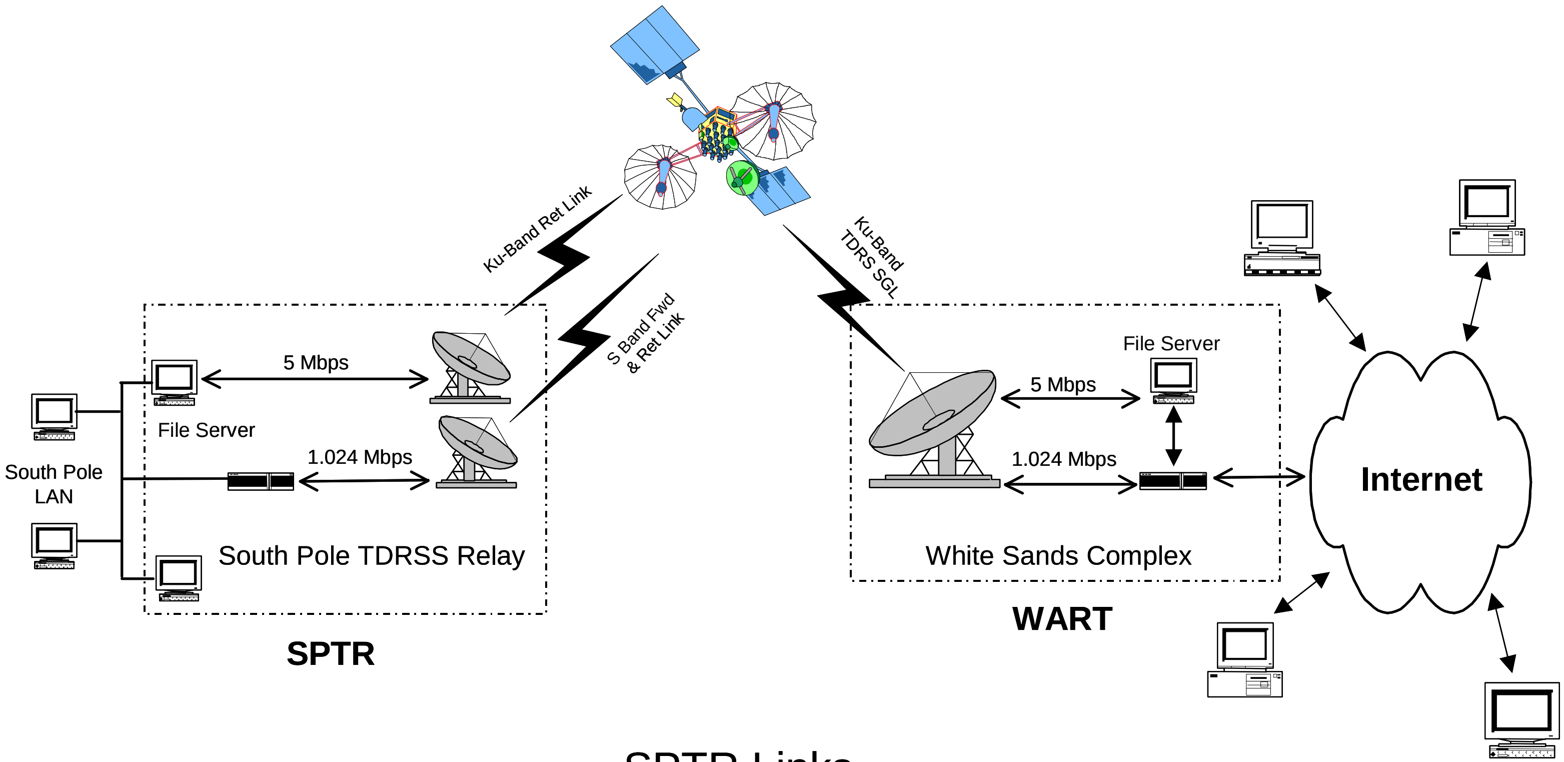
b. SSA forward/return at 1.024 Mbps

c. KuSA return at 5 Mbps

M.2 Operational Overview

Figure M-1 depicts an overview of the SPTR/WART data flow. TDRSS service via the SPTR/WART consists of using the SSAF and SSAR services at a 1Mbps rate for full duplex Internet communications, and the KuSAR at a 5Mbps rate for simplex file transfer communications (server-to-server file replication). The SPTR system can only use the highly inclined TDRS F1 spacecraft currently located at 49° West longitude, which provides approximately 5 hours of daily communications.

WART, located at WSGT and using the spare 60-foot antenna, provides dedicated support to the NSF operations at the South Pole and control of the TDRS F1. WART is interfaced to the NASA Internet for real time South Pole TCP/IP communications and contains a file server from which the customers can FTP their stored files once transfered via SPTR. Please refer to the Standard Operating Procedures, CSOC-WSC-SOP-306, for the SPTR System, and the Operations Concept, CSOC-WSC-OC-001310 for the WART system, for additional information.



SPTR Links

- S-Band Forward and Return @ 1.024 Mbps IP
- Ku-Band Return 5 Mbps File Transfer Service

Figure M-1. SPTR/WART Data Flow

Appendix N. Network Test Services

N.1 General

This Appendix presents overview information that supplements existing NASA test documentation regarding NASA's compatibility test methodology and SN systems test methodology. The contents are completed to a level intended to summarize the test methodology, possible configurations, resources, participating organization responsibilities, and test planning activities.

N.2 Verification Methods

The following methods of verification can be applied to verify the customer functional, interface, and performance requirements.

a. Test

b. Evaluation

c. Demonstration

N.2.1 Test Method of Verification

Test is the method of verification whereby requirements are verified by measurement during or after the controlled application of functional and environmental stimuli. These measurements may require using laboratory equipment, recorded data, procedures, test support items, or services. For all test activities, pass or fail test criteria or acceptance tolerances are specified prior to conducting the test. This method ensures that the actual performance of tested equipment or systems meets or exceeds specification requirements.

