Technical Assistance

1 DVB-T Transport Stream Data Rates

This paper is intended to provide insight into the data rates of the ASI transport stream, as applied to DVB-T Modulation.

1.1 ASI Transport Stream Encoder Output Digital Bandwidth

Digital television signals have wide digital bandwidths at their origin. The following are typical.

- Uncompressed high definition video has a digital bandwidth of 1.485 Gbits per second.
- Uncompressed standard definition video has a digital bandwidth of 270 Mbps.
- AES/PCM digital audio (left plus right audio) has a digital bandwidth of 1.536 Mbps.
- 5.1 Surround requires 3 AES pairs, which has a total digital bandwidth of 4.608 Mbps.

The problem of digital TV is that combinations of digital video and digital audio must be made to fit into a standard television channel with bandwidths which range from 5 to 8 MHz, depending on the modulation system. Also, depending on format, more than one program stream may be multiplexed into one channel.

The total output bandwidth (ASI transport stream bit rate) is determined by entering a maximum value into the transport stream encoder. This represents the maximum transport stream bit rate. The combined data rate of all (one or more) program streams multiplexed into the transport stream must not exceed this maximum value.

Required program stream digital bandwidth (bit rate) depends on picture content. A still picture requires much less bandwidth and a sporting event, which has much action, or a scene change, where everything changes, requires more bandwidth. Depending on the efficiency and versatility of the compression algorithm, the bit rate of a program stream may very somewhat depending on the content of the picture. Therefore, the combined program stream data rate must be less than the programed maximum transport stream bandwidth to accommodate the varying data bandwidths. The unused digital bandwidth, the difference between these two rates, is occupied by null packets.

The bandwidth of the null packets ranges from 100 kbps to 1.5 Mbps, depending on the efficiency and versatility of the compression algorithm.

To reduce the null packet bandwidth, various forms of Statistical Multiplexing can be employed. These processes keeps track of the instantaneous excess bandwidth of each program stream so that it can be temporarily used by one program stream when its bandwidth momentarily exceeds its nominal value.

An example of a transport stream which includes three program streams is shown in Table 1-1.

Table 1-1 Example: Transport Stream Bandwidth

Program Stream Name and Type	**Total Program Stream Bandwidth**	**Combined Bandwidth of all Program Streams (**	**Null Packet Bandwidth**	**Total TS Bit Rate (TS Encoder BW Limit)**
1: High Definition	12 Mbps			
2: Extended Definition, Sports	7 Mbps			
3: Standard Definition, News, Entertainment	4 Mbps	23 Mbps	1 Mbps	24 Mbps

1.1.1 Transport Stream Bandwidth verses picture quality

Figure 1-1 shows the range of digital bandwidth, using MPEG 2 encoding, for the various types of programs which can be transmitted and the numbers of the various programs which can be multiplexed together in one transport stream. The various program formats can be multiplexed together as long as their total bandwidth is less than or equal to the specified maximum bandwidth (bit rate) of the transport stream.

As one progresses down the chart, from HDTV to LDTV, the fine detail of the reproduced picture decreases and the picture look increasingly soft. LDTV and SDTV with lower bandwidth will have difficulty reproducing pictures with much motion, such as from sports events, and they will also require additional time to reproduce scene changes where much of the picture detail is changed.

MPEG 4 encoding is 4 times more efficient than MPEG 2, therefore, the bit rates for the various types of programs would be significantly lower when using MPEG 4.

