Link Budget Analysis Guide

iDX Release 4.3.x

September 18, 2023

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Document Name: HI_LBA_Guide_iDX_4.3.1_T0001440_18_Sept_2023

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)
Revision 1	31-January-2023	Initial release for iDX 4.3.0. • Introduction of Adaptive TDMA – High Efficiency Mode (ATDMA-HEM) features of Low roll-off (5%) and New MODCODs on ULC line cards and iQ/3315 Series remotes • DVB-S2 support to 45 Msps, DVB-S2X support up to 64 Msps, TDMA support up to 29 Msps on 3315 Series remotes • Enablement of low order MODCODs in DVB-S2X mode for iQ/3315 Series remotes • Enablement of high symbol rates from 100 Msps to 119 Msps in DVB-S2X mode for iQ Series remotes • Removed EOS legacy remotes and line cards • Removed legacy SCPC return feature
Revision 2	31-May-2023	Updated for iDX Release 4.3.1. • Improvement update of 170B TDMA QEF performance of some legacy MODCODs
Revision 3	18-September-2023	Removed three MODCODs (QPSK-1/4, QPSK-1/3, QPSK-2/5) from DVB-S2X ACM Downstream section for iQ Desktop/iQ 200/iQ LTE Series Remotes.

Disclaimer

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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 4.3 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

The iDirect Technical Assistance Center (iDirect TAC) and the iDirect Government Technologies Technical Assistance Center (iDirectGov TAC) are available to provide assistance 24 hours a day, 365 days a year. Software user guides, installation procedures, an FAQ page, and other documents that support iDirect and iDirect Government products are available on the respective TAC Web site.

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1 Downstream

This chapter describes Downstream Carrier specifications for the Evolution 4.3 network and contains the following sections:

- DVB-S2 ACM Downstream
- DVB-S2X ACM Downstream

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. Linear pre-distortion for full transponder operation (both DVB-S2 / DVB-S2X modes) is as well supported.

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 remotes is provided in **Table 1**:

- Section 1 for X5 Series remotes
- Section 2 for X1/X7/-950mp/9350/900 Series remotes
- Section 3 for iQ Desktop/iQ 200/iQ LTE Series remotes
- Section 4 for MDM3315/SMB3315 Series remotes

32ASPK operation is supported only in X7/950mp/9350/900/iQ/3315 Series remote models.

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

Carrier Scheme	DVB-S2, ACM, Short Frame, Pilots On, Filter roll-off [1] (α) of 5, 10, 15 and 20%					
Modulation/Forward Error Correction (FEC)	Modulation: QPSK/8PSK/16APSK/32APSK FEC: LDPC/BCH					
Symbol Rate	1 to 45 Msps					
Minimum Carrier Spacing [1]	(1+α) * Symbol Rate					
Section 1: SNR Threshold for Evolution 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 2: SNR Threshold for Evolution X1[5]/X7/950mp/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
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	5.4	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 3: SNR Threshold for iQ Desktop/iQ 200 Series Remotes [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
21	16APSK Rate 5/6	13040	4212	3.10	7.3	12.2
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
Section 4: SNR Threshold for MDM3315/SMB3315 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	3.1	-1.4
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	2.2	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	3.3	5.0
9	QPSK Rate 5/6	13040	8370	1.56	3.7	5.6
10	QPSK Rate 8/9	14120	8370	1.69	4.4	6.7
12	8PSK rate 3/5	9440	5598	1.69	4.0	6.3
13	8PSK Rate 2/3	10520	5598	1.88	4.5	7.2
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	7.1	11.1
18	16APSK Rate 2/3	10520	4212	2.50	5.8	9.8
19	16APSK Rate 3/4	11600	4212	2.75	6.5	10.9
20	16APSK Rate 4/5	12320	4212	2.92	7.0	11.7
21	16APSK Rate 5/6	13040	4212	3.10	7.3	12.2
22	16APSK Rate 8/9	14120	4212	3.35	8.3	13.6
24	32APSK Rate 3/4	11600	3402	3.41	8.7	14.0
25	32APSK Rate 4/5	12320	3402	3.62	9.4	15.0
26	32APSK Rate 5/6	13040	3402	3.83	9.8	15.6
27	32APSK Rate 8/9	14120	3402	4.15	10.8	17.0

[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 and modem type. 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 $1/(1+\alpha)$.

[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 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.

