Link Budget Analysis Guide

iDX Release 4.1.3

May 10, 2019

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Revision History

The following table shows all prior revisions of the document. The most recent revision is available on the Technical Assistance Center (TAC) Web site. Refer to *Getting Help* on page xi for TAC access information.

Release / Revision	Date Released	Reason for Change(s)
iDX4.1.3 / Revision A	01-May-2019	Updates to TDMA Upstream Carrier Performance Specifications and TDMA Upstream Modes and Throughput Limitations sections of the guide for 16QAM feature introduction.

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About

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 the iDirect Evolution series of hub and remote products for networks associated with Evolution 4.1.3 Software Release.

Target Audience

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

Getting Help

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1 Downstream

This chapter describes Downstream Carrier specifications for the Evolution 4.1.3 network and contains the following sections:

- *DVB-S2 ACM* Downstream
- *DVB-S2X ACM Downstream*
- *Transmit Hub Line Cards*
- *Multi-Protocol Encapsulation Mode Downstream Configuration*

The ULC-T/DLC-T series transmit hub line cards support both DVB-S2 and DVB-S2X Downstream modes of operation. DVB-S2X mode enablement and symbol rate increment are licensed features for these line card models.

DVB-S2 ACM Downstream

This section summarizes the SNR threshold required for downstream link budget analysis of DVB-S2 carriers configured for Adaptive Coding and Modulation (ACM). The modem performance threshold for e8350/e800/e850mp Series remotes is provided in Section 1 of **Table 1**; the same is provided for X3/X5 Series Remotes in Section 2 of **Table 1**, X1/X7/e150/950mp/9350/900 Series remotes in Section 3 of **Table 1** and iQ Desktop/iQ 200 Series remotes in Section 4 of **Table 1**.

32ASPK operation is supported only in DLC-T/ULC-T hub line card models and X7/950mp/9350/900/iQ Desktop and iQ 200 Series remote models. The SNR threshold of these remotes for 32APSK MODCODs is listed under Section 3 and Section 4.

Table 1. DVB-S2 Modem Performance Limit by Remote Model Type

Symbol Rate	1 to 45 Msps					
Carrier Scheme	DVB-S2, ACM, Short Frame, Pilots On, Filter roll off [1] (α) of 5, 10, 15 and 20%					
Modulation/FEC	Modulation: QPSK/8PSK/16APSK/32APSK FEC: LDPC/BCH					
Minimum Carrier Spacing [1]	(1+α)*Symbol Rate					
Section 1: SNR Threshold for Evolution e8350/e800/e850mp Series Remotes						
MODCOD Index	**MODCOD Type**	**Payload bits per Frame (K_b)**	**Symbols per Frame (N_s)**	**Spectral Efficiency [2] (bps)**	**E_b/N_o for QEF [3, 4] (dB)**	**C/N for QEF [3, 4] (dB)**
1	QPSK Rate 1/4	2960	8370	0.35	2.3	-2.2
2	QPSK Rate 1/3	5120	8370	0.61	1.3	-0.8
3	QPSK Rate 2/5	6200	8370	0.74	1.5	0.2
4	QPSK Rate 1/2	6920	8370	0.83	1.7	0.9
5	QPSK Rate 3/5	9440	8370	1.13	2.2	2.7
6	QPSK Rate 2/3	10520	8370	1.26	2.5	3.5
7	QPSK Rate 3/4	11600	8370	1.39	3.0	4.4
8	QPSK Rate 4/5	12320	8370	1.47	3.4	5.1
9	QPSK Rate 5/6	13040	8370	1.56	3.7	5.6
10	QPSK Rate 8/9	14120	8370	1.69	4.3	6.6
12	8PSK Rate 3/5	9440	5598	1.69	4.0	6.3
13	8PSK Rate 2/3	10520	5598	1.88	4.7	7.4
14	8PSK Rate 3/4	11600	5598	2.07	5.3	8.5
15	8PSK Rate 5/6	13040	5598	2.33	6.3	10.0
16	8PSK Rate 8/9	14120	5598	2.52	7.3	11.3

18	16APSK Rate 2/3	10520	4212	2.50	5.6	9.6
19	16APSK Rate 3/4	11600	4212	2.75	6.4	10.8
20	16APSK Rate 4/5	12320	4212	2.92	6.8	11.5
21	16APSK Rate 5/6	13040	4212	3.10	7.5	12.4
22	16APSK Rate 8/9	14120	4212	3.35	8.3	13.6
Section 2: SNR Threshold for Evolution X3/X5 Series Remotes						
MODCOD Index	**MODCOD Type**	**Payload bits per Frame (K_b)**	**Symbols per Frame (N_s)**	**Spectral Efficiency [2] (bps)**	**E_b/N_o for QEF [3,4] (dB)**	**C/N for QEF [3,4] (dB)**
1	QPSK Rate 1/4	2960	8370	0.35	2.8	-1.7
2	QPSK Rate 1/3	5120	8370	0.61	1.4	-0.7
3	QPSK Rate 2/5	6200	8370	0.74	1.4	0.1
4	QPSK Rate 1/2	6920	8370	0.83	1.8	1.0
5	QPSK Rate 3/5	9440	8370	1.13	2.0	2.5
6	QPSK Rate 2/3	10520	8370	1.26	2.3	3.3
7	QPSK Rate 3/4	11600	8370	1.39	2.9	4.3
8	QPSK Rate 4/5	12320	8370	1.47	3.2	4.9
9	QPSK Rate 5/6	13040	8370	1.56	3.6	5.5
10	QPSK Rate 8/9	14120	8370	1.69	4.3	6.6
12	8PSK rate 3/5	9440	5598	1.69	4.0	6.3
13	8PSK Rate 2/3	10520	5598	1.88	4.7	7.4
14	8PSK Rate 3/4	11600	5598	2.07	5.3	8.5
15	8PSK Rate 5/6	13040	5598	2.33	5.9	9.6
16	8PSK Rate 8/9	14120	5598	2.52	6.8	10.8
18	16APSK Rate 2/3	10520	4212	2.50	5.8	9.8
19	16APSK Rate 3/4	11600	4212	2.75	6.8	11.2
20	16APSK Rate 4/5	12320	4212	2.92	7.2	11.9
21	16APSK Rate 5/6	13040	4212	3.10	7.9	12.8
22	16APSK Rate 8/9	14120	4212	3.35	8.5	13.8
Section 3: SNR Threshold for Evolution X1[5]/X7/e150[5]/950mp/9350/900 Series Remotes						
MODCOD Index	**MODCOD Type**	**Payload bits per Frame (K_b)**	**Symbols per Frame (N_s)**	**Spectral Efficiency [2] (bps)**	**E_b/N_o for QEF [3,4] (dB)**	**C/N for QEF [3,4] (dB)**
1	QPSK Rate 1/4	2960	8370	0.35	2.8	-1.7
2	QPSK Rate 1/3	5120	8370	0.61	1.4	-0.7

