ALIGNMENT
CONSULTING AND ENGINEERING

DIFI Rate Calculations and Expansion Factor

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Problem

Network planners currently lack a straightforward method for estimating the capacity required to transport Digital Intermediate Frequency Interoperability (DIFI) traffic. Although DIFI is known to increase network throughput relative to the underlying user data carried by digitized satellite carriers, the magnitude of that increase depends on several signal and transport parameters, including modulation and coding, I/Q bit depth, sampling rate, and packet efficiency. This poster develops an analytical model for the DIFI Expansion Factor (DEF), defined as the ratio of DIFI transport rate to the waveform data rate represented by the digitized carrier. Using published DVB-S2 and DVB-S2X modulation and coding combinations (MODCODs), the analysis calculates DEF across the supported MODCOD set and derives an average DEF for each evaluated I/Q bit depth. The resulting framework provides network planners with a practical basis for estimating DIFI capacity requirements from waveform and digitization parameters rather than relying on payload data rate alone.

Equations

Sample-rate model

For complex baseband I/Q, the sample rate is modeled from the symbol rate and the pulse shaping roll-off, α, and oversampling factor υ:

$$F_s = R_s(1+\alpha)(1+\upsilon) \quad (1)$$

where F_s is the complex sample rate in samples per second, and R_s is the symbol rate in symbols per second. This paper assumes α = 0.2 and $\upsilon = 0.25$.

Raw I/Q payload rate

The raw sampled payload rate is:

$$R_{IQ} = 2NF_s = 2NR_s(1+\alpha)(1+\upsilon) \quad (2)$$

where R_{IQ} is the raw I/Q payload bit rate, and N is the number of bits per I or Q sample component.

Packet efficiency and DIFI transport rate

For data packets, packet efficiency η_p is the fraction of counted frame bytes that carry signal data payload:

$$\eta_p = \frac{P_s}{P_s + H_E + H_{IP} + H_{UDP} + H_D} \quad (3)$$

where η_p is packet efficiency, P_s is signal payload bytes per data packet, H_E is Ethernet media access control header plus frame check sequence bytes, H_{IP} is IP header bytes, H_{UDP} is UDP header bytes, and H_D is the DIFI packet header bytes.

The resulting DIFI transport line rate is:

$$R_D = \frac{R_{IQ}}{\eta_p} + R_C \quad (4)$$

where R_D is the DIFI transport line rate, R_{IQ} is the raw I/Q payload bit rate, η_p is packet efficiency, and R_C is the rate contribution of associated context packets. Under the stated jumbo-frame assumption, R_C is small relative to the sampled payload rate and left out of later calculations for simplicity.

Waveform data-rate model

When symbol rate is known directly:

$$R_W = R_s\eta_m \quad (5)$$

where R_W is the waveform data rate, R_s is the symbol rate, and η_m is the published MODCOD spectral efficiency in bits per symbol.

When starting from occupied bandwidth F_s and pulse-shaping roll-off α:

$$R_W = \frac{F_s}{(1+\alpha)(1+\upsilon)}\eta_m \quad (6)$$

DIFI Expansion Factor

DEF is defined as:

$$DEF = \frac{R_D}{R_W} \quad (7)$$

R_D is the DIFI transport line rate, and R_W is the waveform data rate. If $F_s = R_s(1+\alpha)(1+\upsilon)$, context packets are negligible, and packet efficiency is constant, the terms combine into:

$$DEF \approx \frac{2N(1+\alpha)(1+\upsilon)}{\eta_m\,\eta_p} \quad (8)$$

where η_m is MODCOD spectral efficiency.

Definitions

Roll-off Factor: The fractional excess bandwidth added by the pulse-shaping filter beyond the symbol rate, expressed as α

Oversampling Factor: The fractional increase in sample rate above the minimum rate required to represent the occupied signal bandwidth, expressed as υ.

DIFI Expansion Factor: The ratio of the DIFI transport data rate to the waveform data rate represented by the digitized signal

MODCOD: The combination of modulation order and forward error correction code rate used by a waveform. The selected MODCOD determines the spectral efficiency, expressed in bits per symbol, and therefore the waveform data rate for a given symbol rate.

Symbol Rate: The number of modulation symbols transmitted per second, expressed in symbols per second (sym/s), that defines how quickly waveform information is conveyed.

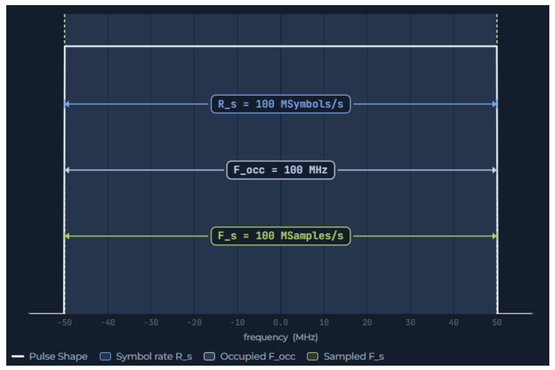
Occupied Bandwidth: The frequency range consumed by the modulated carrier, including the additional bandwidth introduced by pulse-shaping roll-off, $F_{occ} = R_s(1+\alpha)$.