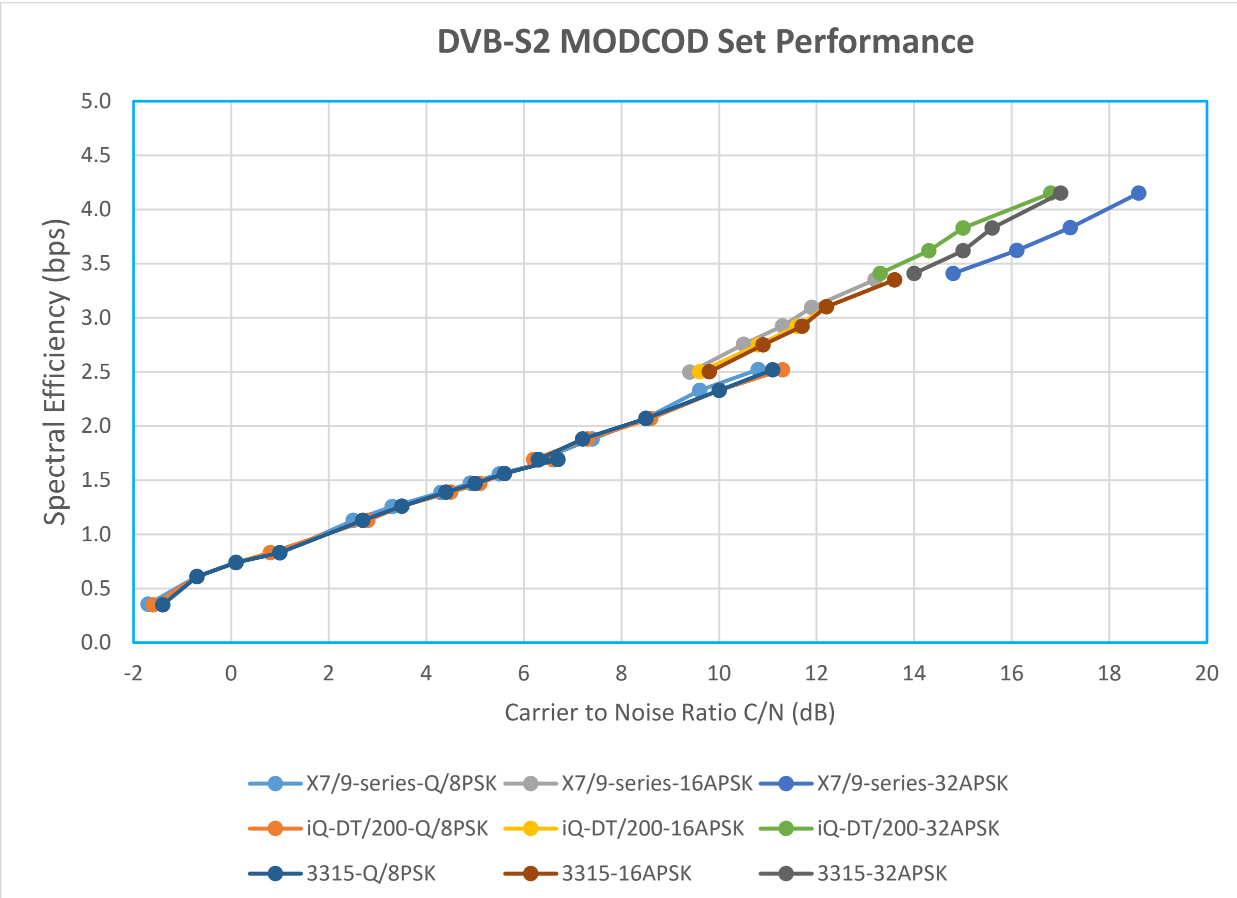

Figure 1: Downstream Performance Graph for DVB-S2

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

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 1 of **Table 2** show the modem performance threshold for iQ Desktop/iQ 200/iQ LTE Series remotes and Section 2 of **Table 2** show the modem performance threshold for MDM3315/SMB3315 Series remotes. There are 27 MODCODs optimally selected to support a C/N dynamic range of roughly 23 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 by Remote Model Type

Carrier Scheme	DVB-S2/S2X, ACM, Normal Frame, Pilots On, Filter roll-off (α) of 5, 10, 15 and 20%
Modulation/FEC	Modulation: All S2/S2X constellations from QPSK to 256APSK FEC: LDPC/BCH
Symbol Rate (Fsym) and Max MODCOD Support per Remote Type	**iQ Series:** 5 < Fsym <= 109 Msps, 256APSK-3/4 Allowed Max MODCOD 109 < Fsym <= 119 Msps, 128APSK-3/4 Allowed Max MODCOD Occupied BW should not exceed 125 MHz hardware limit of linecard/iQ Series **3315 Series:** 5 < Fsym <= 43 Msps[5], 64APSK-4/5 Allowed Max MODCOD 43 < Fsym <= 51 Msps[5], 32APSK-7/9 Allowed Max MODCOD 51 < Fsym <= 64 Msps[5], 16APSK-7/9 Allowed Max MODCOD Symbol rate greater than 64 Msps not allowed
Minimum Carrier Spacing [4]	(1+α) * Fsym

Section 1: SNR Threshold for iQ Desktop/iQ 200/iQ LTE Series Remotes

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

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
Section 2: SNR Threshold for MDM3315/SMB3315 Series Remotes							
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	5	QPSK Rate 1/4	15896	33282	0.48	1.5	-1.7
2	9	QPSK Rate 1/3	21296	33282	0.64	1.0	-0.9
3	13	QPSK Rate 2/5	25616	33282	0.77	1.0	-0.1
4	135	QPSK Rate 9/20	28856	33282	0.87	1.1	0.5
5	137	QPSK Rate 11/20	35336	33282	1.06	1.5	1.8
6	21	QPSK Rate 3/5	38576	33282	1.16	1.8	2.4
7	25	QPSK Rate 2/3	42928	33282	1.29	2.2	3.3
8	29	QPSK Rate 3/4	48296	33282	1.45	2.6	4.2
9	139	8APSK Rate 5/9-L	35696	22194	1.61	3.3	5.4
10	149	16APSK Rate 1/2-L	32096	16686	1.92	3.4	6.2
11	153	16APSK Rate 5/9-L	35696	16686	2.14	3.9	7.2
12	155	16APSK Rate 26/45	37136	16686	2.23	4.4	7.9
13	163	16APSK Rate 23/36	41096	16686	2.46	4.9	8.8
14	167	16APSK Rate 25/36	44696	16686	2.68	5.3	9.6
15	77	16APSK Rate 3/4	48296	16686	2.89	5.9	10.5
16	171	16APSK Rate 7/9	50096	16686	3.00	6.2	11.0
17	175	32APSK Rate 2/3-L	42928	13338	3.22	6.8	11.9
18	179	32APSK Rate 32/45	45776	13338	3.43	7.3	12.7
19	183	32APSK Rate 7/9	50096	13338	3.76	8.2	13.9

20	185	64APSK Rate 32/45-L	45776	11142	4.11	9.3	15.4
21	187	64APSK Rate 11/15	47216	11142	4.24	10.1	16.4
22	195	64APSK Rate 4/5	51536	11142	4.63	11.1	17.8

[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 $1/(1+\alpha)$.

[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. Refer to the *Technical Reference Guide* (on DVB-S2/S2X roll-off factors) for adjacent channel interference limitations based on roll-off factors and modem type.

[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] 3315 Series remotes do not support greater than 64 Msps and can co-exist with iQ Series remotes up to 64 Msps. Traffic will be limited to the allowed maximum MODCOD per symbol rate range defined for 3315 remotes.

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.