3	QPSK Rate 2/5	6200	8370	0.74	1.4	0.1
4	QPSK Rate 1/2	6920	8370	0.83	1.8	1.0
5	QPSK Rate 3/5	9440	8370	1.13	2.0	2.5
6	QPSK Rate 2/3	10520	8370	1.26	2.3	3.3
7	QPSK Rate 3/4	11600	8370	1.39	2.9	4.3
8	QPSK Rate 4/5	12320	8370	1.47	3.2	4.9
9	QPSK Rate 5/6	13040	8370	1.56	3.6	5.5
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15	8PSK Rate 5/6	13040	5598	2.33	5.9	9.6
16	8PSK Rate 8/9	14120	5598	2.52	6.8	10.8
18	16APSK Rate 2/3	10520	4212	2.50	5.4	9.4
19	16APSK Rate 3/4	11600	4212	2.75	6.1	10.5
20	16APSK Rate 4/5	12320	4212	2.92	6.6	11.3
21	16APSK Rate 5/6	13040	4212	3.10	7.0	11.9
22	16APSK Rate 8/9	14120	4212	3.35	7.9	13.2
24	32APSK Rate 3/4	11600	3402	3.41	9.5	14.8
25	32APSK Rate 4/5	12320	3402	3.62	10.5	16.1
26	32APSK Rate 5/6	13040	3402	3.83	11.4	17.2
27	32APSK Rate 8/9	14120	3402	4.15	12.4	18.6

Section 4: SNR Threshold for iQ Desktop/iQ 200 Series Remotes [1,6]

MODCOD Index	MODCOD Type	Payload bits per Frame (K_b)	Symbols per Frame (N_s)	Spectral Efficiency [2] (bps)	E_b/N_o for QEF [3, 4] (dB)	C/N for QEF [3, 4] (dB)
1	QPSK Rate 1/4	2960	8370	0.35	2.9	-1.6
2	QPSK Rate 1/3	5120	8370	0.61	1.4	-0.7
3	QPSK Rate 2/5	6200	8370	0.74	1.4	0.1
4	QPSK Rate 1/2	6920	8370	0.83	1.6	0.8
5	QPSK Rate 3/5	9440	8370	1.13	2.3	2.8
6	QPSK Rate 2/3	10520	8370	1.26	2.5	3.5
7	QPSK Rate 3/4	11600	8370	1.39	3.1	4.5
8	QPSK Rate 4/5	12320	8370	1.47	3.4	5.1

9	QPSK Rate 5/6	13040	8370	1.56	3.7	5.6
10	QPSK Rate 8/9	14120	8370	1.69	4.3	6.6
12	8PSK rate 3/5	9440	5598	1.69	3.9	6.2
13	8PSK Rate 2/3	10520	5598	1.88	4.6	7.3
14	8PSK Rate 3/4	11600	5598	2.07	5.4	8.6
15	8PSK Rate 5/6	13040	5598	2.33	6.3	10.0
16	8PSK Rate 8/9	14120	5598	2.52	7.3	11.3
18	16APSK Rate 2/3	10520	4212	2.50	5.6	9.6
19	16APSK Rate 3/4	11600	4212	2.75	6.4	10.8
20	16APSK Rate 4/5	12320	4212	2.92	6.9	11.6
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22	16APSK Rate 8/9	14120	4212	3.35	8.3	13.6
24	32APSK Rate 3/4	11600	3402	3.41	8.0	13.3
25	32APSK Rate 4/5	12320	3402	3.62	8.7	14.3
26	32APSK Rate 5/6	13040	3402	3.83	9.2	15.0
27	32APSK Rate 8/9	14120	3402	4.15	10.6	16.8

[1] Refer to the *Technical Reference Guide* (on DVB-S2 roll-off factors) for minimum MODCOD, minimum symbol rates, and adjacent channel interference limitations based on roll-off factors. Evolution e8xx platforms do not support roll-off factor lower than 20%. Satellite operators must be consulted to determine the actual carrier spacing.

[2] Spectral efficiency (bps: bits per symbol) includes 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. Carrier spacing is not included in efficiency calculation and bps/Hz efficiency can be determined from the roll-off factor α used by scaling the bps efficiency with 1/(1+α).

[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%).

[5] 32APSK MODCODs are not supported by X1/e150 series remotes.

[6] Performance loss up to about 0.5 dB is seen for symbol rates below 3 Msps. Network operation is unaffected as MODCODs are allotted accounting for this loss.

DVB-S2 Downstream Performance Graph

The downstream performance graph illustrating bits per symbol spectral efficiency versus operating carrier to noise ratio threshold is shown in **Figure 1** for a DVB-S2 carrier.

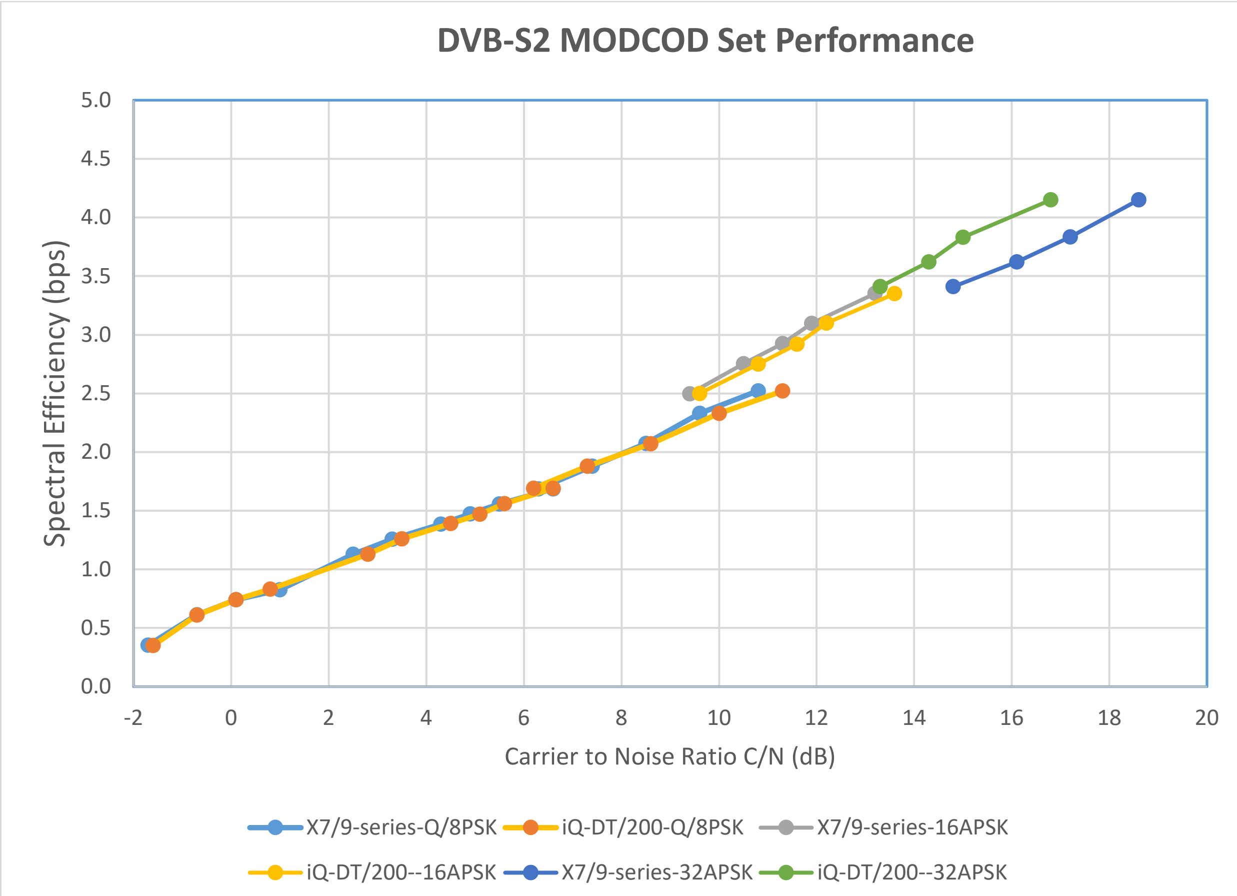


Figure 1: Downstream Performance Graph for DVB-S2

Note: Carrier spacing is not included and efficiency in bps/Hz scales the curve down by 1/(1+a).