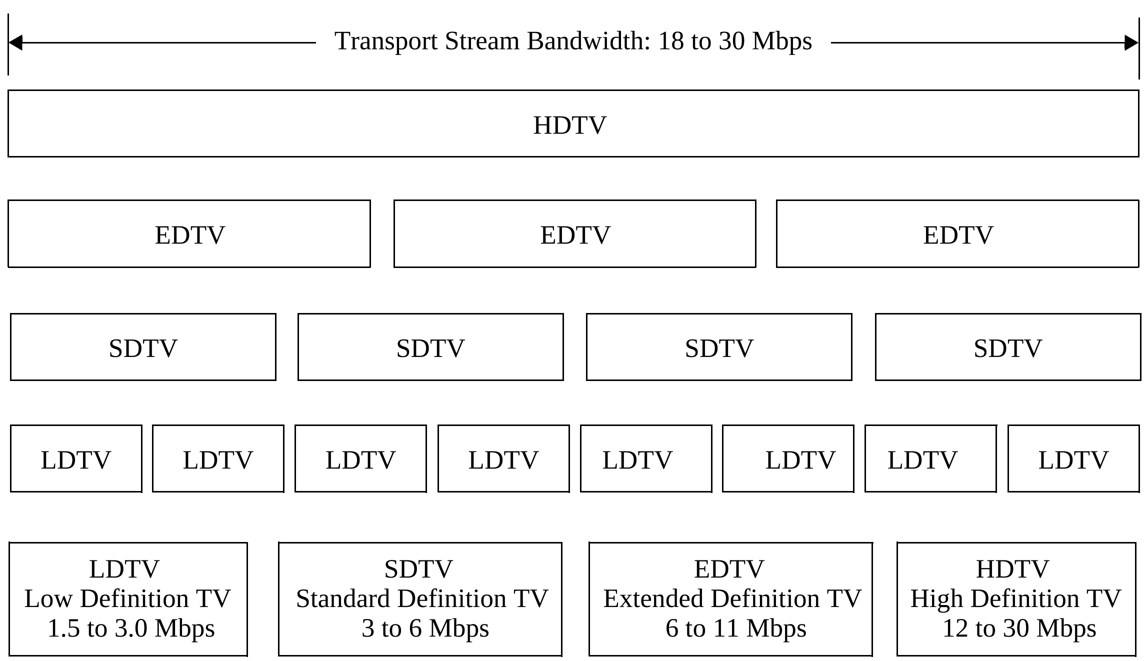


Figure 1-1 Example of Use of Transport Stream Bandwidth

Some notes concerning MPEG 2 transport stream data rates are as follows:

- 1080i (1080 horizontal lines, interlaced scanning) requires 12 Mbps or more for excellent quality reproduction.
- 720p (720 horizontal lines, progressive scanning) requires 9 Mbps or more for the same quality as 1080i.
- For standard definition (SD) a 2 Mbps data rate provides a poor quality reproduction (soft picture with blocking during movements.)

  A 3 Mbps or more data rate provides a more acceptable reproduced picture quality.

1.2 M2X Exciter Required ASI Transport Stream Digital Bandwidth

The transport stream digital bandwidth must be coordinated between the ASI encoder and the transmitter exciter. The ASI encoder transport stream bandwidth has already been discussed, so now the exciter transport stream digital bandwidth limiting factors will be discussed.

Either the transmitter transport stream bandwidth limits will have to be adjusted to meet the ASI encoder output requirements, or the ASI encoder transport stream bandwidth will have to be adjusted to meet the transmitter requirements. Since these two units are often located in different areas and controlled by different personnel with possible conflicting goals, a good understanding of the bandwidth controlling parameters of both units is required by both parties so that a good compromise can be reached.

1.2.1 Determining Transmitter Transport Stream Bandwidth

The ASI transport stream maximum transmitter input bandwidth is determined by the required robustness of the transmitted digital signal. Refer to Figure 1-2. For this discussion, the ERP (effective radiated power) of the channel is fixed. Therefore, the distance the signal can be received with perfect reproduction is determined by the specified C/N (carrier to noise ratio) of the received signal. This is also referred to as the noise limited coverage contour.

Noise caused errors (and other errors) in the digital signal are corrected by the forward error correction included in the transmitted signal. When the forward error correction is exhausted, uncorrected bit errors causes disturbances in the reproduced signal. The C/N (carrier to noise ratio) limit of the received signal is reached when the uncorrected bit errors reaches or exceeds a pre determined threshold. At that point the receiver blanks out the picture and sound, or switches to a backup medium (if provided), until the uncorrected bit error rate again drops below the prescribed limit. This sudden loss of signal is sometimes referred to as the cliff effect, and, if the profile shown in Figure 1-2 is laid out in all directions on a map, including the effects of terrain, frequency, and weather conditions, the noise limited coverage contour can be produced.

Figure 1-2 illustrates the point that as the transport stream digital bandwidth (bit rate) increases, providing a better quality picture, the minimum C/N ratio also increases reducing the distance that the signal can be received. This fact is also illustrated in Table 1-2 on page 1-7, and will be discussed later in this paper.

