# Link Budget Analysis Guide

**Velocity Release 1.1**

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# About

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

## Purpose

The purpose of this guide is to provide 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 Velocity series of hub and remote products for networks associated with 1.1 Release.

## Target Audience

The intended audience for this guide is 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 (TAC) is 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 products are available on the TAC Web site. The TAC Web site is accessed at: http://tac.idirect.net. The TAC may also be contacted by telephone or e-mail.

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# Downstream Carrier Performance Specifications

This section describes Downstream Carrier specifications.

## 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 Velocity CX751/753/780 Series Remotes is provided in Section 1 of Table 1.

**Table 1.** DVB-S2 Modem Performance Limit

| | |
|---|---|
| **Symbol Rate** | 1 to 45 Msps |
| **Carrier Scheme** | DVB-S2, ACM, Short Frame, Pilots On,<br>Filter roll off (α) of 20% |
| **Modulation/FEC** | Modulation: QPSK/8PSK/16APSK<br>FEC: LDPC/BCH |
| **Minimum Carrier Spacing** [1] | (1+α)*Symbol Rate |

**Section 1: SNR Threshold for Velocity Series Remotes**

| MODCOD Index | MODCOD Type | 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 | 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 |

[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 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). Satellite operators must be consulted to determine the actual carrier spacing.e

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

[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%).

## Downstream Performance Graph

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

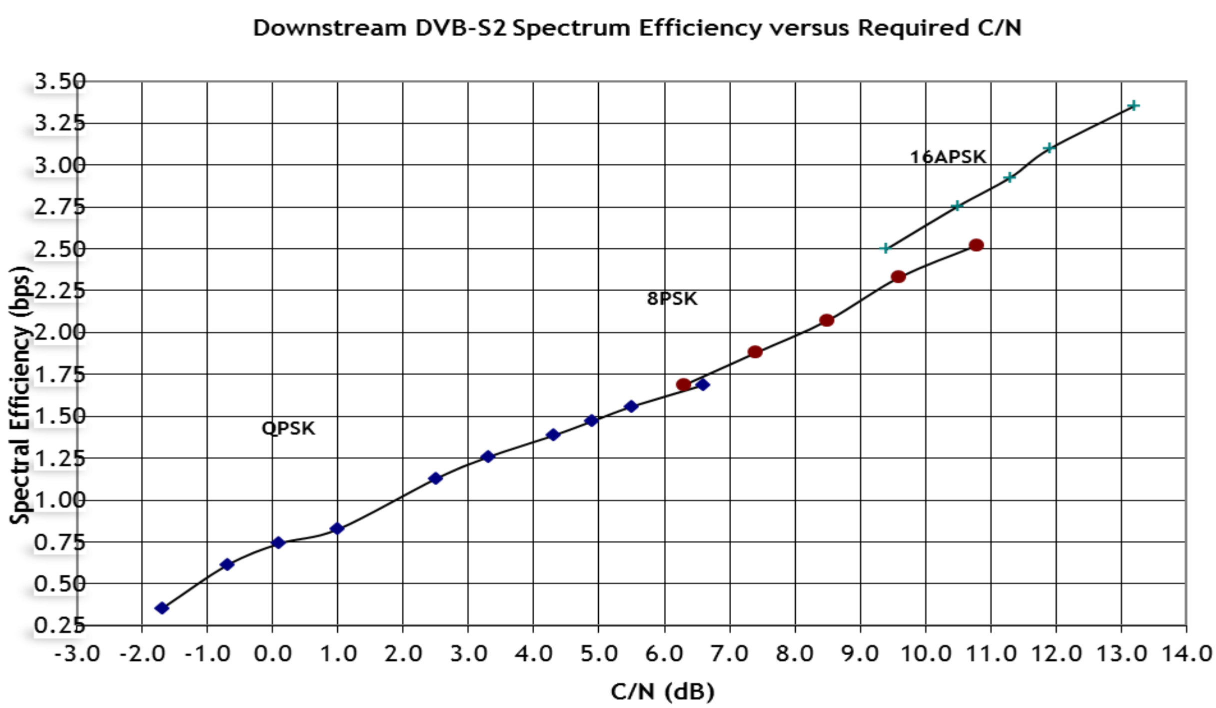


**Figure 1:** Downstream Performance Graph for DVB-S2

## Upstream Carrier Performance Specifications

This section describes Upstream Carrier specifications.

### TDMA Upstream

This section describes the Upstream TDMA carrier performance specifications. The TDMA carrier employs 2D16S FEC with SS-BPSK/BPSK/QPSK/8PSK Modulation schemes.

Table 2 summarizes the specifications required for upstream link budget analysis using TDMA carriers for the Velocity series VLC-R Hub line cards.