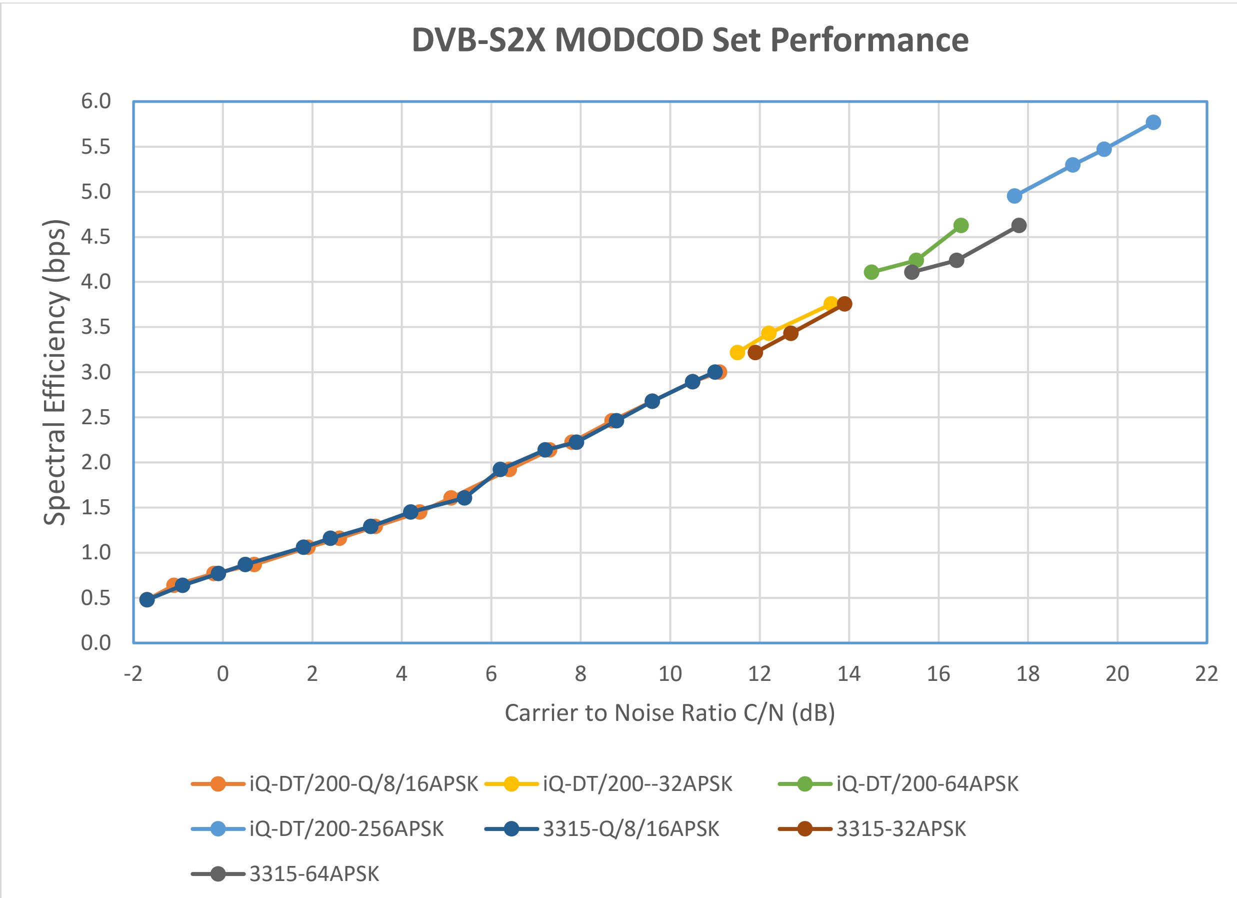

Figure 2: Downstream Performance Graph for DVB-S2X

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. Note performance comparison graph is based on iQ Series thresholds.

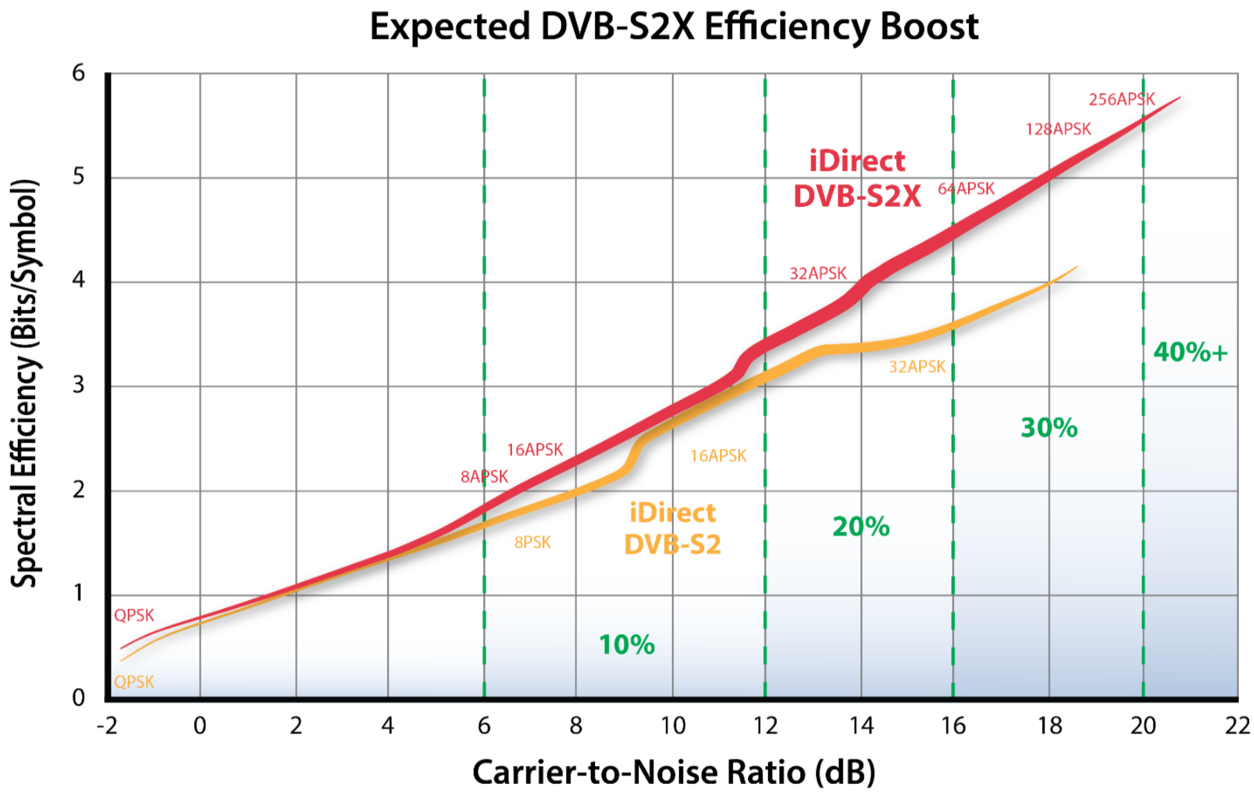

Figure 3: Downstream Efficiency Comparison for DVB-S2X and DVB-S2 modes

2 Upstream

This chapter describes Upstream Carrier specifications for the Evolution 4.3 network and consists of the following sections:

- TDMA Upstream Carrier Performance Specifications
- Adaptive TDMA – High Efficiency Mode
- TDMA Upstream Modes and Throughput Limitations

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 3** summarizes the specifications required for upstream link budget analysis using TDMA carriers. Performance is provided for both ATDMA legacy MODCODs and ATDMA High Efficiency Mode (HEM) MODCODs, separated by payload sizes.