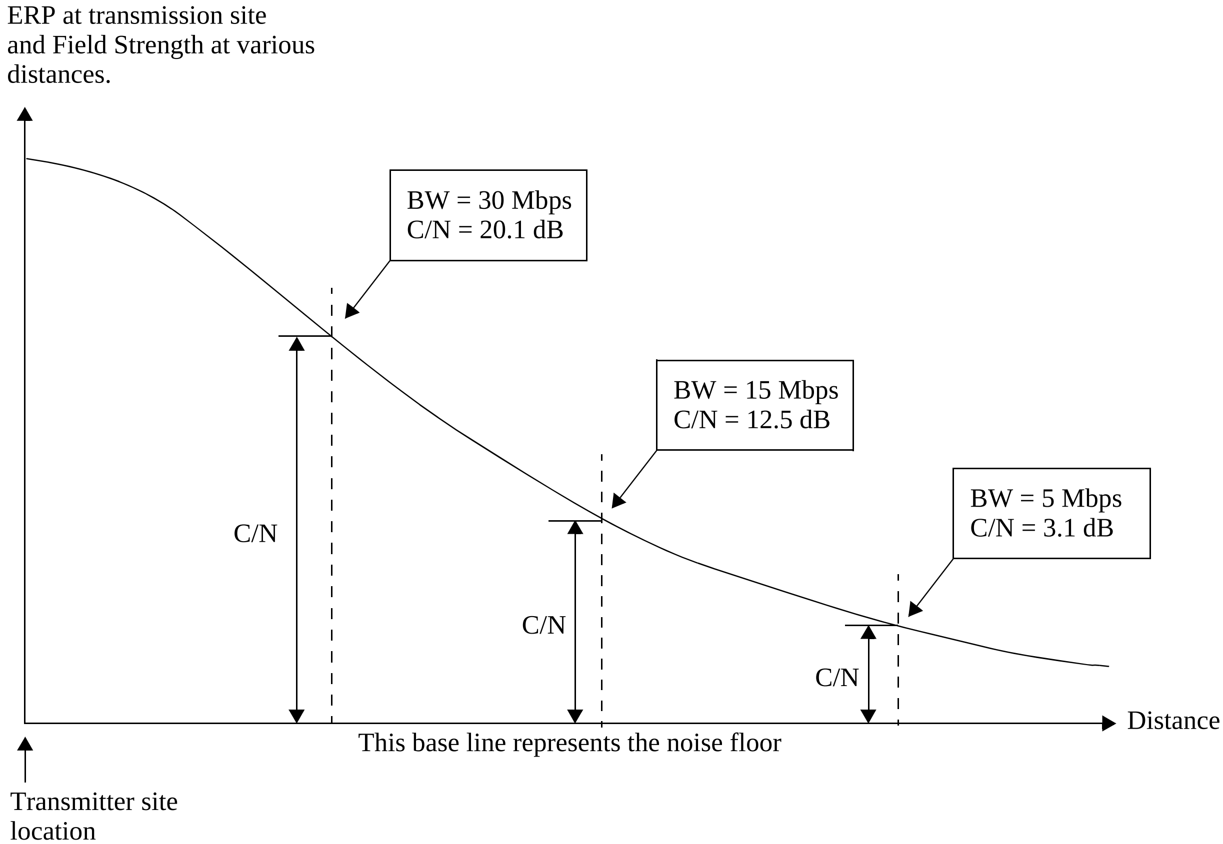


Figure 1-2 Examples Of Coverage Distance For Various C/N and Transport Stream Bandwidth Combinations

Upon careful examination of Figure 1-2, the ERP would have to be increased by 17 dB if the 20.1 C/N signal were to reach the same distance as the 3.1 dB C/N signal. In this example, if the ERP was 12 kW and the transmitter output was 2 kW, the ERP would have to be increased to 600 kW and the transmitter output increased to 100 kW to achieve the above stated distance increase.

The C/N ratio of the transmitted signal is determined by the amount of forward error correction included, and, in the case of DVB, by the code rate (1/2, 2/3, 3/4, 5/6, and 7/8) and the constellation (QPSK, 16-QAM, or 64-QAM). This determines the robustness of the signal. The more robust the signal, the lower its C/N specification will be and the greater the distance the signal can be received, but this happens at the expense of the allocated digital bandwidth of the transport stream. As the forward error correction increases, the constellation complexity is reduced, and/or the guard interval is increased, the signal becomes more robust, but the allowable digital bandwidth of the transport stream decreases.

In the case of standard ATSC, the transmission parameters and the resultant C/N is fixed, as is the digital bandwidth of the transport stream.

1.2.2 DVB-T Setup Screen 5, Modulation Parameters

Figure 1-3 shows the DVB-T Modulation Parameters Setup screen. This is the fifth of eight DVB-T setup screens.

The setups in this screen determine the maximum allowable transport stream input digital bandwidth (bit rate), which includes both the data packets and the null packets. In an upcoming discussion of DVB-T Setup screen 2.3.4, shown in Figure 1-7, on page 1-17, null packet manipulation will be covered.