DVB-S2X ACM Downstream

This section summarizes the SNR threshold required for downstream link budget analysis of DVB-S2X carriers configured for Adaptive Coding and Modulation (ACM). Section 5 of **Table 2** show the modem performance threshold for iQ Desktop/iQ 200 Series remotes. There are 24 MODCODs optimally selected to support a C/N dynamic range of roughly 20 dB among the Normal Frame MODCODs available in the DVB-S2/S2X standard. The MODCODs are arranged in order of increasing spectral efficiency in **Table 2**.

Table 2: DVB-S2X Modem Performance Limit

Carrier ROF and Symbol Rate Support	Filter roll off (α) of 5, 10, 15 and 20% Symbol Rate: 5 Msps (min) to 100 Msps (max) [5] Maximum Occupied BW: (1+α)*Symbol Rate or 125 MHz, whichever is minimum
Carrier Scheme	DVB-S2/S2X, ACM, Normal Frame, Pilots On
Modulation/FEC	Modulation: All S2/S2X constellations from QPSK to 256APSK FEC: LDPC/BCH
Minimum Carrier Spacing [4]	(1+α)*Symbol Rate

Section 5: SNR Threshold for iQ Desktop/iQ 200 Series Remotes

DVB-S2/S2X MODCOD indices arranged in increasing spectral efficiency with PLS codes [5]

Index	PLS Code	MODCOD	Payload bits per Frame (K_b)	Symbols per Frame (N_s)	Spectral Efficiency [1] (bps)	E_b/N_o for QEF [2,3] (dB)	C/N for QEF [2,3] (dB)
1	135	QPSK Rate 9/20	28856	33282	0.87	1.3	0.7
2	137	QPSK Rate 11/20	35336	33282	1.06	1.6	1.9
3	21	QPSK Rate 3/5	38576	33282	1.16	2.0	2.6
4	25	QPSK Rate 2/3	42928	33282	1.29	2.3	3.4
5	29	QPSK Rate 3/4	48296	33282	1.45	2.8	4.4
6	139	8APSK Rate 5/9-L	35696	22194	1.61	3.0	5.1
7	149	16APSK Rate 1/2-L	32096	16686	1.92	3.6	6.4
8	153	16APSK Rate 5/9-L	35696	16686	2.14	4.0	7.3
9	155	16APSK Rate 26/45	37136	16686	2.23	4.3	7.8
10	163	16APSK Rate 23/36	41096	16686	2.46	4.8	8.7
11	167	16APSK Rate 25/36	44696	16686	2.68	5.3	9.6
12	77	16APSK Rate 3/4	48296	16686	2.89	5.9	10.5
13	171	16APSK Rate 7/9	50096	16686	3.00	6.3	11.1
14	175	32APSK Rate 2/3-L	42928	13338	3.22	6.4	11.5
15	179	32APSK Rate 32/45	45776	13338	3.43	6.8	12.2
16	183	32APSK Rate 7/9	50096	13338	3.76	7.9	13.6
17	185	64APSK Rate 32/45-L	45776	11142	4.11	8.4	14.5
18	187	64APSK Rate 11/15	47216	11142	4.24	9.2	15.5
19	195	64APSK Rate 4/5	51536	11142	4.63	9.8	16.5

20	205	256APSK Rate 29/45-L	41456	8370	4.95	10.8	17.7
21	201	128APSK Rate 3/4	48296	9576	5.04	11.7	18.7
22	209	256APSK Rate 31/45-L	44336	8370	5.30	11.8	19.0
23	211	256APSK Rate 32/45	45776	8370	5.47	12.3	19.7
24	215	256APSK Rate 3/4	48296	8370	5.77	13.2	20.8

[1] Spectral efficiency (bps: bits per symbol) includes 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 (BBFRAME) is used to check residual bit errors out of the LDPC/BCH decoder. Carrier spacing is not included in spectral efficiency calculation and bps/Hz (bits per second per Hz) efficiency can be determined from the roll-off factor α used by scaling the bps efficiency with 1/(1+α).

[2] QEF (Quasi Error Free) operation is defined as BBFRAME error rate of 1e-5 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. Performance shall not degrade by more than 0.25 dB with two adjacent identical rate carriers nominally spaced each at +7dBc for symbol rates up to 45 Msps and at +0 dBc for symbol rates above 45 Msps.

[3] $E_b/N_o = C/N - 10\log_{10}(K_b/N_s)$, 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%).

[4] Satellite operators must be consulted to determine the actual carrier spacing.

[5] Symbol rates outside the defined range and MODCODs below QPSK-9/20 are not supported in iDX 4.1.3 Release. Note NMS allows MODCOD definition down to QPSK-1/4 and symbol rates outside this limit.

DVB-S2X Downstream Performance Graph

Downstream performance graph illustrating bits per symbol spectral efficiency versus operating carrier to noise ratio threshold is shown in **Figure** 2 for DVB-S2X carrier.

