Link Budget Analysis Guide

iDX Release 2.0.0.x

December 8, 2009

iDIRECT

Document Name: HI_LBA_iDX_20_RevB_120809.pdf

Document Number: T00000250

About This Guide

This guide includes the purpose, intended audience, contents, and a section for getting help.

Purpose

The purpose of this guide is to provide system and network engineers with satellite modem performance parameters necessary to conduct link budget analysis and accordingly plan system resources for implementing an iDirect network. The information presented in this guide is specific to iDirect Evolution and iNFINITI series of hub and remote products associated with iDX 2.0 Release.

Target Audience

The intended audience for this guide is customer network engineers who are planning the integration of the iDirect hub equipment in an existing teleport or Earth station.

Contents

Other than the information presented in this section, this guide includes:

- *Downstream Carrier Performance Specifications*, which contains carrier efficiency and modem performance data applicable to iDX 2.0 Release
- *DVB-S2 ACM System Guidelines*, which explains how Adaptive Coding and Modulation (ACM) is implemented in an iDirect network

Getting Help

The iDirect Technical Assistance Center (TAC) is available to help you 24x7x365. Software releases, upgrades and patches, product support documentation, and an FAQ page are available on the TAC web page. Please access our TAC web page at http://tac.idirect.net.

If you are unable to find the answers or information you need, you can contact the TAC at (703) 648-8151 or by email at TAC@idirect.net.

iDirect strives to produce documentation that is technically accurate, easy to use, and helpful to our customers. Your feedback is welcomed! Send comments to techpubs@idirect.net.

Downstream Carrier Performance Specifications

This section describes DVB-S2 ACM Downstream specifications and iNFINITI Downstream specifications.

DVB-S2 ACM Downstream

This section summarizes the SNR threshold required for downstream link budget analysis using DVB-S2 carriers in Adaptive Coding and Modulation (ACM) mode operation. The modem performance threshold for Evolution e8350/e800/e850mp Series Remotes is provided in "Section 1" of Table 1 and that of the Evolution X3/X5 Series Remotes is provided in "Section 2" of Table 1.

Table 1. DVB-S2 Modem Performance Limit for Evolution e8350/e800/e850mp/X3/X5 Series Remotes

Symbol Rate	1 to 45 Msps
Carrier Scheme	DVB-S2, ACM, Short Frame, Pilots On, 20% Filter Roll-off
Modulation/FEC	Modulation: QPSK/8PSK/16-APSK FEC: LDPC/BCH
Minimum Carrier Spacing(1)	1.2*Symbol Rate

Section 1: SNR Threshold for Evolution e8350/e800/e850mp Series Remotes

MODCOD Index	Payload Type	Payload bits per Frame (K_b)	Symbols per Frame (N_s)	Spectral Efficiency(2) (bps/Hz)	E_b/N_o for QEF(3)(4) (dB)	C/N for QEF(3)(4) (dB)
1	QPSK Rate 1/4	2960	8370	0.29	2.3	-2.2
2	QPSK Rate 1/3	5120	8370	0.51	1.3	-0.8
3	QPSK Rate 2/5	6200	8370	0.62	1.5	0.2
4	QPSK Rate 1/2	6920	8370	0.69	1.7	0.9
5	QPSK Rate 3/5	9440	8370	0.94	2.2	2.7
6	QPSK Rate 2/3	10520	8370	1.05	2.5	3.5
7	QPSK Rate 3/4	11600	8370	1.15	3.0	4.4
8	QPSK Rate 4/5	12320	8370	1.23	3.4	5.1
9	QPSK Rate 5/6	13040	8370	1.30	3.7	5.6
10	QPSK Rate 8/9	14120	8370	1.41	4.3	6.6