Setup-DVB-T-2,3,5.jpg (310)

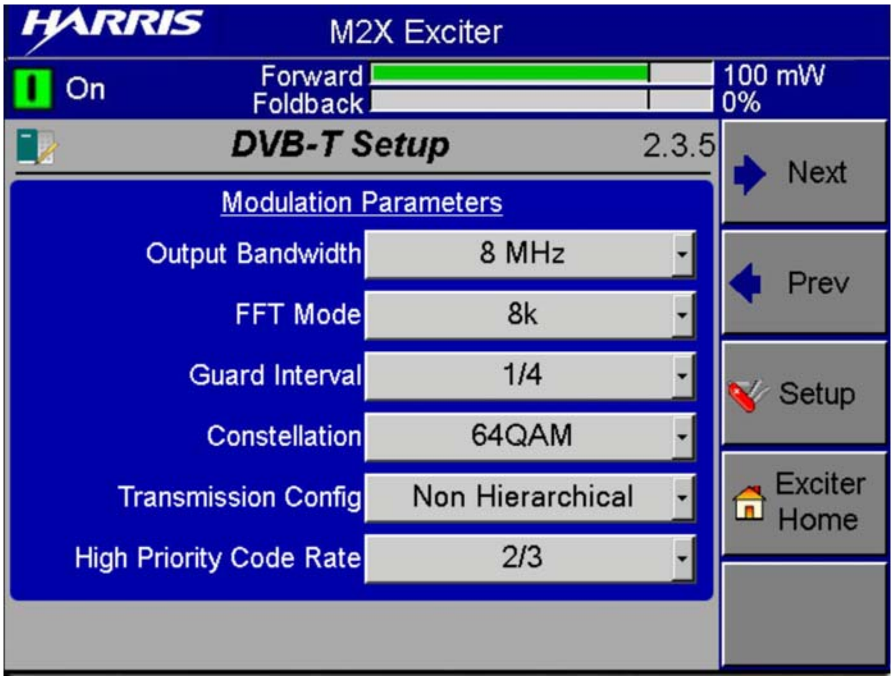


Figure 1-3 DVB-T Setup Screen 5, Modulation Parameters

1.2.2.1 Modulation Parameters

Refer to Figure 1-3. There are six programming setup choices in this screen. These parameters can only be changed by GUI when in MFN mode. In SFN mode these parameters are read from MIP (Mega-frame Initialization Packet) in transport stream input. The effect of these setups on the ASI transport stream digital bandwidth are discussed in Section 1.2.2.2, Maximum Allowable Transport Stream Bandwidth, on page 1-7.

The Six programming choices consist of the following:

- **Output Bandwidth,** choices are 8 MHz, 7 MHz, 6 MHz or 5MHz.

  Output Bandwidth: Selects transmission channel bandwidth.
- **FFT Mode,** choices are 2k, 2k (8k interlaced), 4k, 4k (8k interlaced), or 8k.

  This selects the size of the modulation Fast Fourier Transform, which in turn sets the number of subcarriers used in the COFDM (coded orthogonal frequency division multiplex) signal. It also selects whether the in-depth interleaver (8k) is enabled in 2k and 4k mode.
- **Guard Interval,** choices are 1/4, 1/8, 1/16, and 1/32.

The guard interval is the time, between symbol transmissions. It allows the previous symbol transmissions time to dissipate before the next symbol is transmitted. The guard interval is entered as a fraction, which represents the guard interval time as a fraction of the useful symbol duration. Total symbol duration is the sum of the useful symbol duration plus the guard interval. In the 2k mode, useful symbol duration is 224 microseconds and in the 8k mode, useful symbol duration is 896 microseconds.

- **Constellation,** choices are QPSK (quadrature phase shift keying), 16 QAM (quadrature amplitude modulation), and 64 QAM.

  Constellation refers to the size of each RF sub-carrier constellation.

  Note: When using the hierarchical mode,16 QAM or 64 QAM must be selected.

- **Transmission Config** (configuration), choices are Non Hierarchical or Alpha factor (in the Hierarchical transmission mode).

  In the hierarchical mode the Alpha factor (spacing of constellation) can be selected. Options are Hierarchical with Alpha = 1, Hierarchical with Alpha = 2, or Hierarchical with Alpha = 4.

  Non Hierarchical modulation allows transmission of only one data stream, the HP (high priority) input.

  Hierarchical modulation allows transmission of two data streams, the LP (low priority) and the HP (high priority) transport stream inputs.

  - The low priority stream has a higher data rate which produces a higher quality reproduction, but it is less robust and therefore covers a limited distance.
  - The high priority stream has a lower data rate which produces a lower quality reproduction, but it is more robust and therefore covers a greater distance.

- **High Priority Code Rate,** choices are 1/2, 2/3, 3/4, 5/6, and 7/8.

  These choices affect the convolutional encoder code rate for the high priority channel. It offers a choice between the useful data rate (picture and sound quality) verses signal robustness (distance the signal can be received)

  - A code rate of 1/2 includes one forward error correction bit for one data bit. This yields a lower quality signal which can be received at a greater distance.
  - A code rate of 7/8 includes one forward error correction bit for every seven data bits. This yields a higher quality signal which can be received at a much shorter distance.

- **The Low Priority Code Rate** is only visible when in hierarchical mode.