Table 3. SNR Performance Limit for TDMA Legacy and HEM Carriers

Symbol Rate	Refer to TDMA Upstream Modes and Throughput Limitations for receive line card model types in the end of this document.		
Carrier Scheme	MF-TDMA, Filter roll-off (α) [1] of 5 and 20%		
Modulation/FEC	Modulation: SS-BPSK/BPSK/QPSK/8PSK/16QAM Spreading Factor (SF): 2, 4, 8 and 16 FEC: 2D16S		
Minimum Carrier Spacing [2]	(1+ α) * Symbol Rate		
100 Bytes Legacy MODCODs [1]			
MODCOD	**Spectral Efficiency** [3] **(bps)**	**E_b/N_o** [4,5] **for QEF (dB)**	**C/N** [4] **for QEF (dB)**
8PSK Rate-3/4	1.94	7.3	10.8
8PSK Rate-2/3	1.72	6.0	9.0
QPSK Rate-3/4	1.35	4.7	6.5
QPSK Rate-2/3	1.20	3.9	5.1
QPSK Rate-1/2	0.87	2.5	2.5
BPSK Rate-2/3	0.60	3.6	1.8
BPSK Rate-1/2 [10]	0.43	2.3	-0.7
SF2-BPSK Rate-2/3	0.30	3.6	-1.2
SF2-BPSK Rate-1/2	0.23	3.7	-2.3
SF4-BPSK Rate-2/3	0.15	3.6	-4.2
SF4-BPSK Rate-1/2	0.12	3.4	-5.6
SF8-BPSK Rate-2/3	0.08	3.6	-7.2

SF8-BPSK Rate-1/2	0.06	3.9	-8.1
SF16-BPSK Rate-2/3	0.04	3.9	-9.9
SF16-BPSK Rate-1/2	0.03	3.9	-11.2
170 Bytes Legacy MODCODs [1]			
MODCOD [6]	**Spectral Efficiency [3] (bps)**	**E_b/N_o [4,5] for QEF (dB)**	**C/N [4] for QEF (dB)**
16QAM Rate-6/7	3.08	8.6	14.0
16QAM Rate-4/5	2.88	7.5	12.6
16QAM Rate-3/4	2.69	7.2	12.0
8PSK Rate-6/7	2.22	7.9	12.0
8PSK Rate-4/5	2.08	6.8	10.6
8PSK Rate-3/4	1.94	6.2	9.7
8PSK Rate-2/3	1.73	5.3	8.3
QPSK Rate-6/7	1.60	5.4	7.7
QPSK Rate-3/4	1.40	4.2	6.0
QPSK Rate-2/3	1.20	3.1	4.3
QPSK Rate-1/2	0.90	2.2	2.2
BPSK Rate-2/3	0.62	3.1	1.3
BPSK Rate-1/2 [10]	0.43	1.9	-1.1
SS-BPSK SF=2 Rate-2/3	0.31	3.3	-1.5
SS-BPSK SF=2 Rate-1/2	0.22	2.1	-3.9
SS-BPSK SF=4 Rate-2/3	0.15	3.0	-4.8
SS-BPSK SF=4 Rate-1/2	0.11	2.0	-7.0
SS-BPSK SF=8 Rate-2/3	0.07	2.8	-8.0
SS-BPSK SF=8 Rate-1/2	0.06	1.9	-10.1
170 Bytes HEM MODCODs [1]			
MODCOD [6]	**Spectral Efficiency [3] (bps)**	**E_b/N_o [4,5] for QEF (dB)**	**C/N [4] for QEF (dB)**
16QAM Rate-9/10	3.24	9.8	15.4
16QAM Rate-2/3	2.40	6.1	10.4
16QAM Rate-3/5	2.16	5.4	9.2
16QAM Rate-6/11	1.95	5.0	8.4
16QAM Rate-1/2	1.79	4.4	7.4

QPSK Rate-4/5	1.49	4.2	6.2
QPSK Rate-3/5	1.08	2.4	3.2
QPSK Rate-2/5	0.67	1.5	0.5
QPSK Rate-1/3	0.53	1.2	-0.6
BPSK Rate-2/5	0.33	1.6	-2.4
BPSK Rate-1/3	0.27	1.3	-3.5
438 Bytes Legacy MODCODs			
MODCOD [6]	**Spectral Efficiency [3] (bps)**	**E_b/N_o [4,5] for QEF (dB)**	**C/N [4] for QEF (dB)**
16QAM Rate-6/7	3.20	7.6	13.0
16QAM Rate-4/5	2.98	6.9	12.0
16QAM Rate-3/4	2.80	6.3	11.1
8PSK Rate-6/7	2.40	7.6	11.7
8PSK Rate-4/5	2.24	6.4	10.2
8PSK Rate-2/3	1.87	4.9	7.9
QPSK Rate-6/7	1.60	4.3	6.6
QPSK Rate-4/5	1.49	3.7	5.7
QPSK Rate-2/3	1.24	2.8	4.0
QPSK Rate-1/2	0.90	2.0	2.0
BPSK Rate-2/3	0.62	3.1	1.3
BPSK Rate-1/2	0.43	1.9	-1.1
438 Bytes HEM MODCODs [1]			
MODCOD [6]	**Spectral Efficiency [3] (bps)**	**E_b/N_o [4,5] for QEF (dB)**	**C/N [4] for QEF (dB)**
16QAM Rate-9/10	3.36	8.4	14.0
16QAM Rate-2/3	2.40	5.3	9.6
16QAM Rate-3/5	2.16	4.7	8.5
16QAM Rate-6/11	1.96	4.1	7.5
16QAM Rate-1/2	1.80	3.9	6.9
QPSK Rate-3/4	1.40	2.7	4.5
QPSK Rate-3/5	1.08	1.9	2.7
QPSK Rate-2/5	0.69	1.2	0.2

QPSK Rate-1/3	0.58	1.0	-0.8
BPSK Rate-2/5	0.33	1.4	-2.6
BPSK Rate-1/3	0.27	1.1	-3.7
Acquisition Burst [7]			
MODCOD	**Spectral Efficiency**	**E_b/N_o [4,5] for QEF (dB)**	**C/N [4] for QEF (dB)**
Superburst [8]	N/A	N/A	-2.0
SS-ACQ burst [9]	N/A	N/A	-10.0
Traditional (legacy)	Same as MODCOD and payload employed for traffic slots in the carrier		

[1] Low Filter roll-off (α) of 5% is supported only in ULC-R Series line cards and iQ/3315 Series remotes. Spread spectrum waveforms do not support 5% roll-off.