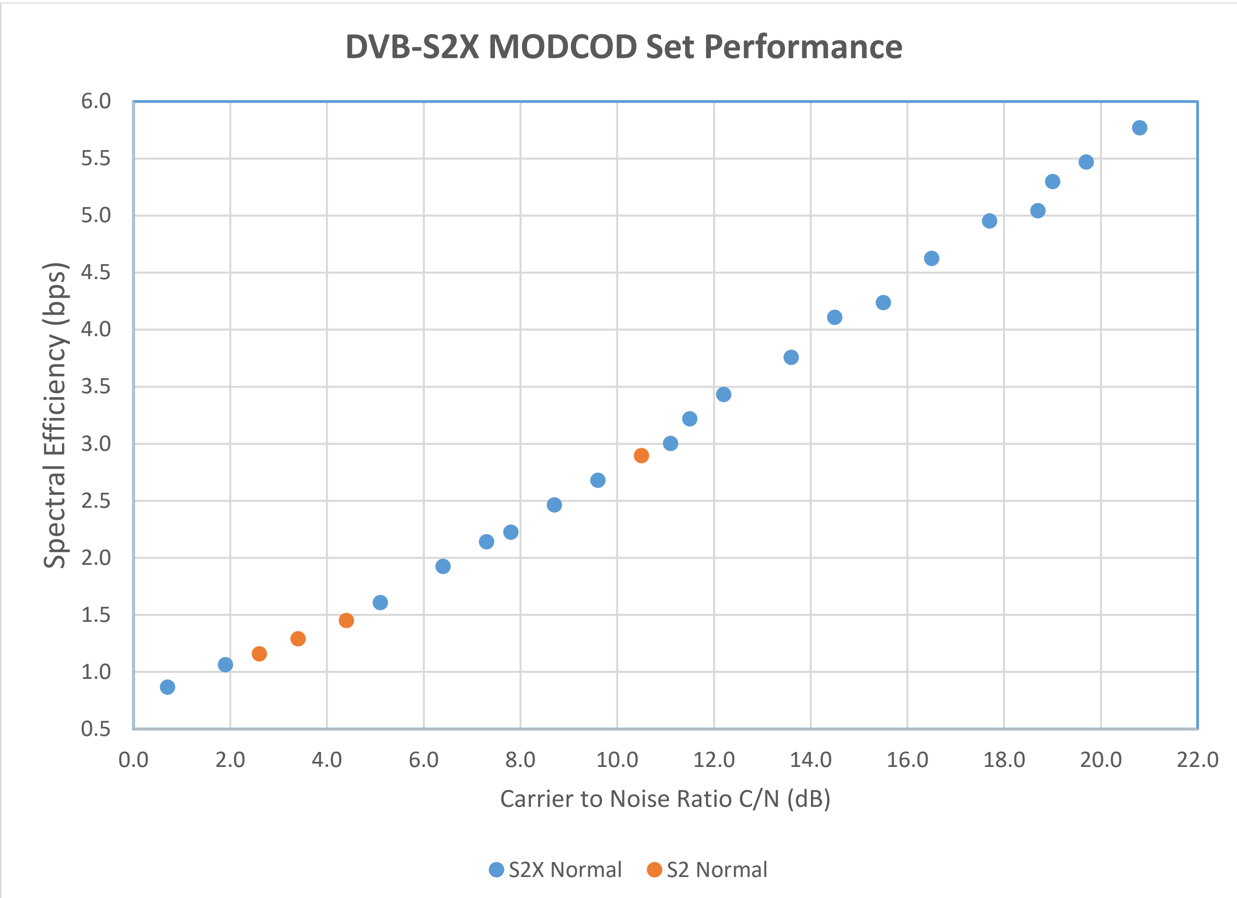


Figure 2: Downstream Performance Graph for DVB-S2X

The spectral efficiency comparison between DVB-S2 and DVB-S2X modes is illustrated in **Figure 3**. Based on the operating C/N, DVB-S2X mode achieves bandwidth efficiency improvement of up to 40% over that of the DVB-S2 mode. The dotted boundaries in **Figure 3** demarcate the percentage efficiency boost.

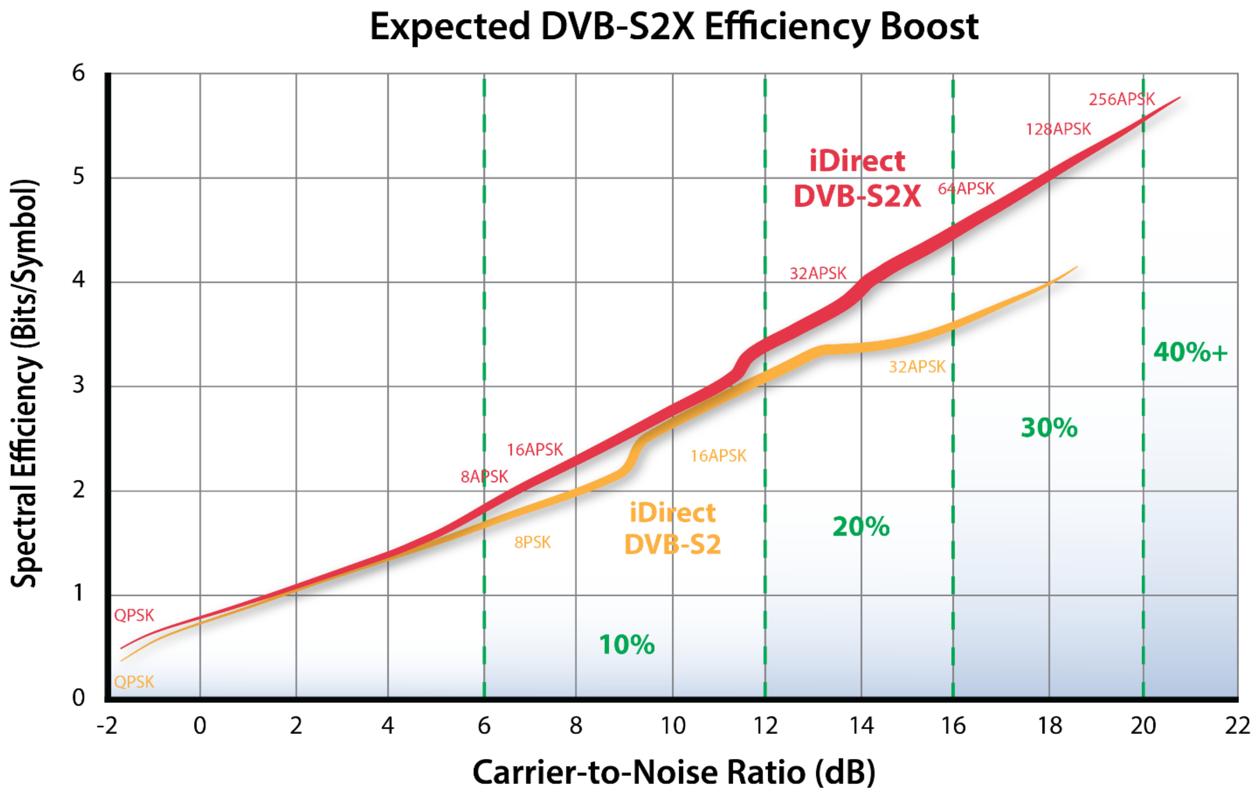


Figure 3: Downstream Efficiency Comparison for DVB-S2X and DVB-S2 modes

Transmit Hub Line Cards

iDX 4.1.3 Release continues to support XLC-11 and eM1D1 Transmit hub line cards for DVB-S2 outbound transmissions from 1 to 45 Msps with 16APSK-8/9 Max MODCOD. The DLC-T Defense and ULC-T Commercial series transmit hub line cards are necessary to support:

- 32APSK MODCODs in DVB-S2 mode operation
- DVB-S2X mode
- Linear pre-distortion for full transponder operation (both DVB-S2 / DVB-S2X modes)

Multi-Protocol Encapsulation Mode Downstream Configuration

Multi-Protocol Encapsulation (MPE) mode of operation is supported as Receive only mode in 950mp/9350 series remotes. Supported MPE DVB-S2 MODCODs are QPSK and 8PSK, Normal Frames (all DVB-S2 code-rates) only with 35% filter roll off. Pilot symbols are recommended to be configured for demodulation robustness. Performance in QPSK mode (without pilots) and 8PSK modes (with pilots) comply with the standard LBA figures provided for 950mp/9350/900 series remotes in Section 3 of **Table 1** for QEF operation. Standard MPE mode is not supported by any of the transmit hub line cards.

2 Upstream

This chapter describes Upstream Carrier specifications for the Evolution 4.1.3 network and consists of the following sections:

- *SCPC Upstream Carrier Performance Specifications*
- *TDMA Upstream Carrier Performance Specifications*
- *TDMA Upstream Modes and Throughput Limitations*

SCPC Upstream Carrier Performance Specifications

This section describes the Upstream SCPC carrier performance specifications.

The SCPC upstream carrier is available only in Evolution networks with DVB-S2 downstream and supported on eM1D1, eM0DM, and XLC-M hub line cards. Only Evolution remote models X3, X5 and e8xx series support the SCPC return feature. This feature is not supported in DLC-R/ULC-R series hub line cards and X1, X7, e150, 9-Series and iQ Series remote models.

Table 3 summarizes the SNR threshold required for SCPC carriers using 170 and 438 bytes payload.