  These choices affect the convolutional encoder code rate for the low priority channel. Choices are: 1/2, 2/3, 3/4, 5/6, 7/8.

1.2.2.2 Maximum Allowable Transport Stream Bandwidth

The maximum allowable ASI transport stream input signal bandwidth (measured in Mbps) and the minimum receiver C/N (carrier to noise ratio in dB) is determined by the selected Modulation Parameters shown above in Figure 1-3. This transport stream input bit rate and the resulting receiver C/N is for an 8 MHz channel and can be found in Table 1-2.

Table 1-2 Required C/N and ASI Stream Bit Rates For An 8 MHz, Non Hierarchical Channel

		Required C/N (approximate) for BER = 2 x 10^{-4} after Viterbi QEF After Reed Solomon			ASI Stream Bitrate (Mbps)			
Modulation	**Code rate**	**Gussian channel**	**Ricean channel (F1)**	**Rayleigh channel (P1)**	**GI =1/4**	**GI =1/8**	**GI =1/16**	**GI =1/32**
QPSK	1/2	3.1	3.6	5.4	4.98	5.53	5.85	6.03
QPSK	2/3	4.9	5.7	8.4	6.64	7.37	7.81	8.04
QPSK	3/4	5.9	6.8	10.7	7.46	8.29	8.78	9.05
QPSK	5/6	6.9	8.0	13.1	8.29	9.22	9.76	10.05
QPSK	7/8	7.7	8.7	16.3	8.71	9.68	10.25	10.56
16-QAM	1/2	8.8	9.6	11.2	9.95	11.06	11.71	12.06
16-QAM	2/3	11.1	11.6	14.2	13.27	14.75	15.61	16.09
16-QAM	3/4	12.5	13.0	16.7	14.93	16.59	17.56	18.10
16-QAM	5/6	13.5	14.4	19.3	16.59	18.43	19.52	20.11
16-QAM	7/8	13.9	15.0	22.8	17.42	19.35	20.49	21.11
64-QAM	1/2	14.4	14.7	16.0	14.93	16.59	17.56	18.10
64-QAM	2/3	16.5	17.1	19.3	19.91	22.12	23.42	24.13
64-QAM	3/4	18.0	18.6	21.7	22.39	24.88	26.35	27.14
64-QAM	5/6	19.3	20.0	25.3	24.88	27.65	29.27	30.16
64-QAM	7/8	20.1	21.0	27.9	26.13	29.03	30.74	31.67
Note 1: QEF (quasi error free) means less than one uncorrected error event per hour, corresponding to a BER = 1011 at the input of the MPEG-2 demultiplexer.								
Note 2: Gussian channel: directional antenna used, with direct reception.								
Note 3: Ricean channel: directional antenna used, with multipath reception.								
Note 4: Rayleigh channel: non-directional receiving antenna used, with multipath reception.								

Table 1-3 ASI Transport Stream Bit Rates For A 7 MHz, Non Hierarchical Channel

		ASI Stream Bitrate (Mbps)			
Modulation	**Code Rate**	**GI =1/4**	**GI =1/8**	**GI =1/16**	**GI =1/32**
QPSK	1/2	4.354	4.838	5.123	5.278
QPSK	2/3	5.806	6.451	6.830	7.037
QPSK	3/4	6.532	7.257	7.684	7.917
QPSK	5/6	7.257	8.064	8.538	8.797
QPSK	7/8	7.620	8.467	8.965	9.237
16-QAM	1/2	8.709	9.676	10.246	10.556
16-QAM	2/3	11.612	12.902	13.661	14.075
16-QAM	3/4	13.063	14.515	15.369	15.834
16-QAM	5/6	14.515	16.127	17.076	17.594
16-QAM	7/8	15.240	16.934	17.930	18.473
64-QAM	1/2	13.063	14.515	15.369	15.834
64-QAM	2/3	17.418	19.353	20.491	21.112
64-QAM	3/4	19.595	21.772	23.053	23.751
64-QAM	5/6	21.772	24.191	25.614	26.390
64-QAM	7/8	22.861	25.401	26.895	27.710

Note: For the hierarchical schemes the useful bit rates can be obtained from this table as follows:

- HP stream: figures from QPSK columns;
- LP stream, 16-QAM: figures from QPSK columns;
- LP stream, 64-QAM: figures from 16-QAM columns.