ATDMA-HEM MODCODs with 170 Bytes and 438 Bytes payloads are supported only in ULC-R Series line cards and iQ/3315 Series remotes. DLC-R Series line cards neither support 5% roll-off nor HEM MODCODs. 3315 Series does not support 100 Bytes payload and does not support spread spectrum with 170 Bytes payload.

[2] Satellite operators must be consulted to determine the actual carrier spacing. The carrier spacing is (1+ α) * Chip rate for spread carriers where the Chip Rate is determined as SF*Symbol Rate.

[3] Spectral Efficiency includes Spreading Factor, FEC and TDMA burst overhead to aid burst detection and synchronization. This does not include the carrier spacing based on filter roll-off. It also 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.

[4] 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 0.3 dB with two adjacent carriers nominally spaced each at +7dBc.

[5] $E_b/N_o=C/N-10\log_{10}(m*r/SF)$, where *m* is the modulation order (BPSK: 1, QPSK: 2, 8PSK: 3, 16QAM: 4), *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.

[6] 16QAM (170/438 Bytes payload) feature is supported only in ULC-R/DLC-R Series line cards and iQ/3315 Series remotes. Adaptive Spread (170 Bytes payload) feature is supported in ULC-R/DLC-R Series line cards, iQ/3315/9-Series remotes. Note DLC-R only supports legacy MODCODs

[7] Acquisition is supported through Superburst for Adaptive Non-spread carriers (all payload types) and through SS-ACQ burst for Adaptive spread carriers (170 Bytes payload only). Traditional (legacy) acquisition based on traffic burst is also supported.

[8] 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 for non-spread mode, 5 and 20% roll-off operation. The maximum number of channels that are Superburst acquisition capable in MCD-TDMA mode is limited to 8. QEF corresponds to 1e-5 acquisition burst error rate at -2 dB C/N. Reduced QEF performance to 1e-3 is permitted down to -3.7 dB C/N to support HEM Low C/N MODCOD operation.

[9] The SS-ACQ burst waveform uses 2D16S FEC codes with BPSK modulation and facilitates fast acquisition of remotes due to its high frequency error tolerance and C/N robustness for adaptive spread mode operation down to -10.0 dB. QEF corresponds to 1e-5 acquisition burst error rate. The maximum number of channels that are SS-ACQ capable in MCD-TDMA mode is limited to 8. SS-ACQ operation is restricted to 20% roll-off.

[10] BPSK-1/2 MODCOD has 0.5 dB loss for 100 Bytes and 170 Bytes payload, when operated at 5% roll-off.

TDMA Upstream Performance Graph

Upstream TDMA performance graphs illustrating spectral efficiency versus operating C/N ratio threshold are shown in **Figure 4** and **Figure 5** for non-SS and SS modes with payload sizes supported.

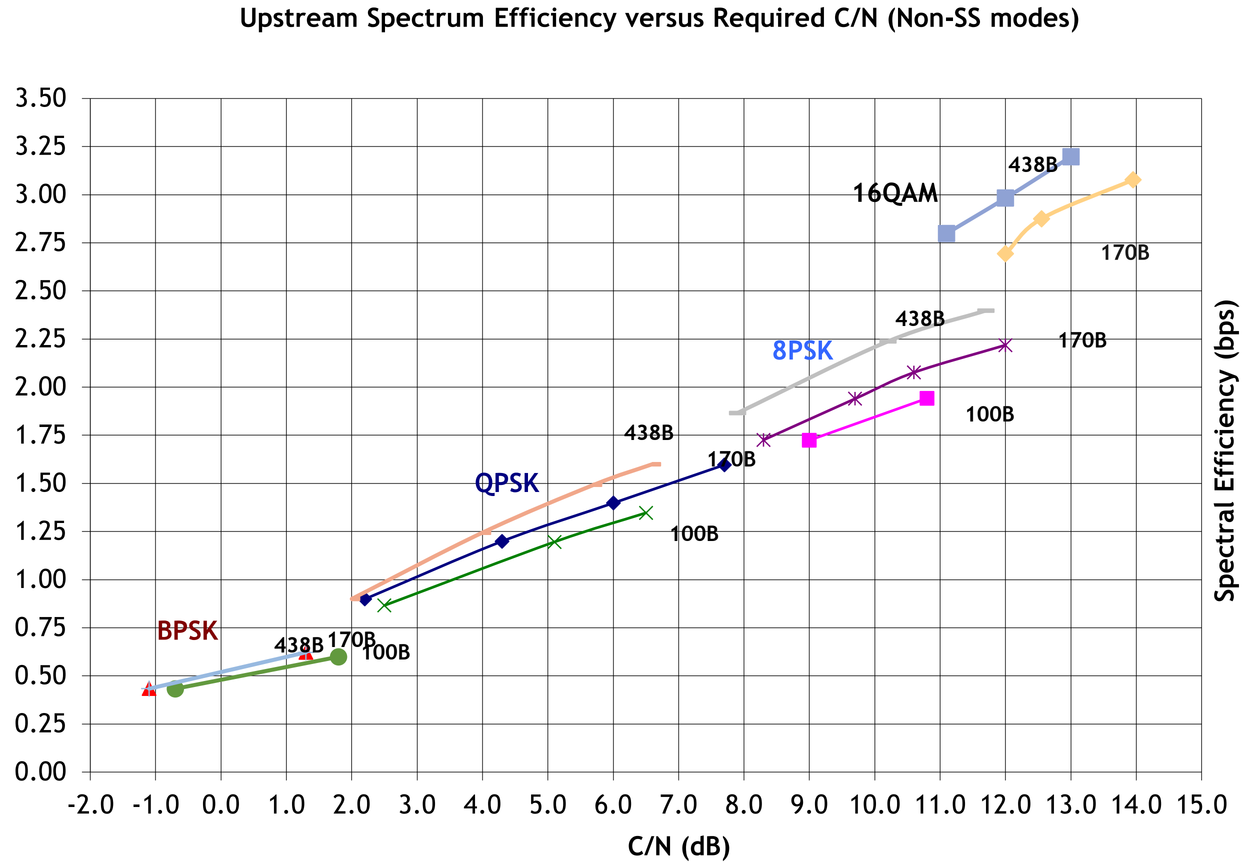

Figure 4: Upstream TDMA Performance Graphs for 100, 170 and 438 Bytes Non-Spread Modes (Legacy MODCODs)