Table 3. SNR Performance Limit for SCPC Carriers

Carrier Parameters	Modulation: SS-BPSK/BPSK/QPSK/8PSK, 20% roll off FEC: 2D16S, 170 Byte and 438 Byte blocks Spreading Factor (SF) [1]: 2, 4 and 8 Symbol Rate [1,6]: 128 ksps (min) to 15 Msps (max) Chip Rate [1]: SF*128 kcps to 15 Mcps (max) Channels per line card [1]: 8 (max) Minimum Carrier Spacing [2]: 1.2*Symbol(Chip) Rate		
MODCOD Type	**Spectral Efficiency [3] (bps/Hz)**	**E_b/N_o for QEF [4] (dB)**	**C/N for QEF [2,4] (dB)**
170 Bytes Payload			
8PSK Rate-4/5 [6]	2.0	6.8	10.6
QPSK Rate-1/2	0.83	2.4	2.4
QPSK Rate-2/3	1.11	3.0	4.2
QPSK Rate-4/5	1.33	4.3	6.3
BPSK Rate-1/2	0.42	2.8	-0.2
BPSK Rate-2/3	0.56	2.7	0.9
SF2-BPSK Rate-1/2	0.21	2.8	-3.2
SF2-BPSK Rate-2/3	0.28	3.6	-1.2
SF4-BPSK Rate-1/2	0.10	2.5	-6.5
SF4-BPSK Rate-2/3	0.14	3.3	-4.5
SF8-BPSK Rate-1/2	0.05	2.9	-9.1
SF8-BPSK Rate-2/3	0.07	3.4	-7.4
438 Bytes Payload			
8PSK Rate-4/5 [(6)]	2.0	6.4	10.2
8PSK Rate-6/7 [(6)]	2.14	7.4	11.5

QPSK Rate-1/2	0.83	2.2	2.2
QPSK Rate-2/3	1.11	2.8	4.0
QPSK Rate-4/5	1.33	4.0	6.0
QPSK Rate-6/7	1.43	4.4	6.7
BPSK Rate-1/2	0.42	2.8	-0.2
BPSK Rate-2/3	0.56	2.7	0.9
SF2-BPSK Rate-1/2	0.21	2.8	-3.2
SF2-BPSK Rate-2/3	0.28	3.1	-1.7
SF4-BPSK Rate-1/2	0.10	2.5	-6.5
SF4-BPSK Rate-2/3	0.14	2.8	-5.0
SF8-BPSK Rate-1/2	0.05	2.7	-9.3
SF8-BPSK Rate-2/3	0.07	2.7	-8.1

[1] Refer to the *Release Notes* for upstream symbol/chip rate limits, composite information bit rate processed, and operation modes allowed based on Evolution line card model type (eM1D1, eM0DM and XLC-M). License is required for operating more than one SCPC channel in eM0DM and XLC-M (max of 8 channels).

[2] Satellite operators must be consulted to determine the actual carrier spacing.

[3] Spectral Efficiency includes $1.2*F_{sym}$ carrier spacing and FEC overhead.

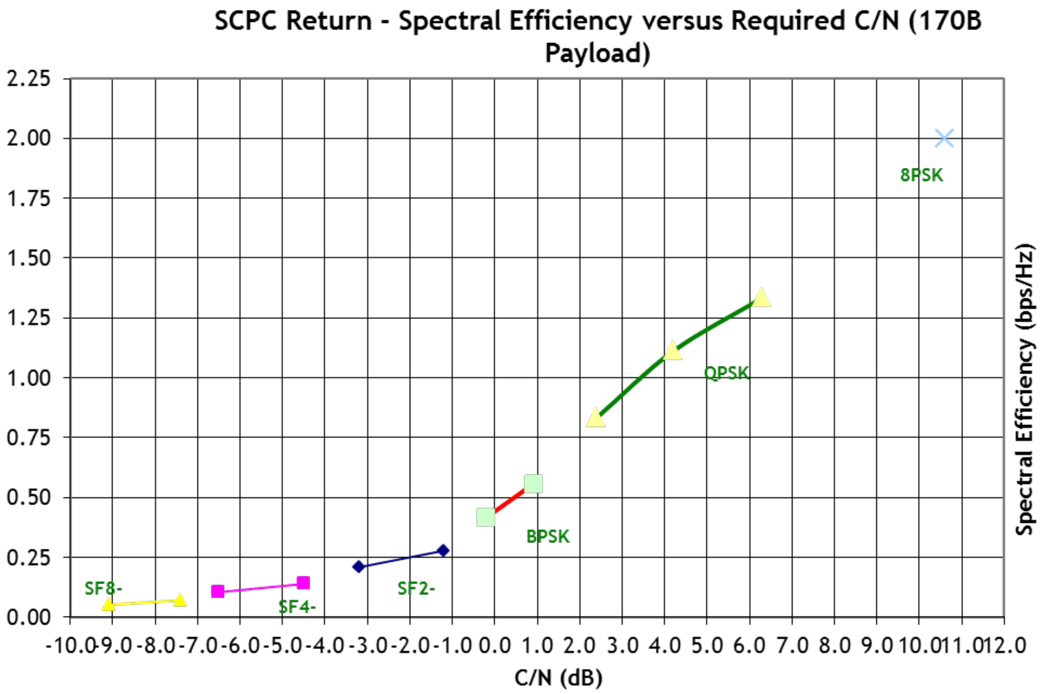
[4] $E_b/N_o=C/N-10\log_{10}(m*r/SF)$, where *m* is the modulation order (BPSK: 1, QPSK: 2, 8PSK: 3), *r* is the FEC ratio and *SF* is the spreading factor.

[5] Modem C/N performance threshold for QEF operation of the SCPC channel is specified for a Bit Error Rate (BER) of 1e-8 at L-Band. C/N is the ratio of signal power spectral density to noise power spectral density at the modem input. Performance shall not degrade by more than 0.25 dB with two adjacent carriers nominally spaced each at +7dBc.

[6] 8PSK SCPC return carriers with symbol rates below 1.5 Msps are not supported.

SCPC Upstream Performance Graph

Upstream SCPC performance graphs illustrating spectral efficiency versus operating carrier to noise ratio threshold are shown in **Figure 4** for both 170 and 438 Bytes Payload.



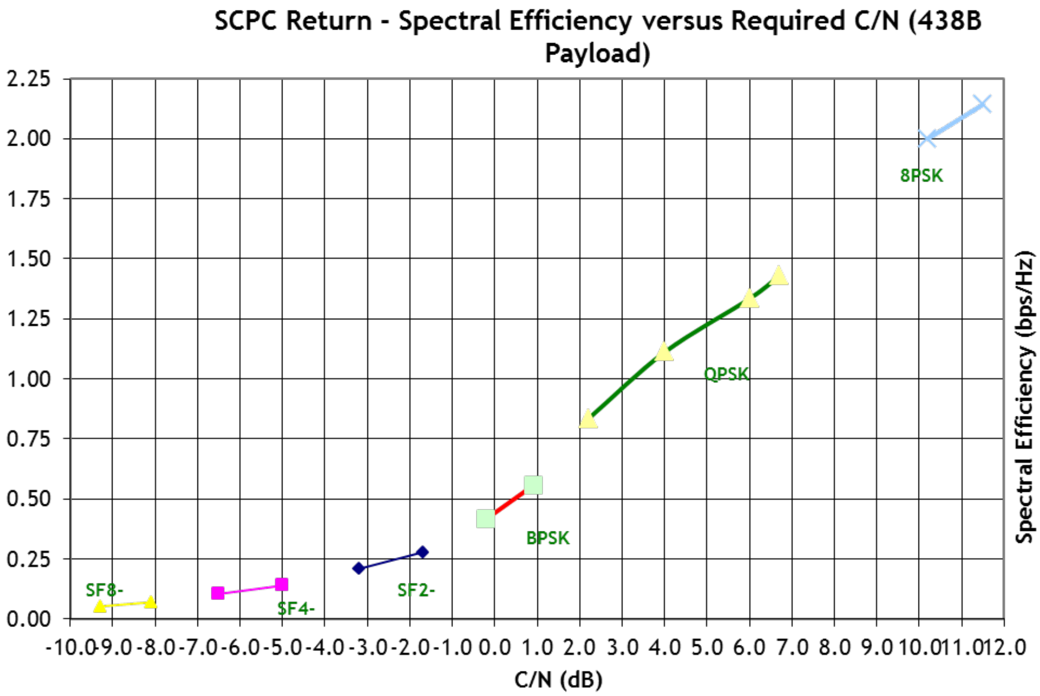


Figure 4: Upstream SCPC Performance Graph (170 and 438 Bytes Payload)

TDMA Upstream Carrier Performance Specifications

This section describes the Upstream TDMA carrier performance specifications. Refer to the section **TDMA Upstream Modes and Throughput Limitations** for modes and carrier configurations allowed based on hub line card models.