N.2.2 Evaluation Method of Verification

The evaluation method of verification is used when actual operational conditions cannot be entirely simulated, the test parameters cannot be completely tested at the "box" level, or it is too costly to use the test method of verification. Evaluation may use the results from limited tests or multiple lower level tests and analyses. The data taken can be compared to the transceiver requirements, but are generally not sufficient to provide verification to the extent of the test method.

N.2.3 Demonstration Method of Verification

Demonstration is a method of verification used to imply the properties of an end item or component in which operations or physical characteristics of the end item are observed. This observation may exercise equipment operations, functions, and/or characteristics that are not specified as explicit end item requirements. Demonstration is used with or without special equipment or instrumentation to verify characteristics such as operational performance, human engineering features, maintainability, built-in transportability, and display data. When used as a formal verification activity, the observed demonstrated performance is recorded.

N.3 Test Services Description

Test services can be discussed in categories of testing. An example of the typical Phased Test & Verification Chronology is:

a. Component Level Testing

b. Integrated System Testing

c. End-to-End Testing

d. Simulations & Training Exercises/Launch Site Testing

N.3.1 Component Level Testing

Component level testing is defined as installation and setup of an individual communication element in a “stand-alone” box test configuration. The objectives are focused on the component’s functional capabilities in order to determine the unit’s adherence to specifications and operational goals. The testing also includes the installation and setup of the test equipment to ensure proper configuration and test readiness. The testing checks new hardware and software to ensure that it will work in the existing network environment.

N.3.2 Integrated System Testing

The integrated system level of testing is performed when the customer communication subsystem is integrated as an operational system and ready for testing. Integration testing confirms hardware connectivity to support systems and that the support software is properly installed and operational. During this testing the overall system capabilities are evaluated. The objectives are focused on the integrated system functional capabilities in order to determine the unit’s adherence to specifications and operational goals. In the integrated configuration the effects of the various avionic equipment are accounted for and compared to the expected overall functionality of the system to meet the necessary operational needs.

N.3.3 End-to-End Testing

End-to-end testing (EET) is conducted to verify data flow through the entire end-to-end system (space to ground). The testing ensures that all mission functional support elements perform in a mission configuration. The testing involves the control center, data circuits, and SN interfaces to the customer platform.

N.3.4 Simulations & Training Exercises/Launch Site Testing

Pre-launch customer/SN simulation testing can be used to validate SN performance with customer communication equipment prior to the launch of the customer platform. This validation includes operations checkout, end-to-end tests, and fault simulation tests. This simulation testing can be performed at a customer facility or at the customer platform launch site. In addition, training for customer project personnel can be accomplished. The guidelines for this support appear in the STDN Test and Simulation Support Plan, 530-NOP-STDN/TS, and the STDN No. 403 series document for a particular customer.

N.4 Network Test Support Organizations

N.4.1 RF Simulation Operations Center (RF SOC)/Simulation Operations Center (SOC)

The RF SOC and SOC, located at GSFC, provide facilities for conducting customer flight project mission simulations for SN customers. It can monitor SN performance during these mission simulations, simulate a mission-unique customer platform, verify SN/customer MOC interfaces, and simulate a customer MOC in support of fault isolation. Additional information regarding the capabilities of the RFSOC can be found at http://tss.gsfc.nasa.gov/rfsoc.htm. Additional information regarding the SOC can be found at http://tss.gsfc.nasa.gov/soc.htm.

N.4.2 Compatibility Test Van (CTV)/Compatibility Test Laboratory (CTL)

Home-based at GSFC, two CTVs provide the means to test customer platforms at remote locations for RF compatibility with the SN, which may include an end-to-end test after compatibility testing is completed. Each CTV can provide cabled RF interfaces to a customer platform for local RF compatibility testing. The CTV also has a rooftop antenna for TDRSS relay performance tests. Similar in capability to the CTV, the GSFC-based CTL can provide cable RF interfaces to a customer platform for local RF testing and a rooftop antenna for SN performance tests. In this case, the customer brings the platform RF components to the GSFC CTL and these components are set up in an RF-shielded screen room for testing. Additional information regarding the capabilities of the CTV and CTL can be found at http://tss.gsfc.nasa.gov/ctl.htm.

N.4.3 TDRSS End-to-End Test Systems

Equipment is available at all three WSC ground terminals (STGT, WSGT, and GRGT) to provide customers with end-to-end system testing capabilities. The TDRSS EET systems provide customer projects the capability of testing the end-to-end SN data communications through a ground-based simulation of the customer platform-to-MOC link via TDRSS, thus eliminating the need for the actual customer platform (see paragraph N.6.1.2.d). Each EET system can simultaneously provide end-to-end testing of forward, return, and tracking services for one S-band (SSA or MA) and one Ku-band

(KuSA) customer. Please note that TDRSS does not provide EET services for Ka-band (KaSA) customers. Also note that since GRGT has no interface to support receiving and transmitting test data with the customer, EET via GRGT is limited to local mode.

N.5 Determining Required Testing

Through coordination with the GSFC MSP Customer Commitment Manager (CCM) and MSP test personnel, the customer project will receive assistance in determining the appropriate testing necessary to confirm SN compatibility and configuration readiness. There are tests that are typically performed at the different levels of customer readiness. For example, a customer preparing for a mission that has proven TDRSS communications components will most likely require testing from the integrated system test perspective. On the other hand, a customer with a first-time TDRSS component may require the whole range of testing. In addition, some testing might be optional (i.e., “ship-n-shoot” with no launch site testing).

N.6 Test Planning, Scheduling, and Reporting

N.6.1 Test Planning

N.6.1.1 Test Planning Process

Coordination with GSFC MSP personnel to obtain the necessary resources is essential. GSFC MSP management and test personnel will schedule WSC, CTL, CTV, SOC, and RF SOC resources accordingly to meet customer mission timeframes.