Table 1-4 ASI Transport Stream Bit Rates For A 6 MHz, Non Hierarchical Channel

		ASI Stream Bitrate (Mbps)			
Modulation	**Code Rate**	**GI =1/4**	**GI =1/8**	**GI =1/16**	**GI =1/32**
QPSK	1/2	3.732	4.147	4.391	4.524
QPSK	2/3	4.976	5.529	5.855	6.032
QPSK	3/4	5.599	6.221	6.587	6.786
QPSK	5/6	6.221	6.912	7.318	7.540
QPSK	7/8	6.532	7.257	7.684	7.917
16-QAM	1/2	7.465	8.294	8.782	9.048
16-QAM	2/3	9.953	11.059	11.709	12.064
16-QAM	3/4	11.197	12.441	13.173	13.572
16-QAM	5/6	12.441	13.824	14.637	15.080
16-QAM	7/8	13.063	14.515	15.369	15.834
64-QAM	1/2	11.197	12.441	13.173	13.572
64-QAM	2/3	14.929	16.588	17.564	18.096
64-QAM	3/4	16.796	18.662	19.760	20.358
64-QAM	5/6	18.662	20.735	21.955	22.620
64-QAM	7/8	19.595	21.772	23.053	23.751

Note: For the hierarchical schemes the useful bit rates can be obtained from this table as follows:
- HP stream: figures from QPSK columns;
- LP stream, 16-QAM: figures from QPSK columns;
- LP stream, 64-QAM: figures from 16-QAM columns.

1.2.2.3 Guard Interval vs Multipath and SFN Transmitter Distance

One of the key modulation parameters which can be selected is the guard interval fraction. This fraction, along with the selected FFT Mode determines the multipath immunity, which is the maximum allowable path length distance difference between direct path and multipath path reception. If the difference distance is less than the above maximum, multipath reception will not interfere with receiver operation, but if this distance is exceeded, multipath reception will degrade receiver performance.

Selected guard interval fraction, along with the selected FFT Mode also determines the maximum allowable distance between single frequency network (SFN) transmitters. Exceeding these distance limitations will cause faulty reception in areas of the single frequency network.

Table 1-5 gives the selected parameters for an 8 MHz channel, Table 1-6, on page 1-10 gives the selected parameters for an 7 MHz channel, and Table 1-7, on page 1-11 gives the selected parameters for an 6 MHz channel,

Table 1-5 Selected Transmitter Parameters for 8 MHz Channel Bandwidth

Parameter	**2k Mode**				**8k Mode**			
Theoretical Number of Carriers	2048				8192			
Existing Number of Carriers (k)	1705				6817			
Carriers Used for Data	1512				6048			
Useful Carrier Duration (Tu)	224 us				896 us			
Carrier Spacing (1/Tu)	4464 Hz				1116 Hz			
RF Bandwidth (k/Tu)	7.612 MHz				7.609 MHz			
Guard Interval Fraction (Tg/Tu)	1/4	1/8	1/16	1/32	1/4	1/8	1/16	1/32
Guard Duration (Tg)	56 us	28 us	14 us	7 us	224 us	112 us	56 us	28 us
Total Symbol Duration (Tg = Tu)	280 us	262 us	238 us	231 us	1120 us	1008 us	952 us	924 us
Maximum Distance Between Direct and Multipath Signals and Maximum Distance Between Single Frequency Network Transmitters. (Tg x V_0)	16.8 km	8.4 km	4.2 km	2.1 km	67.2 km	33.6 km	16.8 km	8.4 km

Table 1-6 Selected Transmitter Parameters for 7 MHz Channel Bandwidth

Parameter	**2k Mode**				**8k Mode**			
Theoretical Number of Carriers	2048				8192			
Existing Number of Carriers (k)	1705				6817			
Carriers Used for Data	1512				6048			
Useful Carrier Duration (Tu)	256 us				1024 us			
Carrier Spacing (1/Tu)	3906.25 Hz				976.563 Hz			
RF Bandwidth (k/Tu)	6.66 MHz				6.66 MHz			
Guard Interval Fraction (Tg/Tu)	1/4	1/8	1/16	1/32	1/4	1/8	1/16	1/32
Guard Duration (Tg)	64 us	32 us	16 us	8 us	256 us	128 us	64 us	32 us
Total Symbol Duration (Tg = Tu)	320 us	288 us	272 us	264 us	1280 us	1152 us	1088 us	1056 us
Maximum Distance Between Direct and Multipath Signals and Maximum Distance Between Single Frequency Network Transmitters. (Tg x V_0)	19.2 km	9.6 km	4.8 km	2.4 km	76.8 km	38.4 km	19.2 km	9.6 km