The DLC-R Defense and ULC-R Commercial series receive hub line cards support high throughput, MCD TDMA mode that provides about 4x increase in aggregate and per-channel carrier capacity than earlier line card models. **Table 4** summarizes the specifications required for upstream link budget analysis using TDMA carriers.

Table 4. SNR Performance Limit for TDMA Carriers

Symbol Rate	Refer to *TDMA Upstream Modes and Throughput Limitations* for receive linecard model types in the end section of this document
Carrier Scheme	MF-TDMA, 20% Filter roll off
Modulation/FEC	Modulation: SS-BPSK/BPSK/QPSK/8PSK/16QAM Spreading Factor (SF): 2, 4, 8 and 16 FEC: 2D16S
Minimum Carrier Spacing [1]	1.2*Symbol Rate

100 Bytes Payload

MODCOD	Spectral Efficiency [2] (bps/Hz)	E_b/N_o [3,4] for QEF (dB)	C/N [3] for QEF (dB)
8PSK Rate-3/4	1.62	7.3	10.8
8PSK Rate-2/3	1.44	6.0	9.0
QPSK Rate-3/4	1.12	4.7	6.5
QPSK Rate-2/3	1.0	3.9	5.1
QPSK Rate-1/2	0.72	2.5	2.5
BPSK Rate-2/3	0.50	3.6	1.8
BPSK Rate-1/2	0.36	2.3	-0.7
SF2-BPSK Rate-2/3	0.25	3.6	-1.2
SF2-BPSK Rate-1/2	0.19	3.7	-2.3
SF4-BPSK Rate-2/3	0.12	3.6	-4.2
SF4-BPSK Rate-1/2	0.10	3.4	-5.6
SF8-BPSK Rate-2/3	0.06	3.6	-7.2
SF8-BPSK Rate-1/2	0.05	3.9	-8.1

SF16-BPSK Rate-2/3	0.03	3.9	-9.9
SF16-BPSK Rate-1/2	0.02	3.9	-11.2
170 Bytes Payload			
MODCOD [6]	**Spectral Efficiency** [2] **(bps/Hz)**	**E_b/N_o** [3,4] **for QEF (dB)**	**C/N** [3] **for QEF (dB)**
16QAM Rate-6/7	2.56	8.6	14.0
16QAM Rate-4/5	2.40	7.5	12.6
16QAM Rate-3/4	2.24	7.3	12.1
8PSK Rate-6/7	1.85	8.2	12.3
8PSK Rate-4/5	1.73	7.0	10.8
8PSK Rate-3/4	1.62	6.3	9.8
8PSK Rate-2/3	1.44	5.4	8.4
QPSK rate-6/7	1.33	5.5	7.8
QPSK Rate-3/4	1.17	4.2	6.0
QPSK Rate-2/3	1.00	3.1	4.3
QPSK Rate-1/2	0.75	2.2	2.2
BPSK Rate-2/3	0.52	3.1	1.3
BPSK Rate-1/2	0.36	1.9	-1.1
438 Bytes Payload [6]			
MODCOD [6]	**Spectral Efficiency** [2] **(bps/Hz)**	**E_b/N_o** [3,4] **for QEF (dB)**	**C/N** [3] **for QEF (dB)**
16QAM Rate-6/7	2.66	7.8	13.2
16QAM Rate-4/5	2.49	7.0	12.1
16QAM Rate-3/4	2.33	6.3	11.1
8PSK Rate-6/7	2.00	7.6	11.7
8PSK Rate-4/5	1.87	6.4	10.2
8PSK Rate-2/3	1.56	4.9	7.9
QPSK rate-6/7	1.33	4.3	6.6
QPSK Rate-4/5	1.24	3.7	5.7
QPSK Rate-2/3	1.04	2.8	4.0
QPSK Rate-1/2	0.75	2.0	2.0
BPSK Rate-2/3	0.52	3.1	1.3
BPSK Rate-1/2	0.36	1.9	-1.1

Acquisition Burst [5]			
MODCOD	**Spectral Efficiency**	**E_b/N_o for QEF (dB)**	**C/N [3] for QEF (dB)**
Superburst (BPSK RM FEC)	N/A	N/A	-2.0
Traditional (legacy)	Same as MODCOD and payload employed for traffic slots in the carrier		

[1] 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.

[2] Spectral Efficiency includes 1.2*F_{sym} carrier spacing, FEC and TDMA burst overhead to aid burst detection and synchronization. This does not include the guard band between traffic slots and the acquisition slot duration that roughly amounts 2 to 3% loss based on symbol rates and MODCODs.

[3] 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. Performance shall not degrade by more than 0.25 dB with two adjacent carriers nominally spaced each at +7dBc.

[4] 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. This does not include TDMA burst pilot overhead, traffic guard band and acquisition slot duration – loss in Eb/No due to these factors is bounded within 0.8 dB based on payload size and MODCOD. Customers are encouraged to compute TDMA link budgets based on C/N thresholds specified and iNPT tool be referred for network throughput requirements.

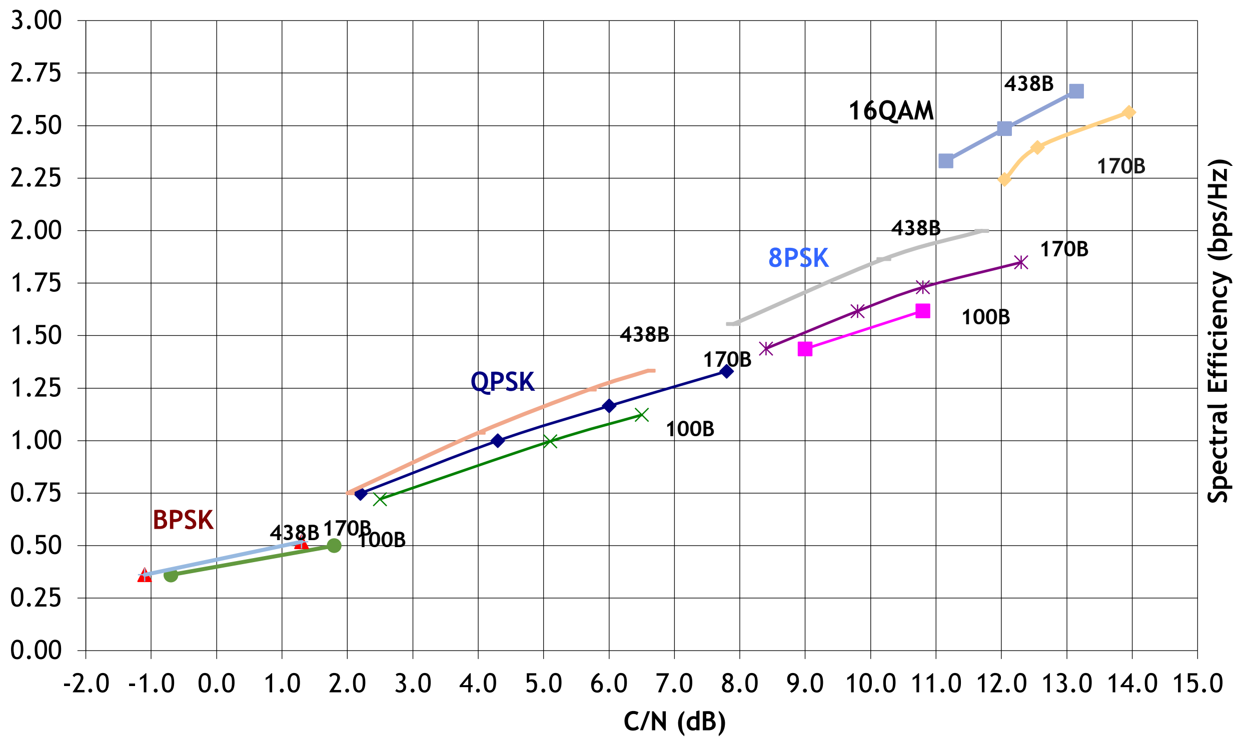
[5] Acquisition is supported through either superburst or traditional traffic burst. Superburst waveform uses Reed-Muller (RM) FEC codes with BPSK modulation and facilitates fast acquisition of remotes due to its high frequency error tolerance and C/N robustness compared to traditional acquisition.