N.6.1.2 Basic Phases of Testing

The basic phases of testing supported by the SN are as follows:

a. RF Engineering Lab/Bench Testing. RF Engineering Lab/Bench Testing is performed by network engineering personnel using the TDRSS User RF Test Set (TURFTS) to complete engineering tests not readily supported by the hardware vendor. This testing is a prerequisite to TDRSS compatibility testing, and involves physical interface checks and an initial checkout of the overall functionality of the stand-alone communications transmitter/receiver. Additional vendor supplemental testing may also be conducted. Additional information regarding the capabilities of the TURFTS can be found at http://tss.gsfc.nasa.gov/rfs.htm.

b. TDRSS Compatibility Testing. The purpose of TDRSS compatibility testing is to verify that the communication unit parameters and equipment are compatible with TDRSS. Successful TDRSS compatibility testing is a prerequisite for a SN commitment to support a customer project and is a building block in the progression to certifying mission readiness. The customer’s RF ICD with the SN is one of the primary documents used to develop the Compatibility Test Plan (CTP). Compatibility testing is performed by the CTV (for testing at remote customer locations) and the CTL (for testing customer systems at GSFC). Information about TDRSS compatibility testing is contained in STDN No. 408, the TDRS and GSTDN Compatibility Test Van Functional Description and Capabilities.

In general, the CTV and CTL perform the following functions: (1) act as a SN simulator to verify the integrity of the RF link; (2) provide assurance that the SN tracking, telemetry and command parameters, as well as equipment and operational procedures, are adequate to meet the communication requirements; (3) serve as an RF relay between customer equipment and the TDRS; and, (4) serve as a test set for fault isolation.

Compatibility tests are performed to analyze the SN command forward link and telemetry return link modes of transmissions to and from the unit. Testing is conducted with pseudorandom data generated from a data transmission test set. A series of preliminary RF engineering tests are selected and conducted in accordance with STDN No. 408.1, the STDN Spacecraft RF Compatibility Test Procedure and Data Sheets document. These compatibility tests check the unit performance parameters and verify the interoperability of the system signals with the SN. These tests are designated by number groups which are categorized by customer platform carrier tests, command signal tests, acquisition and tracking tests, and forward/return link bit error rate (BER) tests.

Verification tests are a variety of tests that are performed after engineering tests are complete. This series of tests provide an initial validation of command, telemetry, and tracking data services with the new customer. The testing encompasses verification of scheduling, status, and control functions. These tests emphasize problem resolution and assist a new customer with meeting all SN interface requirements.

c. SN Interface Testing. SN Interface Testing is designed to test the end-to-end RF link performance of the unit with an operational TDRS. The test utilizes the CTL and/or the CTV.

SN RF Tests operationally verify the following:

1. Forward link service from a TDRS to the unit.

2. Return link BER Performance and link margin for SN services from the unit to a TDRS with simulated antenna assembly gain.

3. Reacquisition of both forward and return services, following a momentary interruption of services.

d. SN Performance Baseline Testing. The SN utilizes the TDRSS EET capability to validate the network’s ability to support forward and return link services for a customer unit. This testing verifies the SN configurations required to support the return and forward links, configuration codes, and WSC modifications and configurations independent of the customer, through the conduct of EET simulations. This evaluation confirms the SN configuration required to support customer testing, and provides SN performance evaluation and characterization baseline data. This testing is available for the simulation of SSA, MA, and KuSA services, however, it is not available for KaSA services. Figure N-1 provides a high level illustration of SN Baseline Characterization.

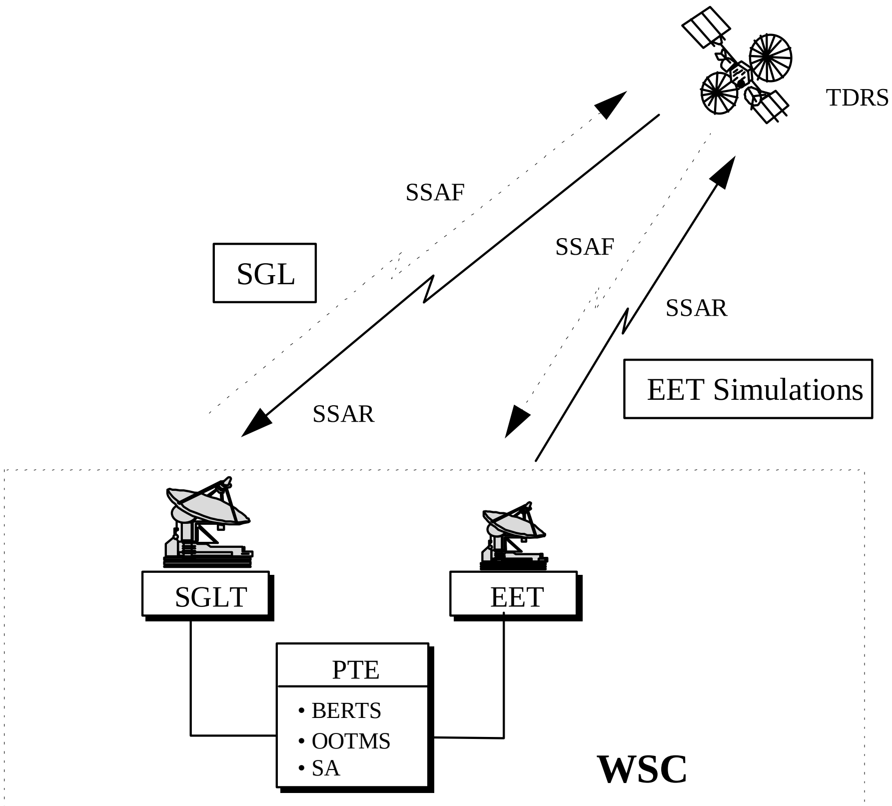


Figure N-1. SN Baseline Characterization

N.6.2 Test Scheduling

The use of all SN test resources must be formally coordinated through the GSFC MSP. These resources include, but are not limited to, the SN, NISN, and other supporting elements. Refer to paragraph N.6.1 to see the process for test planning.