Table 1-7 Selected Transmitter Parameters for 6 MHz Channel Bandwidth

Parameter	**2k Mode**				**8k Mode**			
Theoretical Number of Carriers	2048				8192			
Existing Number of Carriers (k)	1705				6817			
Carriers Used for Data	1512				6048			
Useful Carrier Duration (Tu)	298.6667 us				1194.667 us			
Carrier Spacing (1/Tu)	3348.214 Hz				837.054 Hz			
RF Bandwidth (k/Tu)	5.71 MHz				5.71 MHz			
Guard Interval Fraction (Tg/Tu)	1/4	1/8	1/16	1/32	1/4	1/8	1/16	1/32
Guard Duration (Tg)	74.7 us	37.3 us	18.7 us	9.3 us	299 us	149.5 us	74.8 us	37.4 us
Total Symbol Duration (Tg = Tu)	373 us	336 us	317 us	308 us	1494 us	1344 us	1269 us	1232 us
Maximum Distance Between Direct and Multipath Signals and Maximum Distance Between Single Frequency Network Transmitters. (Tg x V_0)	22.4 km	11.2 km	5.6 km	2.8 km	89.7 km	44.9 km	22.4 km	11.2 km

1.2.2.4 Transport Stream BW and C/N for Hierarchical Modulation

Table 1-8 gives the carrier to noise ratio (C/N) and the ASI transport stream bit rate for QPSK in non uniform 16-QAM Hierarchal modulation with alpha factors of 2 and 4.

Table 1-9, on page 1-13 gives the carrier to noise ratio (C/N) and the ASI transport stream bit rate for QPSK in uniform and non uniform 64-QAM Hierarchal modulation with alpha factors of 1 and 2.

An explanation of the a factor is given in Section 1.2.2.4.1 on page 1-14

Table 1-8 Required C/N and ASI Stream Bit Rates For An 8 MHz, Hierarchical Channel

			Required C/N (approximate) for BER = 2 x 10^{-4} after Viterbi QEF After Reed Solomon			**ASI Stream Bitrate (Mbp/s)**			
Modulation	**Code rate**	**α**	**Gussian channel**	**Ricean channel (F1)**	**Rayleigh channel (P1)**	**GI =1/4**	**GI =1/8**	**GI =1/16**	**GI =1/32**
QPSK	1/2		4.8	5.4	6.9	4.98	5.53	5.85	6.03
	2/3		7.1	7.7	9.8	6.64	7.37	7.81	8.04
	3/4		8.4	9.0	11.8	7.46	8.29	8.78	9.05
in		2							
	1/2		13.0	13.3	14.9	4.98	5.53	5.85	6.03
non	2/3		15.1	15.3	17.9	6.64	7.37	7.81	8.04
uniform	3/4		16.3	16.9	20.0	7.46	8.29	8.78	9.05
16-QAM	5/6		16.9	17.8	22.4	8.29	9.22	9.76	10.05
	7/8		17.9	18.7	24.1	8.71	9.68	10.25	10.56
QPSK	1/2		3.8	4.4	6.0	4.98	5.53	5.85	6.03
	2/3		5.9	6.6	8.6	6.64	7.37	7.81	8.04
	3/4		7.1	7.9	10.7	7.46	8.29	8.78	9.05
in		4							
	1/2		17.3	17.8	19.6	4.98	5.53	5.85	6.03
non	2/3		19.1	19.6	22.3	6.64	7.37	7.81	8,04
uniform	3/4		20.1	20.8	24.2	7.46	8.29	8.78	9.05
16-QAM	5/6		21.1	22.0	26.0	8.29	9.22	9.76	10.05
	7/8		21.9	22.8	28.5	8.71	8.29	8.78	9.05

Note 1: QEF (quasi error free) means less than one uncorrected error event per hour, corresponding to a BER = 1011 at the input of the MPEG-2 demultiplexer.

Note 2: Gussian channel: directional antenna used, with direct reception.

Note 3: Ricean channel: directional antenna used, with multipath reception.

Note 4: Rayleigh channel: non-directional receiving antenna used, with multipath reception.

Table 1-9 Required C/N and ASI Stream Bit Rates For An 8 MHz, Hierarchical Channel

			Required C/N (approximate) for BER = 2 x 10^{-4} after Viterbi QEF After Reed Solomon			**ASI Stream Bitrate (Mbps)**			
Modulation	**Code rate**	α	**Gussian channel**	**Ricean channel (F1)**	**Rayleigh channel (P1)**	**GI =1/4**	**GI =1/8**	**GI =1/16**	**GI =1/32**
QPSK	1/2	1	8.9	9.5	11.4	4.98	5.53	5.85	6.03
	2/3		12.1	12.7	14.8	6.64	7.37	7.81	8.04
in	3/4		13.7	14.3	17.5	7.46	8.29	8.78	9.05
	1/2		14.6	14.9	16.4	9.95	11.06	11.71	12.06
uniform 64-QAM	2/3		16.9	17.6	19.4	13.27	14.75	15.61	16.09
	3/4		18.6	19.1	22.2	14.93	16.59	17.56	18.10
	5/6		20.1	20.8	25.8	16.59	18.43	19.52	20.11
	7/8		21.1	22.2	27.6	17.42	19.35	20.49	21.11
QPSK	1/2	2	6.5	7.1	8.7	4.98	5.53	5.85	6.03
	2/3		9.0	9.9	11.7	6.64	7.37	7.81	8.04
in	3/4		10.8	11.5	14.5	7.46	8.29	8.78	9.05
	1/2		16.3	16.7	18.2	9.95	11.06	11.71	12.06
non uniform 64-QAM	2/3		18.9	19.5	21.7	13.27	14.75	15.61	16.09
	3/4		21.0	21.6	24.5	14.93	16.59	17.56	18.10
	5/6		21.9	22.7	27.3	16.59	18.43	19.52	20.11
	7/8		22.9	23.8	29.6	17.42	19.35	20.49	21.11