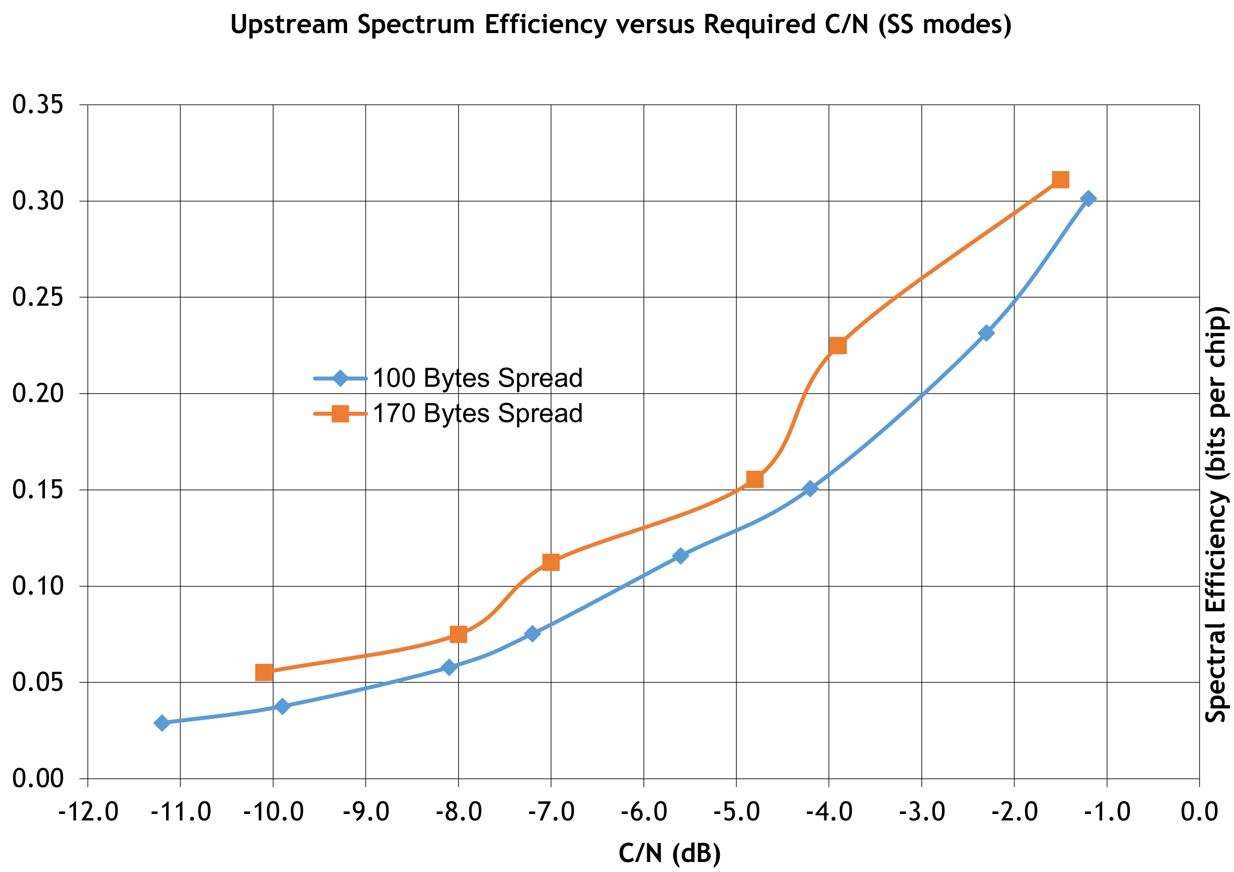

Figure 5: Upstream TDMA Performance Graphs for 100 and 170 Bytes Spread Spectrum Modes

Adaptive TDMA – High Efficiency Mode

This section describes Adaptive TDMA waveform enhancements for High Efficiency Mode (ATDMA-HEM) operation. ATDMA-HEM achieves high spectral efficiency, better granularity in MODCODs and extends the C/N dynamic range over legacy MODCOD space and complements it in certain operating regions (for example QPSK and 16QAM space). ATDMA-HEM feature is supported only in ULC-R line card and iQ/3315 Series remotes.

ATDMA-HEM combines new MODCODs, made possible with FEC technology advances, with low roll-off support in providing the following advantages:

- Low roll-off of 5% provides about 14.3% bps/Hz improvement resulting in 12.5% savings in bandwidth across entire MODCOD space (legacy and HEM) and payload sizes (100, 170 and 438 Bytes) over 20% roll-off.
- Mixed inroute group supporting combination of 5% and 20% carriers for flexibility in bandwidth and network planning suited to satellite operation / transponder requirement.
- HEM MODCODs, along with legacy MODCODs, extend the non-spread carrier C/N operating range to roughly 18 dB spanning from -3.5 dB to about 15.0 dB. Feature is available with both 170 Bytes and 438 Bytes payload, supporting both 5% and legacy 20% roll-offs. Following advantages listed in order of SNR regions:
    - Fills up the spectral efficiency (bits per symbol) coverage gaps by providing more granular and higher efficient modes in Low SNR region (-3.5 to 6.0 dB)
    - Achieves 20 to 35% efficiency boost based on payload and operating C/N, replacing (all) legacy 8PSK with HEM 16QAM MODCODs in Medium SNR region (6.0 to 12.0 dB)
    - Provides high spectral efficiency in high SNR region (>12.0 dB) exceeding 3.0 bps/Hz. For 438 Bytes 16QAM-9/10, roughly 3.2 bps/Hz efficiency is achieved at a C/N of 14 dB
- **Adaptive carrier** advantage with HEM MODCODs over legacy MODCODs is shown below based on LBA figures in **Table 3** for Medium and Low SNR regions.