Sampled bandwidth: The bandwidth represented by the digitized I/Q samples and carried for digital processing or transport, F_s.

I/Q bit depth: The number of bits used for each in-phase (I) or quadrature (Q) sample component. A complex sample uses 2N bits when each component uses N bits.

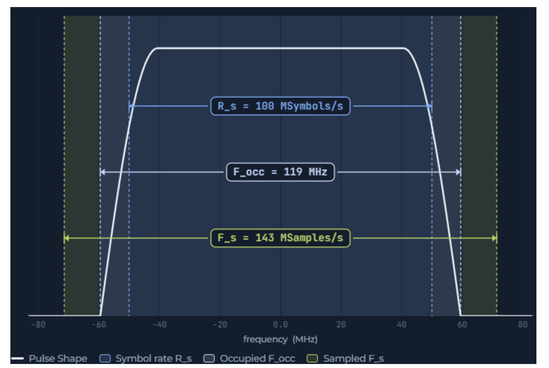
Waveform data rate: The nominal rate implied by published modulation and coding (MODCOD) spectral efficiency and symbol rate.

DIFI Rate Calculator Use Cases



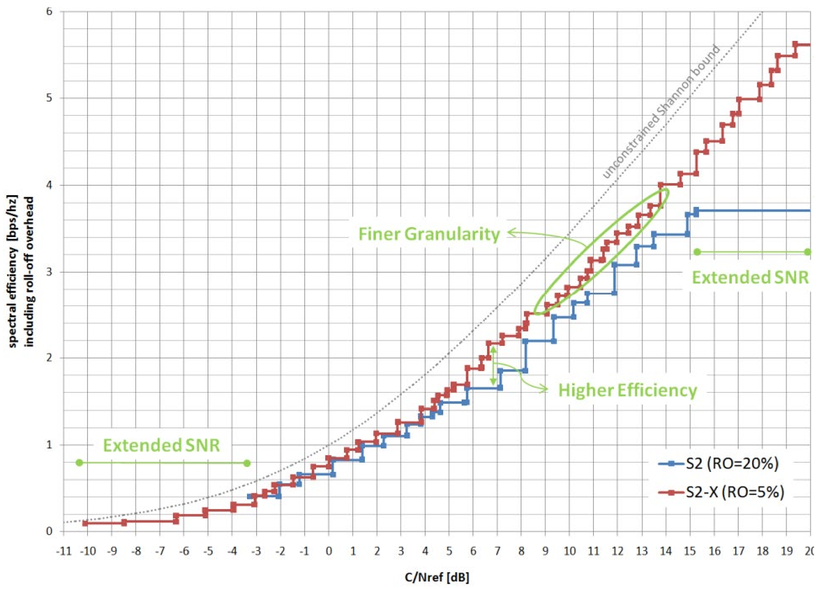
IFC Digitized Bandwidth with out Oversampling

IFC Digitized Bandwidth with Oversampling



Digitized Modem Carrier with Oversampling and Roll-Off

DVB MODCODS



DEF by N and MODCOD

N	QPSK	8-ary	16-ary	32-ary	64-ary	128-ary	256-ary	Avg
4	13.4x	5.9x	4.5x	3.1x	2.7x	2.3x	2.2x	**4.9x**
6	20.1x	8.8x	6.8x	4.7x	4.0x	3.5x	3.3x	**7.3x**
8	26.7x	11.7x	9.1x	6.3x	5.3x	4.6x	4.4x	**9.7x**
10	33.4x	14.7x	11.4x	7.9x	6.6x	5.8x	5.5x	**12.2x**
12	40.1x	17.6x	13.6x	9.4x	8.0x	6.9x	6.6x	**14.6x**
14	46.8x	20.6x	15.9x	11.0x	9.3x	8.1x	7.7x	**17.1x**
16	53.5x	23.5x	18.2x	12.6x	10.6x	9.2x	8.8x	**19.5x**

The results show two clear trends: DEF increases approximately linearly with I/Q bit depth, while DEF decreases as modulation order increases because higher-order modulation carries more waveform data per symbol. QPSK produces the highest DEF at every evaluated bit depth, ranging from 13.4x at 4-bit I/Q to 53.5x at 16-bit I/Q, while 256-ary modulation produces the lowest values, ranging from 2.2x to 8.8x. The reported modulation-order averages include the applicable DVB-S2/S2X MODCODs within each group; Very Low Signal-to-Noise Ratio (VLSNR) modes and short-frame codes were excluded from the analysis.