MODCOD Index	Payload Type	Payload bits per Frame (K_b)	Symbols per Frame (N_s)	Spectral Efficiency[2] (bps/Hz)	E_b/N_o for QEF[3][4] (dB)	C/N for QEF[3][4] (dB)
12	8PSK Rate 3/5	9440	5598	1.41	4.0	6.3
13	8PSK Rate 2/3	10520	5598	1.57	4.7	7.4
14	8PSK Rate 3/4	11600	5598	1.73	5.3	8.5
15	8PSK Rate 5/6	13040	5598	1.94	6.3	10.0
16	8PSK Rate 8/9	14120	5598	2.10	7.3	11.3
18	16-APSK Rate 2/3	10520	4212	2.08	5.6	9.6
19	16-APSK Rate 3/4	11600	4212	2.30	6.4	10.8
20	16-APSK Rate 4/5	12320	4212	2.44	6.8	11.5
21	16-APSK Rate 5/6	13040	4212	2.58	7.5	12.4
22	16-APSK Rate 8/9	14120	4212	2.79	8.3	13.6
Section 2: SNR Threshold for Evolution X3/X5 Series Remotes						
MODCOD Index	**Payload Type**	**Payload bits per Frame (K_b)**	**Symbols per Frame (N_s)**	**Spectral Efficiency[2] (bps/Hz)**	**E_b/N_o for QEF[3][4] (dB)**	**C/N for QEF[3][4] (dB)**
1	QPSK Rate 1/4	2960	8370	0.29	2.8	-1.7
2	QPSK Rate 1/3	5120	8370	0.51	1.4	-0.7
3	QPSK Rate 2/5	6200	8370	0.62	1.4	0.1
4	QPSK Rate 1/2	6920	8370	0.69	1.8	1.0
5	QPSK Rate 3/5	9440	8370	0.94	2.0	2.5
6	QPSK Rate 2/3	10520	8370	1.05	2.3	3.3
7	QPSK Rate 3/4	11600	8370	1.15	2.9	4.3
8	QPSK Rate 4/5	12320	8370	1.23	3.2	4.9
9	QPSK Rate 5/6	13040	8370	1.30	3.6	5.5
10	QPSK Rate 8/9	14120	8370	1.41	4.3	6.6
12	8PSK rate 3/5	9440	5598	1.41	4.0	6.3
13	8PSK Rate 2/3	10520	5598	1.57	4.7	7.4

MODCOD Index	Payload Type	Payload bits per Frame (K_b)	Symbols per Frame (N_s)	Spectral Efficiency[2] (bps/Hz)	E_b/N_o for QEF[3][4] (dB)	C/N for QEF[3][4] (dB)
14	8PSK Rate 3/4	11600	5598	1.73	5.3	8.5
15	8PSK Rate 5/6	13040	5598	1.94	5.9	9.6
16	8PSK Rate 8/9	14120	5598	2.10	6.8	10.8
18	16-APSK Rate 2/3	10520	4212	2.08	5.8	9.8
19	16-APSK Rate 3/4	11600	4212	2.30	6.8	11.2
20	16-APSK Rate 4/5	12320	4212	2.44	7.2	11.9
21	16-APSK Rate 5/6	13040	4212	2.58	7.9	12.8
22	16-APSK Rate 8/9	14120	4212	2.79	8.5	13.8

(1) Satellite operators must be consulted to determine the actual carrier spacing.

(2) Spectral efficiency includes $1.2*F_{sym}$ carrier spacing, FEC, Physical layer frame overhead including Pilots and PLHEADER symbols and Baseband frame overhead including BBHEADER and CRC-32. The CRC-32 field at the end of the Baseband frame is used to check residual bit errors out of the LDPC/BCH decoder.

(3) QEF (Quasi Error Free) operation is defined as no BBHEADER CRC-8 errors with BER better than 1e-8 for an IF-loopback (L-band). C/N is the ratio of signal power spectral density to noise power spectral density at the modem input.