Table 2. TDMA Performance Limit

| | |
|---|---|
| **Symbol Rate** [1] | Minimum: 0.128 Msps<br>Maximum: 5.875 Msps (non-spread); 5.875/SF Msps (spread) |
| **Carrier Scheme** | MF-TDMA, 20% Filter roll off |
| **Modulation/FEC** | Modulation: SS-BPSK/BPSK/QPSK/8PSK<br>FEC: 2D16S |
| **Minimum Carrier Spacing** [2] | 1.2*Symbol (Chip) Rate |

| 170 Bytes Payload | | | |
|---|---|---|---|
| **MODCOD** | **Spectral Efficiency** [3] **(bps/Hz)** | **$E_b/N_o$** [4,5] **for QEF (dB)** | **C/N** [4] **for QEF (dB)** |
| 8PSK Rate-6/7 | 1.85 | 7.9 | 12.0 |
| 8PSK Rate-4/5 | 1.73 | 6.8 | 10.6 |
| 8PSK Rate-3/4 | 1.62 | 6.2 | 9.7 |
| 8PSK Rate-2/3 | 1.44 | 5.3 | 8.3 |
| QPSK rate-6/7 | 1.33 | 5.4 | 7.7 |
| QPSK Rate-3/4 | 1.17 | 4.2 | 6.0 |
| QPSK Rate-2/3 | 1.0 | 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 | 2.0 | -1.0 |
| SS-BPSK SF=2 Rate-2/3 | 0.26 | 3.3 | -1.5 |
| SS-BPSK SF=2 Rate-1/2 | 0.19 | 2.1 | -3.9 |
| SS-BPSK SF=4 Rate-2/3 | 0.13 | 3.0 | -4.8 |
| SS-BPSK SF=4 Rate-1/2 | 0.09 | 2.0 | -7.0 |

| | | | |
|---|---|---|---|
| SS-BPSK SF=8 Rate-2/3 | 0.063 | 2.8 | -8.0 |
| SS-BPSK SF=8 Rate-1/2 | 0.046 | 1.9 | -10.1 |
| **Acquisition Burst** | | | |
| **Burst Type** | **Spectral Efficiency** | **$E_b/N_o$ for QEF (dB)** | **C/N [4] for QEF (dB)** |
| Superburst[6] (BPSK RM FEC) | N/A | N/A | -2.0 |
| SS-ACQ burst[7] | N/A | N/A | -10.0 |

[1] For VLC-R in MCD-TDMA mode (M≤32 carriers) maximum symbol (chip) rate supported per channel is 5.875 Msps (Mcps). Aggregate symbol/chip rate rate of all M channels processed is 30 Msps/Mcps maximum. MCD-mode supports heterogeneous MODCODs and symbol/chip rates.

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

[3] Spectral Efficiency (bps/Hz – bits per symbol per Hz) includes $1.2*F_{sym}$ carrier spacing, FEC and TDMA burst overhead to aid burst detection and synchronization. The efficiency 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 0.25 dB with two adjacent identical rate 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), *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.

[6] 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 operation. The maximum number of channels that are Superburst acquisition capable in MCD-TDMA mode is limited to 8.

[6] The SS-ACQ waveform uses 2D16S FEC codes with BPSK modulation and 8 byte payload. The waveform facilitates fast acquisition of remotes due to its high frequency error tolerance and C/N robustness for spread mode operation. The maximum number of channels that are SS-ACQ capable in MCD-TDMA mode is limited to 8.

## Upstream TDMA Performance Graph

Upstream TDMA performance graphs illustrating spectral efficiency versus operating C/N ratio threshold are shown in Figure 2 for 170B block sizes.

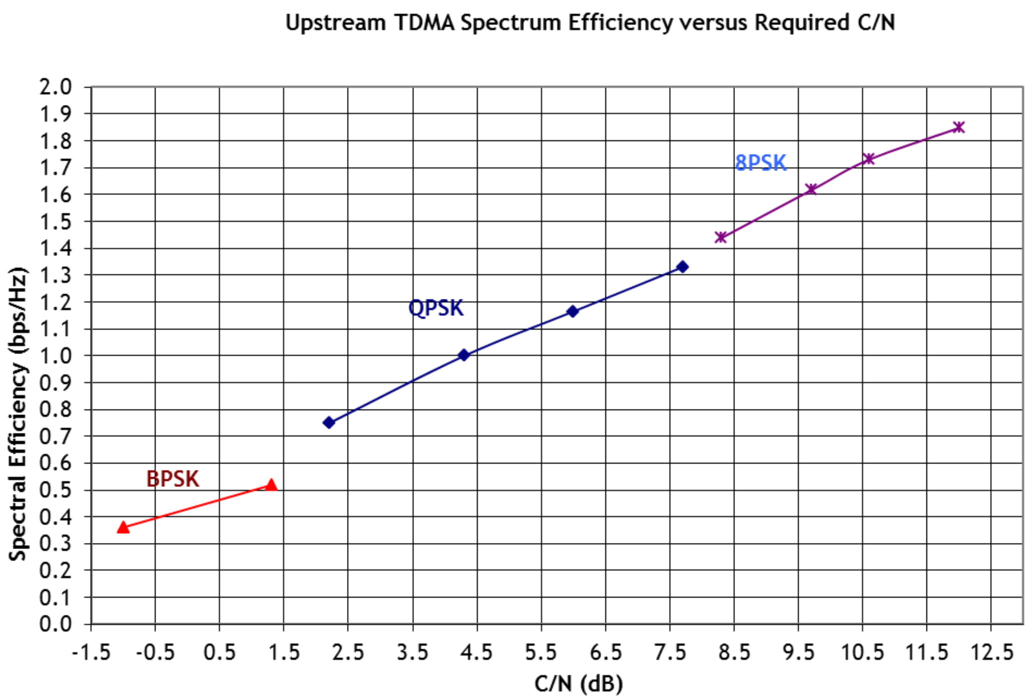


**Figure 2:** Upstream Performance Graphs for 170B TDMA Non-spread Modes

## DVB-S2 ACM System Guidelines

This section explains how DVB-S2 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.

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.

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.

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 2, plus M1 + M2. The default values of M1 and M2 are 0.6 and 1 dB respectively.

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, including choice of suitable symbol rates and MODCOD combinations, is an integral part of the overall network design.

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