The scheduling of SN test resources is initiated by the Goddard Test Director (GTD), who is located at GSFC. Based on customer coordination with the GSFC MSP, the GTD submits planning inputs to the SN Forecast Schedule (see Section 10 for a description of SN event scheduling), which is issued on a weekly basis for planning purposes. Contingency or backup test dates may also be scheduled for tests that require critical or scarce resources.

N.6.3 Network Configuration and Briefing Messages

The network configuration is specified in the Briefing Message (BM), which is issued for each TDRS test. Control of the overall network is maintained by WSC, which provides details of specific configurations for specific test dates. A BM is issued three days before the RF-through-TDRS test in order to orient and advise all SN participants and supporting elements. Draft BMs are circulated up to two weeks in advance for review and refinement. The BM is generated by the GTD and contains a test title, the date and time for the test, a test time line, and a description of the element responsibilities for the test. BM coordination and scheduling normally begins four weeks prior to a test.

N.6.4 Test Readiness Review

Test personnel may conduct an internal Test Readiness Review (TRR) prior to the start of testing to verify equipment and personnel safety.

A TRR may be held no later than 2 days prior to the performance of test events. At this meeting, all test activities and responsibilities are reviewed for completeness.

N.6.5 Test Reporting

Test results are documented in reports that cover all phases of testing.

a. RF Engineering Report. Test results are logged in an engineering notebook. A memorandum documenting the test results is prepared by test personnel and distributed the following workday after the completion of each day's tests.

b. CTV Compatibility Test Report. A test result report is produced by compatibility test personnel after detailed analysis of the data taken during the RF link compatibility tests. This report includes performance plots, equipment/setup photographs, and completed data sheets. The report is usually delivered within two months after test conclusion.

c. SN Test Report. A series of daily SN Test Reports (TRs) produced by the GTD provides the inputs required to conduct a post-test evaluation and data analysis contained the SN Test Report. The report is usually delivered a few days after test conclusion.

d. Quick-Look Report. A quick-look report is a technical performance evaluation provided on the following workday. This report also outlines the test objectives and notes whether all the objectives were met, or if a retest is required. For Compatibility Testing, compatibility test personnel generate a quick-look memo that provides a preliminary look at the results of the test. Responsible test personnel provide quick-look memorandums 1-3 days after the completion of each test. Test procedures and briefing messages detail the information collected from all participants.

Appendix O. Self/Mutual Interference Considerations for New Customers at 2287.5 MHz

O.1 Introduction

This Appendix provides an assessment of self/mutual interference in the TDRSS MA environment at 2287.5 MHz, based on the results of an interference analysis performed on the 2287.5 MHz RF environment[1]. Self interference is the interference incurred from other MAR/SMAR customers. Mutual interference is the interference incurred from SSAR customers operating at 2287.5 MHz. The amount of self and mutual interference included in a customer's MAR/SMAR link budget should be negotiated with the GSFC MSP.

Improving TDRSS capabilities potentially increase interference on the MAR link due to rising data rates. The F1-F7 series increased its maximum data rate to 150 kbps per channel from 100 kbps. In addition, the TDRS F8-F10 series will expand the MAR capability to a data rate of 1.5 Mbps per channel. Finally, for the DAS, the quantity of customers is not limited by the SN ground infrastructure.

Currently 2 dB is built into the MAR/SMAR required P_{rec} equations given in Section 5 for self and mutual interference degradation. In addition, ACRS may be used to mitigate interference. ACRS is a tool that customers can utilize to determine potential future interference periods with other customers. The customers can then try and schedule their services around the times when they would be subject to high interference. The GSFC MSP may support customers with a self and mutual interference degradation of less than 2 dB; however, this type of support needs to be coordinated with the GSFC MSP.

O.2 Interference Study

The MA interference study was conducted to examine the impact of the near term interference environment, with different TDRSS constellations, on system interference. The current allocation of 2 dB for mutual and self-interference was evaluated on its ability to protect customers from data loss due to interference, as well as its appropriateness for Demand Access type customers.

The interference was studied using large Monte Carlo simulations, designating one customer as a victim, and the other customers as interferers. The simulation considered the orbits, antenna patterns, and TDRS link budgets of all the customers. A candidate mission model was developed for 2287.5 MHz customers in 2003. This mission model included: current customers, BRTS, projected unspread high data rate

[1] "Interference Analysis for Management of the Interference Environment at 2287.5 MHz", Prepared for Badri Younes by ITT Industries under contract S-87070-Y, ETS-450-100028, August 18, 2000.

customers, and projected profile of Demand Access customers. Besides identifying customers and their link characteristics, the mission model also determined duty cycles for each link. For further information concerning the mission model, contact the GSFC MSP to obtain a copy of the full analysis report[1].

The simulations generated interference statistics for different customers and TDRSS constellation scenarios. Different TDRSS constellation scenarios were investigated to represent the phasing of the F8-F10 satellites, which can support higher customer data rates. The principal output was the percentage of time that a given customer experienced different levels of E_b/N_0 degradation due to the interference from other customers.

Table O-1 shows the scenarios for which simulation runs were done, including the TDRS satellite locations for each. The simulations accounted for geometric considerations as well as customer duty cycles. The analysis report also presents static analysis results for a worst-case boresight interference, which do not consider geometry or duty cycles.

Table O-1. Defined Interference Scenarios

Scenario	F1-F7 TDRSS satellites Locations (note 1)	F8-F10 TDRSS satellite locations (note 1)	Mission Model
1	41W, 174W, 85E	None	• 2003 mission model • Projected Demand Access profile
2	41W, 46W, 171W, 174W, 85E	None	• Same as scenario 1
3	41W, 46W, 174W, 85E	171W	• 2003 mission model • Projected Demand Access profile • High power, high data rate DG2 customers with directional antennas • High power, high data rate DG2 customer with omni antenna
4	41W, 174W, 85E	46W, 171W	• Same as scenario 3
Note: 1. For all scenarios, customers were randomly assumed to receive support from available TDRS East (41W and 46W) and West (171W and 174W) satellites. Customers were only assumed to receive support from the TDRS ZOE (85E) satellite when no other TDRS was in view.			