(4) $E_b/N_o = C/N - 10\log_{10}(K_b/N_s)$, where K_b is the number of Payload bits per Baseband Frame and N_s is the number of transmitted symbols per Physical layer Frame. IP and other network layer packets are transported on the Baseband Frame using the highly efficient DVB-S2 Generic Stream Encapsulation (GSE) protocol. The parameter K_b does not include the moderate GSE overhead (roughly 1 to 2%).

iNFINITI Downstream

This section describes iNFINITI downstream specifications.

Table 2 summarizes the SNR threshold required for iNFINITI downstream carriers using Evolution e8350/e800/e850mp/X5 Series Remotes and iNFINITI 3000/5000/7000/8350 Series Remotes.

Table 2. Modem Performance Limit for iNFINITI Downstream Carrier

Symbol Rate	Minimum: 64 Ksps[1] (all modes) Maximum: 11.5 Msps (for Non Spread-spectrum (SS) modes) 15 Mcps (for SS modes)				
Modulation/FEC	Modulation: SS-BPSK/BPSK/QPSK/8PSK Spreading Factor (SF): 2, 4 and 8 FEC: TPC				
Minimum Carrier Spacing[2]	1.2*Symbol Rate				
Modulation	**FEC Rate**	**Block Size**	**Spectral Efficiency**[3] **(bps/Hz)**	**E_b/N_o** [4, 5, 6] **(dB)**	**C/N** [4, 5] **(dB)**
8PSK	0.879	16 K	2.2	7.9	12.1
8PSK	0.793	4 K	1.98	7.0	10.8
QPSK	0.879	16 K	1.47	4.8	7.2
QPSK	0.793	4 K	1.32	4.6	6.6
QPSK[7]	0.533	1 K	0.89	3.9	4.2
QPSK	0.495	4 K	0.83	4.0	4.0
BPSK	0.879	16 K	0.73	4.6	4.0
BPSK	0.793	4 K	0.66	4.3	3.3
BPSK[7]	0.533	1 K	0.44	3.9	1.2
BPSK	0.495	4 K	0.41	4.1	1.0
SS-BPSK SF=2[8]	0.879	16 K	0.37	5.1	1.5
SS-BPSK SF=2[8]	0.793	4 K	0.33	4.6	0.6
SS-BPSK SF=2[8]	0.495	4 K	0.21	4.9	-1.2

Modulation	FEC Rate	Block Size	Spectral Efficiency[3] (bps/Hz)	E_b/N_o [4, 5, 6] (dB)	C/N [4, 5] (dB)
SS-BPSK SF=4[8]	0.879	16 K	0.18	5.0	-1.6
SS-BPSK SF=4[8]	0.793	4 K	0.17	4.8	-2.2
SS-BPSK SF=4[8]	0.495	4 K	0.1	4.6	-4.5
SS-BPSK SF=8[8]	0.879	16 K	0.09	4.9	-4.7
SS-BPSK SF=8[8]	0.793	4 K	0.08	4.7	-5.3
SS-BPSK SF=8[8]	0.495	4 K	0.05	4.7	-7.4

(1) Minimum symbol rate supported by the Evolution X5 Series Remote is 128 ksps.

(2) Satellite operators must be consulted to determine the actual carrier spacing. The carrier spacing is 1.2*Chip Rate for spread carriers where the Chip Rate is determined as SF*Symbol Rate.

(3) Spectral Efficiency includes $1.2*F_{sym}$ carrier spacing, Modulation/FEC, and overhead.

(4) Modem C/N performance threshold is specified at a BER of 10^{-8} for L-Band loopback. C/N is the ratio of signal power spectral density to noise power spectral density at the modem input. Performance is specified with two adjacent carriers each at +7dBc.

(5) Performance may degrade slightly (<0.5 dB) for data rates > 10 Mbps.

(6) $E_b/N_o = C/N-10\log_{10}(m*r/SF)$, where *m* is the modulation order (BPSK: 1, QPSK: 2, 8PSK: 3), *r* is the FEC ratio and *SF* is the spreading factor.

(7) This FEC combination is not recommended for new designs. For new network designs, iDirect recommends using FEC 0.495. If you have an existing network using FEC 0.533 operating at an information rate of 10 Msps or greater, the network may experience errors due to an FEC decoding limitation.