  HEM 16QAM Rate-2/3 provides about 15.4% improvement in throughput over Legacy 8PSK Rate-4/5 for 170 Bytes payload along with improvement in LBA.

8PSK Rate-4/5 (legacy)	bps: 2.08	C/N: 10.6 dB
16QAM Rate-2/3 (HEM)	bps: 2.40	C/N: 10.4 dB

  HEM QPSK Rate-2/5 provides about 1.1 dB improvement in LBA and about 11.3% improvement in throughput over Legacy BPSK Rate-2/3 for 438 Bytes payload.

BPSK Rate-2/3 (legacy)	bps: 0.62	C/N: 1.3 dB
QPSK Rate-2/5 (HEM)	bps: 0.69	C/N: 0.2 dB

- **Adaptive spread** carriers can now utilize HEM BPSK and HEM QPSK MODCODs, replacing SF2-BPSK legacy and BPSK legacy MODCODs respectively, providing significant link budget advantages. Illustrated below is a comparison table from LBA figures in **Table 3**.

  HEM BPSK Rate 2/5 carriers provide about 1 dB improvement in LBA and about 6.5% improvement in throughput over Spread Factor 2 BPSK Rate 2/3 for 170 Bytes payload.

SS-BPSK SF=2 Rate-2/3 (legacy)	bps: 0.31	C/N: -1.5 dB

BPSK Rate-2/5 (HEM)	bps: 0.33	C/N: -2.4 dB

HEM QPSK Rate 2/5 carriers provide about 1 dB improvement in LBA and about 8.0% improvement in throughput over Legacy BPSK Rate 2/3 for 170 Bytes payload.

BPSK Rate-2/3 (legacy)	bps: 0.62	C/N: 1.3 dB
QPSK Rate-2/5 (HEM)	bps: 0.67	C/N: 0.5 dB

Adaptive spread carrier inclusive of HEM MODCODs is only available at 20% roll-off.

- Acquisition bursts (traditional, superburst) support both 5 and 20% roll-off operation and over HEM MODCOD space for Adaptive carrier. SS-ACQ acquisition burst for Adaptive spread carrier is only available at 20% roll-off.

Remote terminal parameters of Output Back off (OBO, in dB) from maximum power of Block Upconverter (BUC) and BUC MODCOD limit are configurable from the Hub side (NMS parameters) on a per remote basis. This allows optimization of higher order, HEM and Legacy MODCODs/roll-offs as needed based on terminal BUC characteristics during commissioning or in real time operation. Power correction limit and slot allocations are appropriately adjusted by the Hub to an individual remote for flexibility in operation in an HEM capable Inroute group with mixed remote RF characteristics. OBO limit is only applied to carriers that are configured for 16QAM and/or low roll-off operation.

ATDMA-HEM Performance Graph

HEM Upstream TDMA performance graphs illustrating spectral efficiency versus operating C/N ratio are shown in **Figure 6** and **Figure 7** for 170 and 438 Bytes payloads respectively. The SNR regions are demarcated in both charts demonstrating ATDMA-HEM efficiency benefits in terms of extended dynamic range, efficiency boost and granularity.