O.3 Conclusions From Interference Study

Several conclusions were drawn from the results of the interference simulations:

a. For Scenarios 1 and 2, which do not include TDRS F8-F10 spacecraft or high power TDRS F8-F10 customers, most of the existing MA customers have enough extra EIRP margin to keep the self/mutual interference rate below 5%.

   1. Those customers that have only the 2 dB self/mutual interference allocation experience interference rates approaching 10%.

   2. This indicates that P_{rec} margin is a strong predictor of performance against self-interference.

   3. As expected, the interference rates show a consistent small reduction in scenario 2, due to the presence of 5 TDRS satellites instead of 3.

b. The results for Scenarios 3 and 4 show somewhat increased interference, as might be expected in the presence of high power F8-F10 customers, but interference rates still remain below 10% for the most part.

c. With roughly 2 dB of margin beyond the SNUG P_{rec}, the percentage of time that service is impacted for a victim by the MA self/mutual interference can be reduced to less than 5%.

d. Even more margin seems to eliminate the effect of self-interference altogether.

O.4 Effect of P_{rec} Margin on Interference

The P_{rec} specified in the SNUG already includes a 2 dB allocation for self/mutual-interference. The amount by which an MA customer's P_{rec} differs from the SNUG P_{rec} is called the margin. The point at which service is impacted with loss of data is defined as the case when the margin against the P_{rec} has been used up, as well as the self and mutual 2 dB allocation for interference.

The results from the simulations were analyzed for the effect of P_{rec} margin on the interference. The plots below show average service impact percentages for different victims, versus the P_{rec} margin above the 2 dB interference allocation. Scenario 3 was not plotted due to its similarity to Scenario 4 for most of the victims. Figure O-1, Figure O-2, and Figure O-3 show results for Scenarios 1, 2, and 4. Certain conclusions can be drawn from this analysis of interference versus P_{rec} margin:

a. With roughly 1.5 to 2 dB of margin beyond the SNUG P_{rec}, the percentage of time that service is impacted for a victim by the MA self/mutual interference can be reduced to less than 5%, for Scenarios 1 and 2.

b. With no additional margin allocated beyond the SNUG P_{rec}, a victim suffers worse interference on average in Scenario 4. However, additional margin of 2 dB is sufficient to reduce the average interference time to less than 5%.