(8) The Evolution X5 Series Remote does not support Spread Spectrum (SS) modes. The Evolution X3 Series Remote does not support any iNFINITI carrier modes.

Upstream TDMA Carrier Performance Specifications

This section describes the Upstream TDMA carrier performance specifications.

iDX Release 2.0 introduces both the 2D-16-State (2D-16-S) FEC (which is more granular and powerful than the TPC FEC) and synchronization enhancements to the demodulator.

Note: These features are available only in the iDirect Evolution series (eM1D1, XLC-11, and XLC-M) hub line cards.

Table 3 summarizes the specification required for upstream link budget analysis using TDMA carriers for the Evolution series (eM1D1, XLC-11, XLC-M) and iNFINITI series (M1D1, M1D1-TSS, M0D1) hub line cards. The SNR thresholds are indicated independently for these two series line cards. It is recommended to use the higher SNR limit in networks where both Evolution and iNFINITI Series receive line cards co-exist.

Table 3. SNR Performance Limit for TDMA Carriers

Symbol Rate(1)	Minimum: 0.064 Msps (for e8350/e800/e850mp) 0.128 Msps (for X3/X5) Maximum: 7.5 Msps (for Non Spread-spectrum (SS) modes) 7.5 Mcps (for SS modes)					
Carrier Scheme	MF-TDMA, 20% Filter Roll-off					
Modulation/FEC	Modulation: SS-BPSK/BPSK/QPK/8PSK Spreading Factor (SF): 1, 2, 4, 8 and 16 FEC: TPC/2D-16-S					
Minimum Carrier Spacing(2)	1.2*Symbol Rate					
Upstream Performance Threshold						
Modulation	**FEC Type**(3)	**Spectral Efficiency**(4) **(bps/Hz)**	**E_b/N_o** (5, 6) **(dB)**		**C/N** (5) **(dB)**	
			iNFINITI	**Evolution**	**iNFINITI**	**Evolution**
8PSK(7)	2D-16-S-100B-2/3	1.41	N/A	6.3	N/A	9.3
8PSK(7)	2D-16-S-170B-4/5	1.77	N/A	7.9	N/A	11.7
8PSK(7)	TPC-1K-0.66	1.36	7.7	6.9	10.7	9.9
8PSK(7)	TPC-4K-0.793	1.88	N/A	8.9	N/A	12.7
QPSK	2D-16-S-100B-1/2	0.79	N/A	4.5	N/A	4.5

QPSK	2D-16-S-100B-3/4	1.16	N/A	4.8	N/A	6.6
QPSK	2D-16-S-170B-1/2	0.81	N/A	3.6	N/A	3.6
QPSK	2D-16-S-170B-3/4	1.20	N/A	4.1	N/A	5.9
Modulation	**FEC Type[3]**	**Spectral Efficiency[4] (bps/Hz)**	**E_b/N_o [5, 6] (dB)**		**C/N [5] (dB)**	
			iNFINITI	**Evolution**	**iNFINITI**	**Evolution**
QPSK	2D-16-S-438B-2/3	1.09	N/A	3.8	N/A	5.0
QPSK	2D-16-S-438B-4/5	1.31	N/A	4.6	N/A	6.6
QPSK	2D-16-S-438B-6/7	1.40	N/A	5.2	N/A	7.5
QPSK	TPC-1K-0.533	0.82	5.4	4.4	5.7	4.7
QPSK	TPC-1K-0.66	1.02	4.9		6.1	
QPSK[8]	TPC-4K-0.793	1.30	4.6		6.6	
BPSK	2D-16-S-100B-1/2	0.40	N/A	4.2	N/A	1.2
BPSK	2D-16-S-100B-2/3	0.53	N/A	4.2	N/A	2.4
BPSK	2D-16-S-170B-3/4	0.60	N/A	4.5	N/A	3.3
BPSK	2D-16-S-438B-5/6	0.68	N/A	5.2	N/A	4.4
BPSK	TPC-1K-0.431	0.34	4.6		0.9	
BPSK	TPC-1K-0.533	0.42	4.7		2.0	
BPSK	TPC-1K-0.66	0.52	4.7		2.9	
BPSK	TPC-4K-0.793	0.65	5.4		4.4	
SS-BPSK SF=1	2D-16-S-100B-1/2	0.38	N/A	3.5	N/A	0.5
SS-BPSK SF=1	2D-16-S-100B-2/3	0.50	N/A	3.8	N/A	2.0
SS-BPSK SF=1	TPC-1K-0.431	0.32	4.1		0.4	
SS-BPSK SF=1[8]	TPC-1K-0.533	0.39	3.8		1.1	
SS-BPSK SF=1[8]	TPC-1K-0.66	0.49	4.1		2.3	
SS-BPSK SF=2	2D-16-S-100B-1/2	0.19	N/A	3.7	N/A	-2.3
SS-BPSK SF=2	2D-16-S-100B-2/3	0.25	N/A	3.6	N/A	-1.2