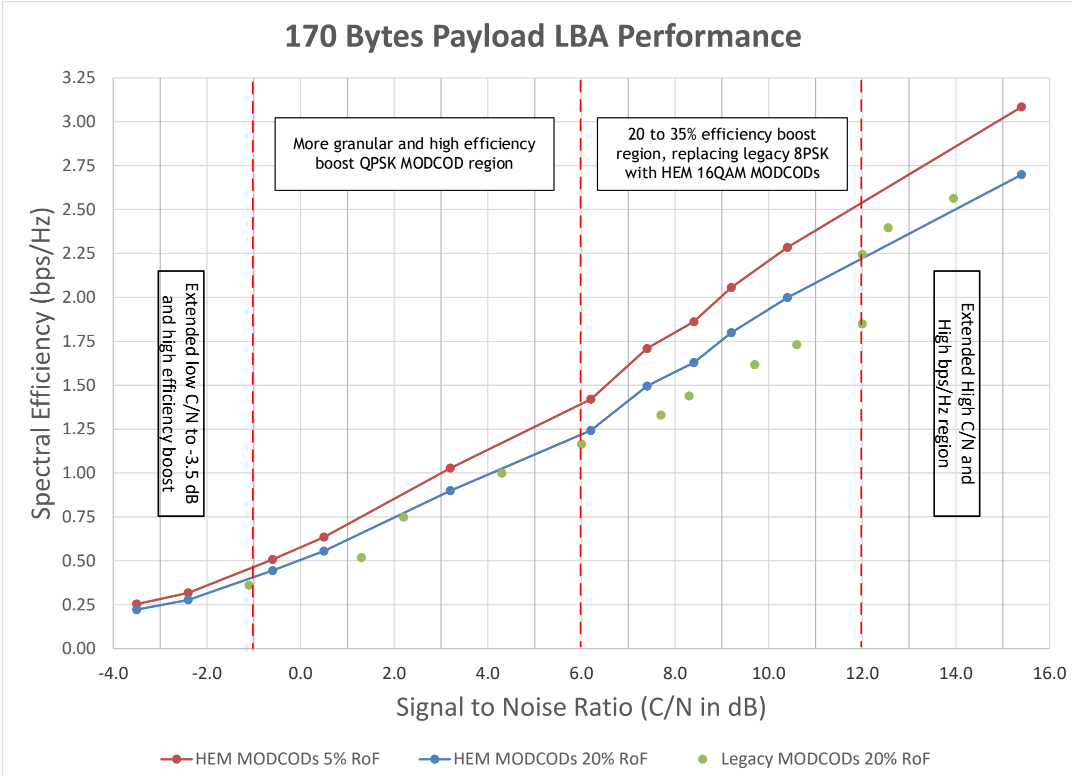

Figure 6: ATDMA-HEM Performance Advantage for 170 Bytes Payload

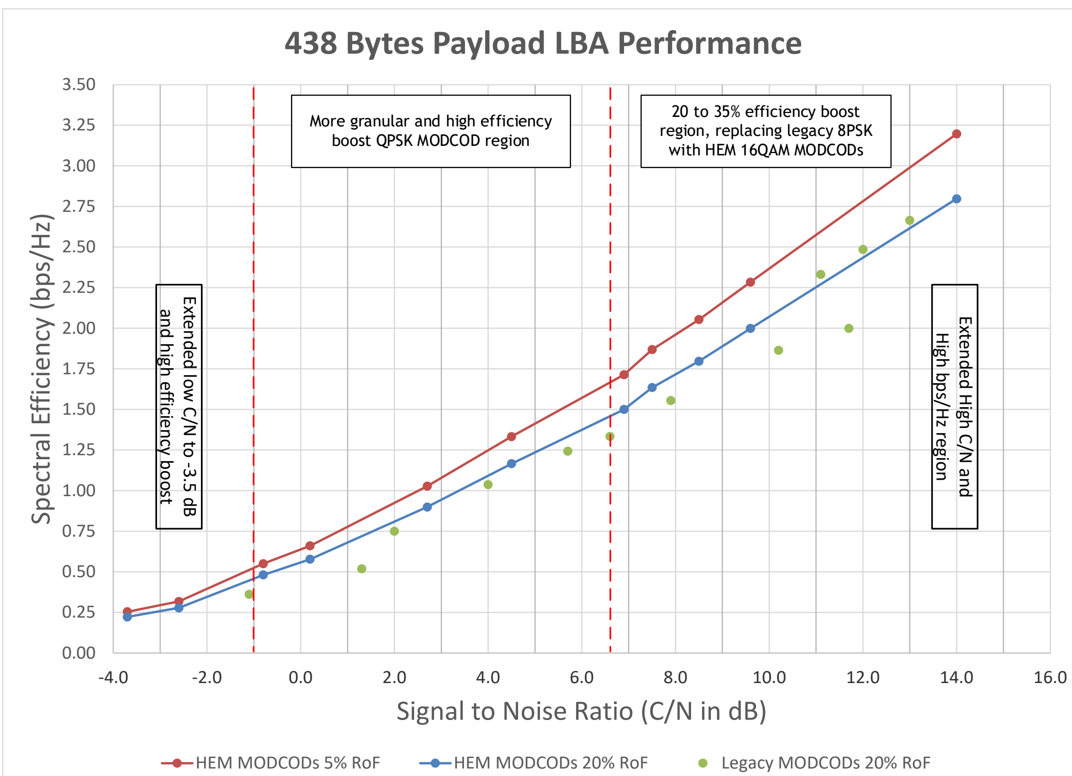

Figure 7: ATDMA-HEM Performance Advantage for 438 Bytes Payload

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, 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. Roll-off support is 20%.
- 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 + Spread (DLC-R, ULC-R)

- Maximum composite symbol/chip rate, aggregate of all carriers assigned to the line card in MCD mode, is 29.0 Msps/Mcps.
- Maximum number of channels is 16.
- Maximum symbol/chip rate per channel is 7.5 Msps/Mcps.
- 100/170/438B payload types supported with BPSK/QPSK/8PSK MODCODs. 170/438B payload types supported with 16QAM MODCODs. Adaptive spread carrier with spread BPSK MODCODs supported with 170B payload only. MODCODs are supported within the 1998 slots per frame limit or 7.5 Msps/Mcps symbol/chip rate, whichever limit occurs earlier.
- Roll-offs of 5% and 20% are supported. Spread spectrum / Adaptive spread carriers support 20% roll-off only. HEM MODCODs (170/438B) are supported.
- Superburst, SS-ACQ or Traditional acquisition burst types are supported. Superburst and SS-ACQ burst supported with Adaptive (Non-spread) and Adaptive spread carrier types respectively. For >8 channels, only traditional acquisition is supported. Traditional acquisition cannot be mixed with any other ACQ burst types in an Inroute group.
- Superburst and/or SS-ACQ burst types can be mixed in any combination with up to a maximum of 8 channels.
- MODCOD of the assigned carrier in MCD mode can be kept static or adaptive across the IGCs. For 170B Adaptive spread carrier type, MODCOD adaptation inclusive of HEM MODCODs is permitted up to QPSK-2/3 MODCOD max.
- DLC-R does not support 5% roll-off and HEM MODCODs.
- Evolution Mesh Remote receiver features ULC-R in Multi-Channel TDMA mode of operation with Mesh TDMA channel performance compliant to **Table 4**. ATDMA-HEM is not supported.

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

- Maximum composite symbol/chip rate, aggregate of all carriers assigned to the line card in MCD mode, is 29.0 Msps/Mcps.
- Maximum number of channels is 16.
- Maximum symbol/chip rate per channel is 29.0 Msps/Mcps.

- Roll-offs of 5% and 20% are supported. Spread spectrum / Adaptive spread carriers support 20% roll-off only. HEM MODCODs (170/438B) are supported.
- 100B payload: Not supported.
- 170B payload: All MODCODs (BPSK/QPSK/8PSK/16QAM) are supported within the 1998 slots per frame limit or 29 Msps/Mcps symbol/chip rate, whichever limit occurs earlier. Adaptive spread carrier with spread BPSK MODCODs supported with this payload only.
- 438B payload: All Non-spread MODCODs are supported within the 1998 slots per frame limit or 29 Msps symbol rate, whichever limit occurs earlier.
- Superburst, SS-ACQ or Traditional acquisition burst types are supported. Superburst and SS-ACQ burst supported with Adaptive (Non-spread) and Adaptive spread carrier types respectively. For >8 channels, only traditional acquisition is supported. Traditional acquisition cannot be mixed with any other ACQ burst types in an Inroute group.
- Superburst and/or SS-ACQ burst types can be mixed in any combination with up to a maximum of 8 channels.
- DLC-R does not support 5% roll-off and HEM MODCODs.
- MODCOD of the assigned carrier in MCD mode can be kept static or adaptive across the IGCs. For 170B Adaptive spread carrier type, MODCOD adaptation inclusive of HEM MODCODs is permitted up to QPSK-2/3 MODCOD max.

Minimum TDMA Carrier Rates (All operating modes)

- 100B payload: 128 ksps for SS-BPSK/BPSK/QPSK/8PSK
- 170B payload: 128 ksps for BPSK/QPSK/8PSK/16QAM
1000 kcps for SS-BPSK (Adaptive spread chip rate)
- 438B payload: 384 ksps for BPSK; 256 ksps for QPSK/8PSK/16QAM
- When a line card is configured for Multi Wide-Channel TDMA mode with 170B/438B payload types, the minimum symbol rate allowable for any Non-spread carrier assigned to it is 512 ksps, independent of payload size and MODCOD
- 5% roll-off HEM mode: 256 ksps

3 System Guidelines

This chapter describes System Guidelines for the Evolution 4.3 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 footprint, 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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