[6] 16QAM feature is supported in ULC-R/DLC-R line cards and iQ Desktop/iQ 200 Series remotes only.

TDMA Upstream Performance Graph

Upstream TDMA performance graphs illustrating spectral efficiency versus operating C/N ratio threshold are shown in **Figure 5** for non-SS and SS modes with payload sizes supported.

Upstream Spectrum Efficiency versus Required C/N (Non-SS modes)



Upstream Spectrum Efficiency versus Required C/N (SS modes)

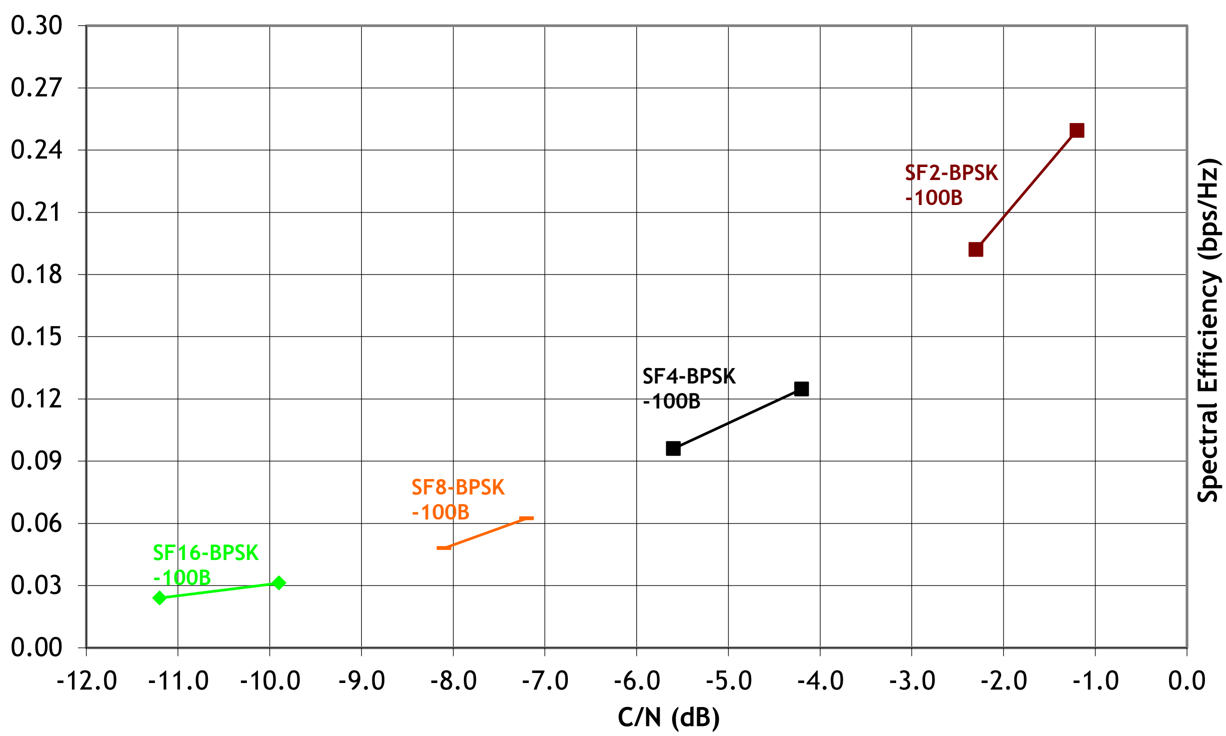


Figure 5: Upstream Performance Graphs for Non-SS and SS Modes

TDMA Upstream Modes and Throughput Limitations

This section provides carrier size restrictions, carrier properties, and model types supported based on the TDMA operating mode of the Evolution receive line card with applicable licenses.

Single Channel TDMA Static, Non-Spread (XLC-11, XLC-M, eM1D1 and eM0DM)

- All payload types supported (100/170/438 Bytes).
- For 100B payloads, maximum symbol rate is 2 Msps across all MODCODs.
- For 170B payloads, maximum symbol rate is 3.1, 4.25 and 7.5 Msps for 8PSK, QPSK and BPSK MODCODs, respectively.
- For 438B, maximum symbol rate is 7.5 Msps across all MODCODs.
- Acquisition type supported is traditional for static configuration mode. MODCOD of the carrier remains static in this operating mode across the IGCs.

Single Channel TDMA Adaptive, Non-Spread (eM1D1)

- All payload types supported (100/170/438 Bytes).
- For 100B payloads, maximum symbol rate is 3.5 Msps for 8PSK MODCODs and 5.875 Msps for QPSK and BPSK MODCODs.
- For 170B and 438B payloads, maximum symbol rate is 5.875 Msps across all MODCODs.
- Acquisition type supported is traditional or superburst in adaptive configuration mode. In this operating mode, MODCOD of the carrier can change dynamically if configured to change across the IGCs.

Single Channel TDMA, Spread (XLC-11, eM1D1)

- Only 100B payload mode with BPSK MODCOD is supported. Maximum chip rate is 7.5 Mcps.
- Maximum symbol rate is 3.75, 1.875, 0.9375 and 0.46875 Msps for Spreading Factors of 2, 4, 8 and 16, respectively.
- Acquisition type supported is traditional in spread configuration mode. MODCOD of the carrier remains static in this operating mode across the IGCs.

Multi-Channel TDMA, Non-Spread (XLC-M, eM0DM)

- All payload types supported (100/170/438 Bytes).
- Maximum composite symbol rate, aggregate of all carriers assigned to the line card, is 7.5 Msps.
- Number of channels per line card is 1 (default), licensable up to 4 and up to 8 in standard modes.
- For 100B payloads, per channel maximum symbol rate is 3.5 Msps for 8PSK MODCODs and 5.875 Msps for QPSK and BPSK MODCODs.
- For 170B and 438B payloads, per channel maximum symbol rate is 5.875 Msps across all MODCODs.
- Acquisition type supported is traditional or superburst in adaptive configuration mode for up to 8 channels and cannot be mixed. MODCOD of the carrier can change dynamically, if configured to change across the IGCs, in this operating mode.