SS-BPSK SF=2	TPC-1K-0.431	0.16	4.0		-2.7	
SS-BPSK SF=2	TPC-1K-0.533	0.2	4.0		-1.7	
SS-BPSK SF=2	TPC-1K-0.66	0.24	4.0		-0.8	
Modulation	**FEC Type[3]**	**Spectral Efficiency[4] (bps/Hz)**	**E_b/N_o [5, 6] (dB)**		**C/N [5] (dB)**	
			iNFINITI	**Evolution**	**iNFINITI**	**Evolution**
SS-BPSK SF=4	2D-16-S-100B-1/2	0.10	N/A	3.4	N/A	-5.6
SS-BPSK SF=4	2D-16-S-100B-2/3	0.12	N/A	3.6	N/A	-4.2
SS-BPSK SF=4	TPC-1K-0.431	0.08	4.7	3.7	-5.0	-6.0
SS-BPSK SF=4	TPC-1K-0.533	0.1	4.4	3.9	-4.4	-4.9
SS-BPSK SF=4	TPC-1K-0.66	0.12	4.3		-3.5	
SS-BPSK SF=8	2D-16-S-100B-1/2	0.05	N/A	3.9	N/A	-8.1
SS-BPSK SF=8	2D-16-S-100B-2/3	0.06	N/A	3.6	N/A	-7.2
SS-BPSK SF=8	TPC-1K-0.431	0.04	N/A	3.7	N/A	-9.0
SS-BPSK SF=8	TPC-1K-0.533	0.05	N/A	4.6	N/A	-7.2
SS-BPSK SF=8	TPC-1K-0.66	0.06	N/A	4.5	N/A	-6.3
SS-BPSK SF=16	2D-16-S-100B-1/2	0.02	N/A	3.9	N/A	-11.2
SS-BPSK SF=16	2D-16-S-100B-2/3	0.03	N/A	3.9	N/A	-9.9
SS-BPSK SF=16	TPC-1K-0.431	0.02	N/A	4.2	N/A	-11.5
SS-BPSK SF=16	TPC-1K-0.533	0.025	N/A	4.4	N/A	-10.4
SS-BPSK SF=16	TPC-1K-0.66	0.03	N/A	4.6	N/A	-9.2

(1) Refer to the Release Notes that pertain to the iDX Release that the network is running for upstream symbol rate limits.

(2) Satellite operators must be consulted to determine the actual carrier spacing. The carrier spacing is 1.2*Chip rate for spread carriers where the Chip Rate is determined as SF*Symbol Rate.

(3) The 2D-16-S FEC type indicates the payload length in bytes followed by FEC rate. For example, 2D-16-S-100B-1/2 indicates a payload length of 100 bytes with FEC rate at 0.50. For TPC FEC types, the coded bit length is indicated in kilobits followed by the FEC rate. For example, TPC-1K-0.66 indicates a coded block size of 1K (1024) bits with FEC rate at 0.66. Note that the 2D-16-S FEC option is available on the upstream only with DVB-S2 downstream.