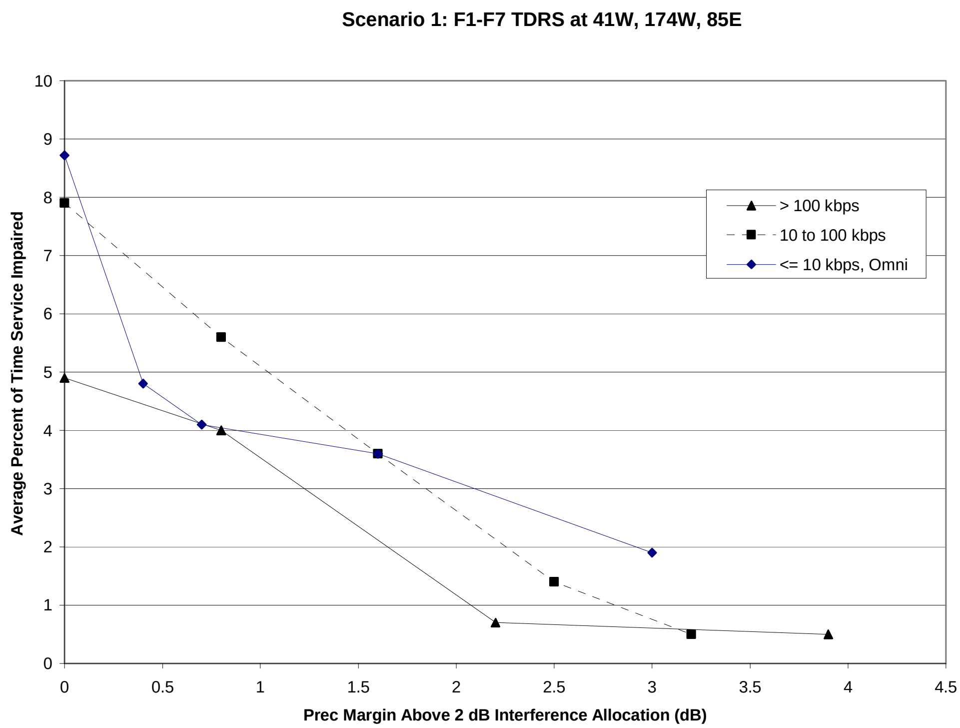


Figure O-1. Average Service Impact Versus P_{rec} Margin, Scenario 1

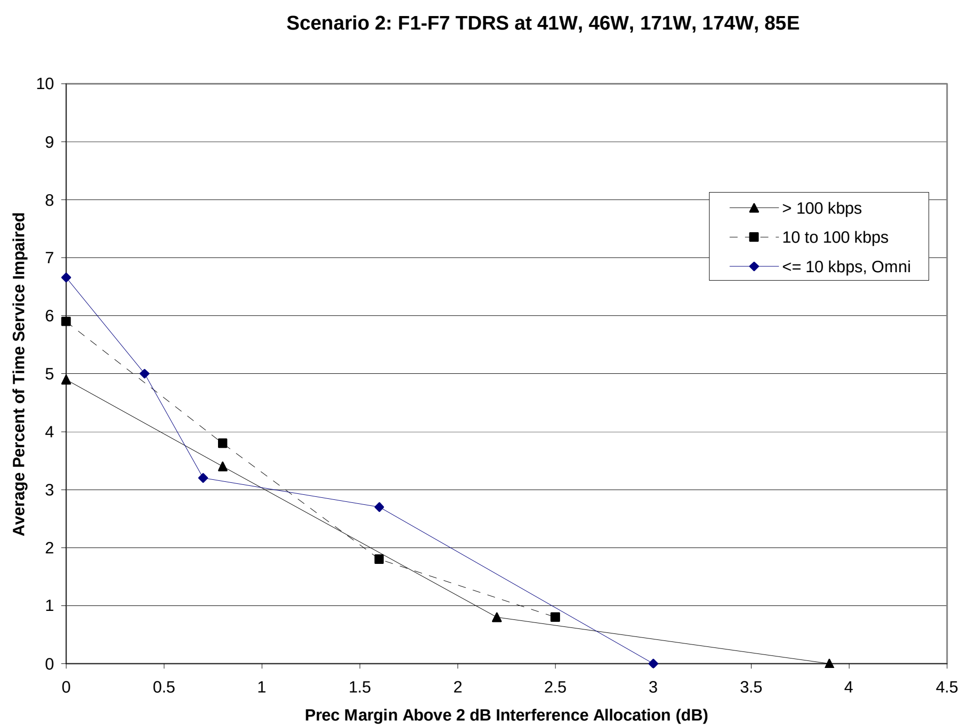


Figure O-2. Average Service Impact Versus P_{rec} Margin, Scenario 2

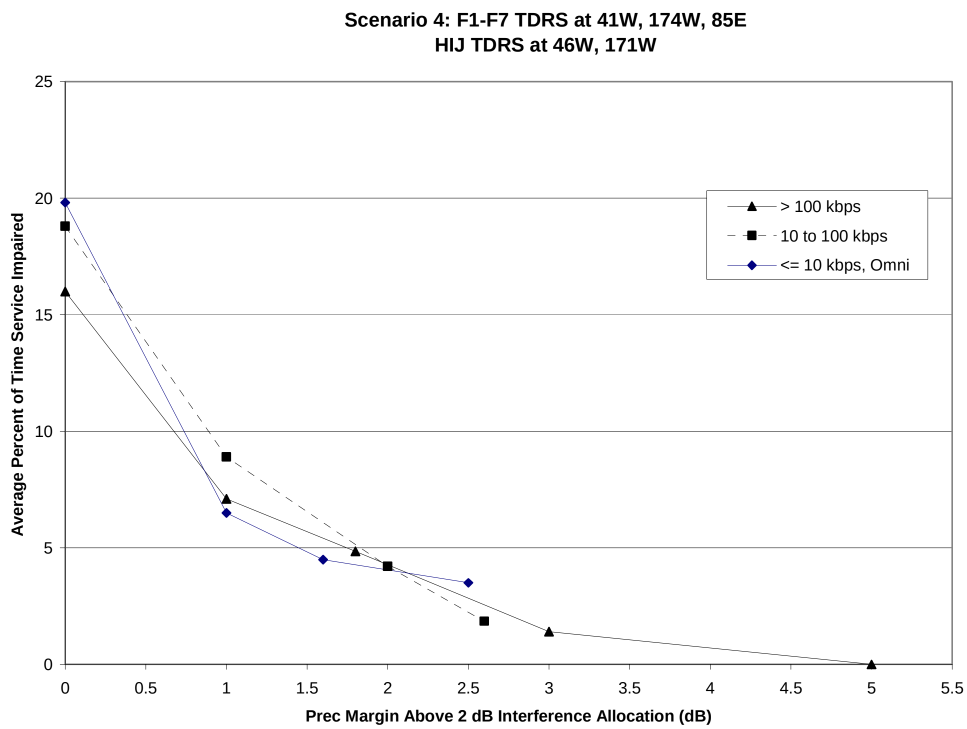


Figure O-3. Average Service Impact Versus P_{rec} Margin, Scenario 4

Glossary

µsec	microsecond
$\dot{R}$	range velocity between TDRS and customer platform (meter/second)
$\ddot{R}$	range acceleration between TDRS and customer platform (meter/second^2)
$\dddot{R}$	jerk (m/sec^3)
ACRS	Automated Conflict Resolution System
ADR	achievable data rate
AM	amplitude modulation
AO	Announcement of Opportunity
ASCII	American Standard Code for Information Interchange
ASF	Alaska Sythentic Aperature Radar Facility
AWGN	additive white Gaussian noise
baud rate	rate at which a characteristic (i.e., phase, frequency, amplitude) of a carrier wave is changed by the modulating signal
BER	bit error rate
Biφ	biphase
Biφ-L	biphase level
Biφ-M	biphase mark
Biφ-S	biphase space
B_L	loop noise bandwidth
BM	Briefing Message
bps	bits per second
BPSK	binary phase shift keying
BRTS	Bilateration Ranging Transponder System
BSR	bit slippage rate
BW	bandwidth

C	increase in the predicted customer frequency uncertainty due to the WSC software rounding off the customer receive frequency contained in the SHO
C/N	ratio of carrier power-to-noise power (dB)
C/No	carrier power-to-noise spectral density ratio (dB-Hz)
Cacique	one of the two WSC ground terminals located in New Mexico (also referred to as WSGT)
CCB	Configuration Control Board
CCCM	Center Customer Commitment Manager
CCIR	International Radio Consultative Committee (part of the ITU)
CCM	Customer Commitment Manager
CCR	Configuration Change Request
CCSDS	Consultative Committee for Space Data Systems
CF	center frequency
channel	link subdivision used for information transfer and/or two-way range measurement
channel BW	6 MHz for MA, 10 MHz for SSA, 225 MHz for KuSA, 225 MHz or 650 MHz, selectable by ground, for KaSA return links
chip	one bit of a PN sequence as opposed to data bits
CLASS	Communications Link Analysis and Simulation System
CMD	command
CMO	Configuration Management Office
command channel	forward service data channel
COTS	commercial off-the-shelf
CSOC	Consolidated Space Operations Contract
CSR	Customer Service Representative
CTL	Compatibility Test Laboratory
CTP	Compatibility Test Plan
CTV	Compatibility Test Van
Danzante	one of the two WSC ground terminals located in New Mexico (also referred to as STGT)