- For the 16 channel narrowband case, per channel maximum symbol rate is 468.75 ksps and acquisition type is traditional.

Single Channel TDMA, Spread (DLC-R, ULC-R)

- 100B payload mode with BPSK MODCOD is supported. Maximum chip rate is 7.5 Mcps.
- Maximum symbol rate is 3.75, 1.875, 0.9375 and 0.46875 Msps for Spreading Factors of 2, 4, 8 and 16, respectively.
- Acquisition type supported is traditional in spread configuration mode. MODCOD of the carrier remains static in this operating mode across the IGCs.

Multi-Channel TDMA, Non-Spread (DLC-R, ULC-R)

- Maximum composite symbol rate, aggregate of all carriers assigned to the line card in MCD mode, is 29.0 Msps.
- Maximum number of channels is 16.
- Minimum and Maximum symbol rate per channel are 0.128 and 7.5 Msps respectively.
- 100/170/438B payload types supported with BPSK/QPSK/8PSK MODCODs. 170/438B payload types supported with 16QAM MODCODs.
- Acquisition type supported is traditional or superburst for up to 8 channels and cannot be mixed in MCD mode. For >8 channels, only traditional acquisition is supported.
- MODCOD of the assigned carrier in MCD mode can be kept static or adaptive across the IGCs.
- Evolution Mesh receiver features ULC-R in Multi-Channel TDMA, non-spread mode of operation.

Multi Wide-Channel (WC) TDMA, Non-Spread (DLC-R, ULC-R)

- Maximum composite symbol rate, aggregate of all carriers assigned to the line card in MCD WC mode, is 29.0 Msps.
- Maximum number of channels is 16.
- Minimum and Maximum symbol rates per channel are 0.512 and 29 Msps respectively.
- 100B payload: Not supported.
- 170B payload: Supported till 15 Msps symbol rate maximum. For 8PSK and 16QAM MODCODs only, the maximum symbol rate is restricted by the maximum slots per frame system processing limit of 1998. Approximate 8PSK max symbol rate limits are 11.7, 12.5, 13.4 and 15 Msps for code rates of 6/7, 4/5, 3/4 and 2/3 respectively to be within the slots per frame limit. Approximate 16QAM max symbol rate limits are 8.4, 9.0 and 9.6 Msps for code rates of 6/7, 4/5 and 3/4 respectively to be within the slots per frame limit.
- 438B payload: Supported till 29 Msps symbol rate maximum. For 8PSK and 16QAM MODCODs only, the maximum symbol rate is restricted by the maximum slots per frame system processing limit of 1998. Approximate 8PSK max symbol rate limits are 27.9, 29, 29 Msps for code rates of 6/7, 4/5 and 2/3 respectively to be within the slots per frame limit. Approximate 16QAM max symbol rate limits are 20.9, 22.4 and 23.9 Msps for code rates of 6/7, 4/5 and 3/4 respectively to be within the slots per frame limit.
- Acquisition type supported is traditional or superburst for up to 8 channels and cannot be mixed in MCD WC mode. For >8 channels, only traditional acquisition is supported.
- MODCOD of the assigned carrier in MCD WC mode can be kept static or adaptive across the IGCs.

Minimum TDMA Symbol Rates (All operating modes and line card types)

- 100B payload: 128 ksps for SS-BPSK/BPSK/QPSK/8PSK
- 170B payload: 128 ksps for BPSK/QPSK/8PSK
- 438B payload: 384 ksps for BPSK; 256 ksps for QPSK/8PSK
- **DLC-R/ULC-R Only:**
    - When a line card is configured for Multi Wide-Channel TDMA mode with 170B/438B payload types, the minimum symbol rate allowable for any carrier assigned to it is 512 ksps, independent of payload size and MODCOD.
    - 170B payload: 128 ksps for 16QAM
    - 438B payload: 256 ksps for 16QAM

3 System Guidelines

This chapter describes System Guidelines for the Evolution 4.1.3 network and consists of the following sections:

- *DVB-S2/S2X ACM System Guidelines*
- *Adaptive TDMA System* Guidelines

DVB-S2/S2X ACM System Guidelines

This section explains how DVB-S2/S2X 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 typical in severe rain regions of the world.

In addition to the margin added to the SNR threshold during operation, the system must also account for the variance, or margin of error, associated with the remote SNR measurement. To account for this margin of error, an additional 0.2 dB is added to the SNR threshold when determining when to switch between MODCODs. This error margin is added in both steady state and fade conditions.

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. The procedure for setting the DVB-S2/S2X margins for steady state and fade conditions is contained in the section "DVB-S2/S2X Network Parameters" of the *iBuilder User Guide*.

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.

Adaptive TDMA System Guidelines

This section provides a brief overview of the manner in which adaptive TDMA transmission is implemented in the iDirect system. For a more in-depth explanation, please refer to the *Technical Reference Guide*.

The upstream channel is subject to the same propagation phenomena and impairments as discussed in this guide for the downstream DVB-S2 ACM operation. Without adaptivity to the channel conditions, resources would have to be set aside permanently as a safeguard against these phenomena. The iDirect system implements fade mitigation techniques in the upstream that are similar in nature to the ACM in the downstream. There are, however, some differences dictated by the different nature of the air interface (TDMA vs. continuous TDM).

The core element of iDirect's adaptive TDMA system is a heterogeneous group of TDMA carriers, known as an Inroute Group, which is managed as a single entity. These carriers support different transmission rates and provide different levels of protection (MODCOD) against adverse channel effects such as rain fade. Individual terminals are assigned time slots on carriers commensurate with their need and with their instantaneous capability, as determined by the channel state. A control process continuously monitors the channel state of each remote. In a manner similar to that used for the downstream, the control process speeds up when rapid fade variation is detected and slows down when the situation is more stable. This serves to keep the required margins small and constant. The process also manages transmit power control for the remote.

The link margin required for adaptive operation is relatively small. It needs to account for propagation variation only to the extent that this can vary in the time it takes for the system to detect changes and react. This reaction time is typically 2–3 seconds. The corresponding "reaction time margin" is referred to as M_1 in the NMS. There is a further margin, called M_2 or "hysteresis margin", which serves to prevent spurious equivocation between carrier choices. The control loop will attempt to adjust the carrier choice and transmit power such that the power available from the remote is well utilized and the C/N on any carrier used is equal to the values given in **Table 4**, plus M1 + M2. Refer to the *Release Notes* for the default values of M1 and M2.

In order to maximize the resource utilization, a remote may transmit on several different carriers within a single TDMA frame considered viable by the uplink control process. Different carriers typically require different transmitted power. This variation is too fast for the closed-loop power control loop. An open-loop adjustment is applied to account for this.

In addition, the configuration of the Inroute Group is adjusted over time to maximize the system efficiency. Depending on the number of faded remotes at any time, there will be a higher or lower demand for more-protected carriers. To account for this, a separate process periodically (typically every 30 seconds; this is configurable) assesses the suitability of a number of pre-defined compositions of the Inroute Group and selects the best one for use in the next period. This assessment can also be triggered by sudden, excessive mismatch between the requested and offered capacity. In the current implementation, only the MODCOD of carriers can vary between compositions. The payload block size, the number of carriers, and their frequencies and symbol rates must be the same in all compositions.

Design of the Inroute Group Compositions (IGC), including choice of suitable symbol rates and MODCOD combinations, is an integral part of the overall network design.

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