(4) Spectral Efficiency includes $1.2*F_{sym}$ carrier spacing, FEC and physical layer overhead to aid burst detection and synchronization.

(5) Modem C/N performance threshold for QEF operation of the TDMA channel is specified for a Cell Loss Rate (CLR) of 1e-5 at L-Band. C/N is the ratio of signal power spectral density to noise power spectral density at the modem input.

(6) E_b/N_o=C/N-10log$_{10}$(*m***r*/*SF*), where *m* is the modulation order (BPSK: 1, QPSK: 2, 8PSK: 3), *r* is the FEC ratio and *SF* is the spreading factor.

(7) Minimum symbol rate supported for 8PSK TPC-1K-0.66 and 8PSK 2D-16-S-100B-2/3 is 128 ksps. Minimum symbol rate supported for 8PSK 2D-16-S-170B-4/5 is 256 ksps. Minimum symbol rate supported for 8PSK TPC-4K-0.793 is 768 ksps.

(8) iDX Release 2.0.1 or later is required to achieve the performance values indicated for these modes. Contact the TAC for more information.

Performance Graphs

This section illustrates the spectral efficiency versus operating carrier to noise ratio threshold of downstream (DVB-S2 and iNFINITI) and upstream (TDMA) carriers.

This data allows system designers to determine the optimum modulation and coding scheme combinations for the desired network throughput. Downstream and upstream performance graphs are shown in Figure 1 and Figure 2, respectively.