DAS	Demand Access System
data BW	bandwidth in Hz equal to two times the baud rate
data channel	an independent data signal contained within a link
data rate	rate of a digital information data signal before convolutional encoding and/or conversion to biphase format
dB	decibel
dBc	dB below total signal power
dBi	decibels referenced to an isotropic radiator
dBmi	decibels referenced to one milliwatt isotropically received power
dBW	decibel relative to one watt
dBWi	decibels referenced to one watt isotropically received power
DCE	Doppler compensation enabled
DCI	Doppler compensation inhibited
DG1	Data Group 1
DG2	Data Group 2
DIS	Data Interface System
DMR	Detailed Mission Requirements
DOMSAT	Domestic Communications Satellite
DQM	data quality monitoring
dr	data rate
DSMC	Data Services Management Center
DSN	Deep Space Network
E	maximum uncompensated Doppler on the TDRS forward link signal arriving at the customer platform (Hz); East
E_b/N_o	bit energy-to-noise spectral density ratio (dB-Hz)
EEFOV	Extended Elliptical field of view (degrees)
EES	Earth-exploration satellite services
EET	End-to-End Test

EIRP	effective isotropic radiated power (dBW)
ELV	expendable launch vehicle
EOL	end of life
ES	earth station
F	transmit carrier frequency (Hz)
f	Doppler frequency (Hz)
F_1	carrier frequency transmitted by the customer platform (Hz)
F1, F6, F7, F8	TDRS Flight 1, 6, 7, 8
FA	Forecast Analysis (DSMC)
f_d	Doppler frequency
FDF	Flight Dynamics Facility
FEC	forward error correction
FM	frequency modulation
f_o	nominal center frequency of customer platform receiver (Hz)
forward service	link from the WSC through the TDRS to the customer platform
FOV	field of view (degrees)
F_R	carrier frequency arriving at user spacecraft (Hz)
f_{ref}	user spacecraft transmit frequency (Hz)
f_T	TDRSS forward service transmit frequency after Doppler compensation
FTP	File Transfer Protocol
G	gain
G/T	antenna gain-to-noise temperature ratio (dB/K)
G_1, G_2, G_3	symbol generation functions
GCE	ground control equipment
GCM	Ground Control Message
GCMR	Ground Control Message Request
GDIS	Guam Data Interface System
GHz	gigahertz

GMT	Greenwich Mean Time
GN	Ground Network
GPG	Goddard Procedures and Guidelines
GRGT	Guam Remote Ground Terminal (the WSC ground terminal located in Guam)
GSAMS	GSFC Spectrum Allocation and Management Site
GSFC	Goddard Space Flight Center
GT	Ground Terminal
GTD	Goddard Test Director
Gu	antenna gain of the customer platform (dB)
HPA	high power amplifier
HQ	NASA Headquarters
HR	high rate
HRDS	High Rate Data System
Hz	Hertz
I channel	data channel supported by 0 degree and 180 degree phase modulation of the reference carrier
ICD	Interface Control Document
IF	intermediate frequency
IFL	inter-facility link
IIRV	improved interrange vector
IOnet	IP Operational Network
IP	internet protocol
IRAC	Interdepartmental Radio Advisory Committee (part of the NTIA)
ITU	International Telecommunications Union
ITU-R	International Telecommunications Union Radiocommunication Sector
jerk	rate of change of range acceleration between TDRS and customer platform (meter/second^3)
JPL	Jet Propulsion Laboratory

JSC	Johnson Space Center
JVM	Java Virtual Machine
k	Boltzmann's constant, -228.6 dBW/Hz-K; constraint length of convolutional code
K	Kelvin, unit of temperature
Ka-band	22.5 to 27.5 GHz
KaSA	Ka-band Single Access
KaSAF	Ka-band Single Access Forward
KaSAR	Ka-band Single Access Return
K-band	13.40 to 15.25 GHz
kbps	kilobits per second
kHz	kilohertz
km	kilometer
KSC	Kennedy Space Center
KuSA	Ku-band Single Access
KuSAF	Ku-band Single Access Forward
KuSAR	Ku-band Single Access Return
LAN	local area network
LCP	left circular polarization
LEO	Low Earth Orbit
LEOFOV	low earth orbit field of view (degrees)
LHC	left-hand circular
LI	local interface
link	Includes either all data and/or range channels provided by a TDRS forward or return service to a customer platform. In the case of SA service, a link is defined relative to a specific antenna on a particular TDRS. In the case of MA service, a link is defined relative to a particular TDRS.
LOS	line-of-sight
LR	low rate

MA	Multiple Access
MAF	Multiple Access Forward
MAR	Multiple Access Return
Mbps	megabits per second
MCC	Mission Control Center
MCM	Mission Commitment Manager
MDM	multiplexer/demultiplexer
MGS	McMurdo Ground Station
MHz	megahertz
MI	mutual interference
MIL	Merritt Island Tracking Station
MILA	Merritt Island Launch Area
MOC	Mission Operations Center
MOSP	Mission Operations Support Plan
MSB	most significant bit
msec	millisecond
MSFC	Marshall Space Flight Center
MSP	Mission Services Program
Msps	megasymbols per second
MTRS	McMurdo TDRSS Relay System
N	North
NA	not applicable
NAM	Network Advisory Message
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications Network
NCC	Network Control Center
NCCDS	NCC Data System
NEC	NASCOM Event Cancel

NES	NASCOM Event Schedule
NEST	NASA Event Scheduling Terminal
NISN	NASA Integrated Services Network
NPAS	Network Planning and Analysis System
NRR	NASCOM Reconfiguration Request
NRZ	nonreturn to zero
NRZ-L	nonreturn to zero level
NRZ-M	nonreturn to zero mark
NRZ-S	nonreturn to zero space
nsec	nanosecond
NSF	National Science Foundation
NTIA	National Telecommunications and Information Agency
ODM	Operations Data Message (from WSC to DSMC)
OOB	out-of-band
OPM	Operations Message
OPS	operations
OQPSK	Offset quadriphase shift keying
PA	power amplifier
P_{acq}	probability of correct acquisition
PCA	Program Commitment Agreement
PCD	Project Commitment Document
PCI	periodic convolutional interleaving
PCM	Pulse code modulated
PDL	Ponce de Leon Tracking Station
PFD	power flux density
PFOV	Primary field of view (degrees)
PIP	Payload Integration Plan
PM	phase modulation