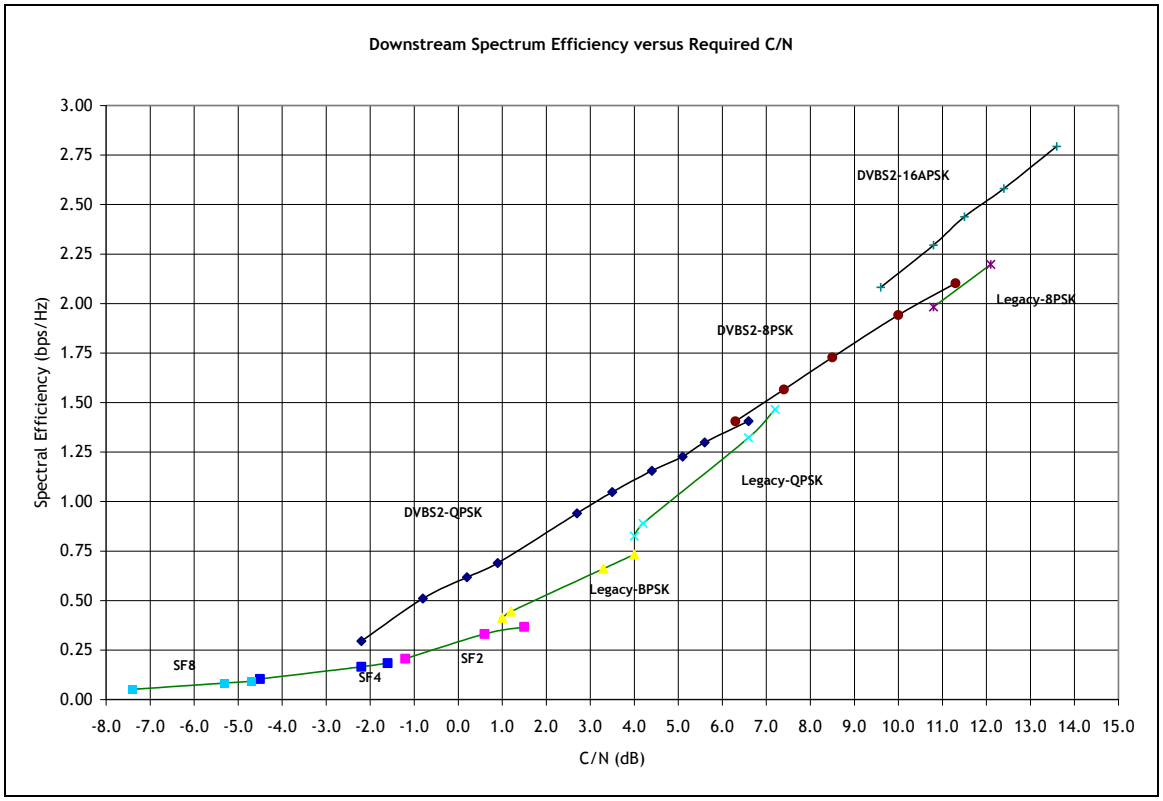

Figure 1. Downstream Performance Graph

Note: SF2, SF4, and SF8 in this figure correspond to Spread Spectrum Modes labeled with the Spreading Factors. DVB-S2 data points in this figure correspond to e8350/e800 Series Remotes.

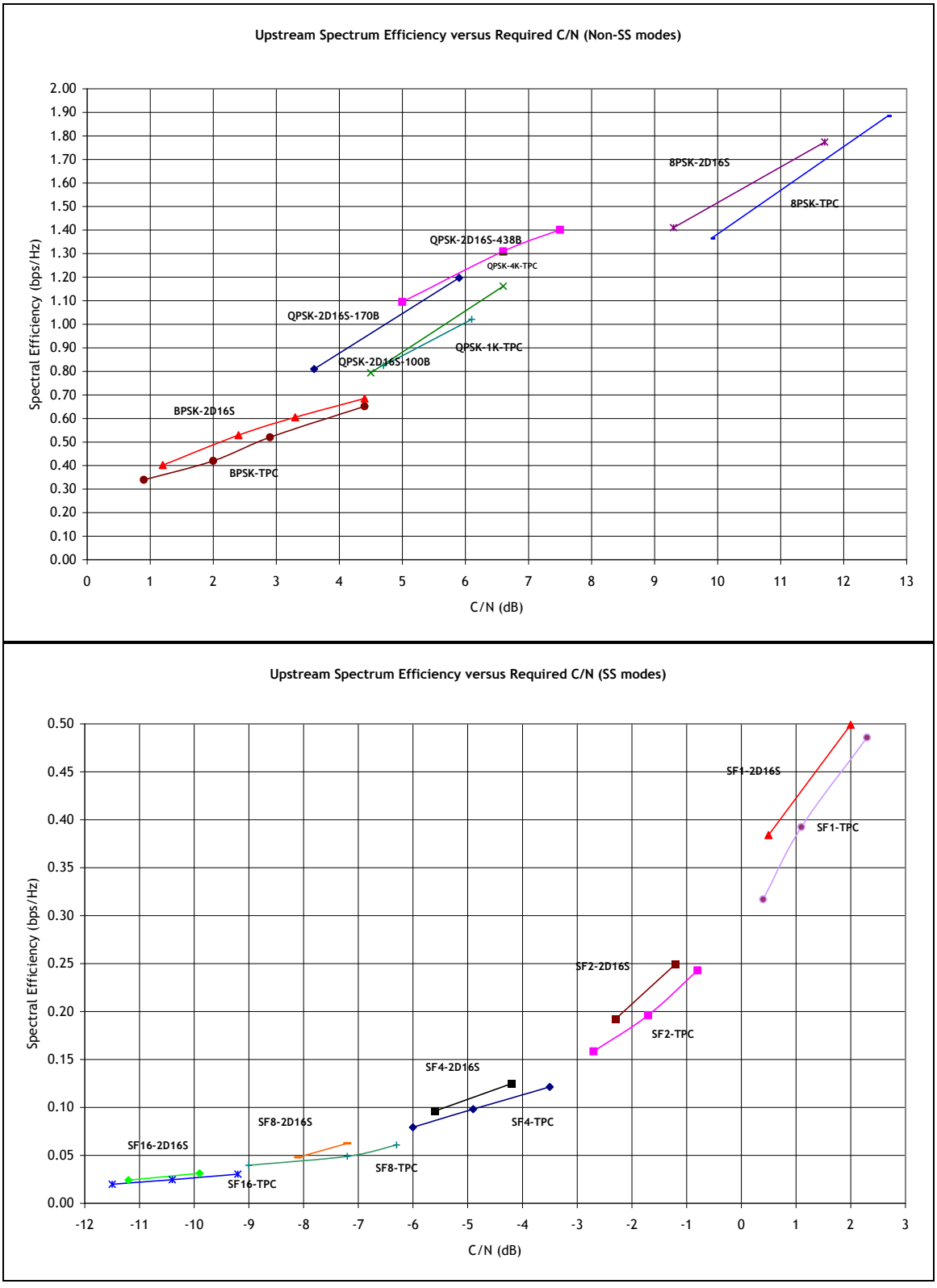

Figure 2. Upstream Performance Graphs for Non-SS and SS Modes

Note: SF1, SF2, SF4, SF8 and SF16 correspond to spreading factors in SS modes. Data points correspond to eM1D1/XLC-11/XLC-M series line cards

DVB-S2 ACM System Guidelines

This section explains how Adaptive Coding and Modulation (ACM) is implemented in an iDirect network.

Satellite network systems that use Constant Coding and Modulation (CCM) on the downstream are typically designed to include a 1 dB to 2 dB steady-state margin at the worst-case service area (defined by the Edge of Coverage EIRP) and to meet worst-case propagation conditions (typically determined by the target link availability) with the minimum antenna size used in the network (as dictated by link closure for the upstream channel). This kind of network design can result in the occurrence of high power margins for most of the remotes during most of the time (up to 95%). The margin is typically near 6 dB to 8 dB, since a difference of at least 4 dB exists between the peak antenna gain at beam center as compared to edge of coverage EIRP, and since the rain fade curves can be particularly steep (99.0% to 99.9% availability), depending on the rain region.

iDirect's Adaptive Coding and Modulation (ACM) system can use the otherwise unused (and unavailable) power margin in CCM systems to increase the system throughput to remotes that experience favorable Signal-to-Noise Ratio (SNR) conditions due to a remote's location, antenna size, and channel conditions. Under nominal conditions, the ACM control loop adapts the coding and modulation every five seconds at each remote to match the path conditions in real-time. Under steady-state conditions, the remote operates at a margin of 0.5 dB. Under fast-fade conditions, the ACM control loop adaptation rate increases to every one second. An additional margin of 1.0 dB above the steady-state margin is used for the modulation/coding combinations (MODCODs) assigned to the remote during these conditions. The margin reverts to the default steady-state value once the fast-fade condition ends. The system can manage a fade slope of 0.5 dB/s, which is typically experienced in severe rain regions of the world. By default, both steady-state margin and fast-fade margins are set at 0.5 dB and 1.0 dB, respectively. You can change these values by setting custom parameters for the network. To operate all remotes close to the thresholds stated within this Link Budget Analysis, set both steady-state margin and fast-fade margins to zero.

Broadcast signaling information for synchronization of the upstream channel, the burst time plan assignments, and other data that is categorized as high-priority traffic and vital for network operation are sent on the lowest MODCOD setting for the network. Data transmitted to a remote is sent in a higher MODCOD (within the maximum MODCOD set for the network) as appropriate for channel conditions. It is critical that the minimum MODCOD is carefully evaluated to ensure reliable reception by all remotes in the network. To achieve targeted link availability, this evaluation should be based on a remote's location within the satellite foot print, available G/T, and amount of predicted rain fade depth that is characteristic for the region where the remote is located.

iDirect
13865 Sunrise Valley Drive
Herndon, VA 20171
+1 703.648.8000
+1 866.345.0983
www.idirect.net
Advancing a Connected World