PN	pseudorandom noise
POP	Project Operating Plan
PP	peak-to-peak
PRD	Program Requirements Document
P_{rec}	signal power received isotropically at a TDRS from a customer platform
P_s	signal power at antenna output
PSD	power spectral density
PSK	phase-shift keying; phase-shift key modulation using differential encoded data
PSLA	Project Service Level Agreement
Q channel	data channel supported by $\pm$90 degree phase modulation of the reference carrier
QPSK	quadriphase shift keying
R	ratio between data rate and convolutionally encoded symbol rate; range between TDRS and customer platform (meters)
range channel	forward service channel used for transferring the PN code used for two-way range measurement
RCP	right circular polarization
RCTD	return channel time delay
R_d	channel data rate (b/sec)
return service	link from the customer platformthrough the TDRS to the WSC
RF	radio frequency
RFA	Request for Actions
RFI	radio frequency interference
RFP	Request for Proposal
RF SOC	Radio Frequency Simulation Operations Center
RHC	right-hand circular
rms	root mean square
RR	Radio Regulations

R_S	channel symbol rate
R-S	Reed-Solomon
Rx	receiver
S	South
S/(N+I)	signal-to-(noise plus interference) ratio
S/N_o	signal-to-noise density ratio
SA	Single Access
SAR	Synthetic Aperature Radar; Schedule Add Request
SAT_b	forward buffering delay for reserialized output data delivery
SAT_d	return buffering delay for reserialized output data delivery
S-band	2000 to 2300 MHz
SD	sweep duration
sec	second
service	consists of any of the forward, return, tracking, simulation, or verification services
SGL	Space-Ground Link
SGLT	Space-Ground Link Terminal
SHO	Schedule Order (DSMC to WSC)
SIC	Spacecraft Identification Code
SIEB	Security Impact Evaluation Board
Signal EIRP	total EIRP + L_p + L_t (dBW) where: L_p = loss resulting from imperfect antenna pointing (dB) ($L_p \leq 0$ dB) L_t = all tandem link losses including power robbing caused by noise and spurious signals (dB) ($L_t \leq 0$ dB)
SLR	Service Level Report
SMA	S-band Multiple Access
SMAF	S-band Multiple Access Forward

SMAR	S-band Multiple Access Return
SN	Space Network
SNR	signal-to-noise ratio
SO	spurious outputs; Scheduling Operator (DSMC)
SO	space operations
SOC	Simulation Operations Center
SOCB	Space Operations Control Board
SOMO	Space Operations Management Office
SPTR	South Pole TDRSS Relay
SQPN	Staggered quadriphase pseudorandom noise
SQPN modulation	a modulation process in which the phase of the PN clock modulating the Q channel is delayed 1/2 chip relative to the phase of the PN clock modulating the I channel
SQPSK	staggered quadriphase shift keying
SQPSK modulation	a quadriphase process in which the data bits (symbols if convolutionally encoded) of the Q channel are delayed one-half bit period (one-half symbol period if convolutionally encoded) relative to the I channel
SR	space research; sweep range
SRM	Schedule Result Message
SSA	S-band Single Access
SSAF	S-band Single Access Forward
SSAR	S-band Single Access Return
SSC	service specification code
STATMUX	statistical multiplexer
STDN	Spaceflight Tracking and Data Network
STGT	Second TDRSS Ground Terminal (Danzante)
STS	Space Transportation System (Space Shuttle)

SUPIDEN	support identification code
SWSI	SN Web Services Interface
symbol rate	rate of the digital information data signal before conversion to biphase format. When convolutional encoding is used, the rate of the digital information data signal out of the convolutional encoder before conversion to biphase format.
systematic	original information bits appear in output data stream
T_a	antenna temperature (K)
T_{acq}	time to acquire
TCP	transmission control protocol
TDM	time division multiplexing; Tracking Data Message
TDRS	Tracking and Data Relay Satellite
TDRS-E	TDRS-East
TDRSS	Tracking and Data Relay Satellite System
TDRS-W	TDRS-West
TDZ	TDRS in Zone of Exclusion
T_i	noise temperature contribution due to interference from other multiple access users (K)
TILT	TDRSS Internet Link Terminal
TLAS	TDRS Look Angle System
TLM	telemetry
TOCC	TDRSS Operations Control Center
transparent	I(b) the input to the encoder is mapped into T(b) the output of the encoder, then for transparency to exist, the complement of I(b) must be mapped into the complement of T(b)
TRR	Test Readiness Review
TR	Test Report
T_R	time return service begins
T_s	receiving system noise temperature (K) referenced to the antenna output terminals

TSW	TDRSS Scheduling Window
TT&C	tracking, telemetry, and command
TURFTS	TDRSS User RF Test Set
TUT	TDRSS Unscheduled Time
TWTA	Traveling Wave Tube Amplifier
Tx	transmitter
UDP	User Datagram Protocol
UPD	User Performance Data (from DSMC to MOC)
UPS	User Planning System
UQPSK	unbalanced quadriphase shift keying
USCCS	User Spacecraft Clock Calibration System
USM	User Schedule Message (from DSMC to MOC)
UTC	Universal Time Coordinated
VIC	Vehicle Identification Code
VID	Vehicle Identification
W	West
WAN	wide area network
WART	WSC Alternate Resource Terminal
WDISC	WSC Data Interface Service Capability
WSC	White Sands Complex (consists of WSGT, STGT, and GRGT)
WSGT	White Sands Ground Terminal (Cacique)
www	world wide web
ZOE	zone of exclusion