Note 1: QEF (quasi error free) means less than one uncorrected error event per hour, corresponding to a BER = 1011 at the input of the MPEG-2 demultiplexer.

Note 2: Gussian channel: directional antenna used, with direct reception.

Note 3: Ricean channel: directional antenna used, with multipath reception.

Note 4: Rayleigh channel: non-directional receiving antenna used, with multipath reception.

1.2.2.4.1 Hierarchical Modulation Alpha (α) Factor

Changing the mapping of the QAM constellations effects robustness of the transmitted signal and therefore the minimum receiver C/N (carrier to noise ratio). Non hierarchical modulation uses constellations with an alpha (α) factor of 1. Hierarchical modulation uses an α factor of 1, 2, or 3.

Figure 1-4 shows QPSK, QAM-16 and QAM-64 with an alpha (α) factor of 1.

Figure 1-5, on page 1-15 QAM-16 and QAM-64 with an alpha (α) factor of 2.

Figure 1-6, on page 1-16 QAM-16 and QAM-64 with an alpha (α) factor of 4.

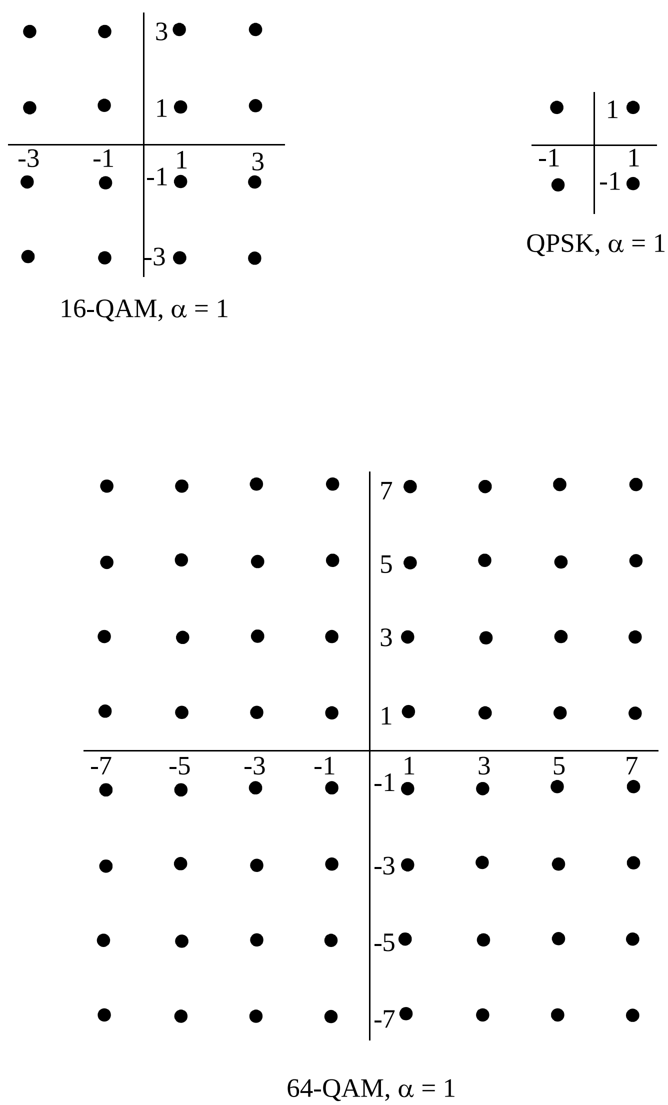
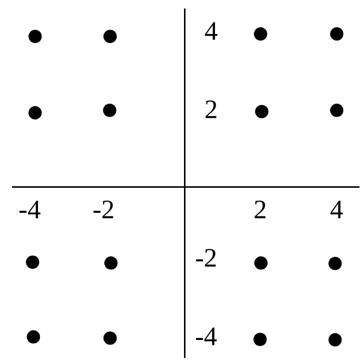
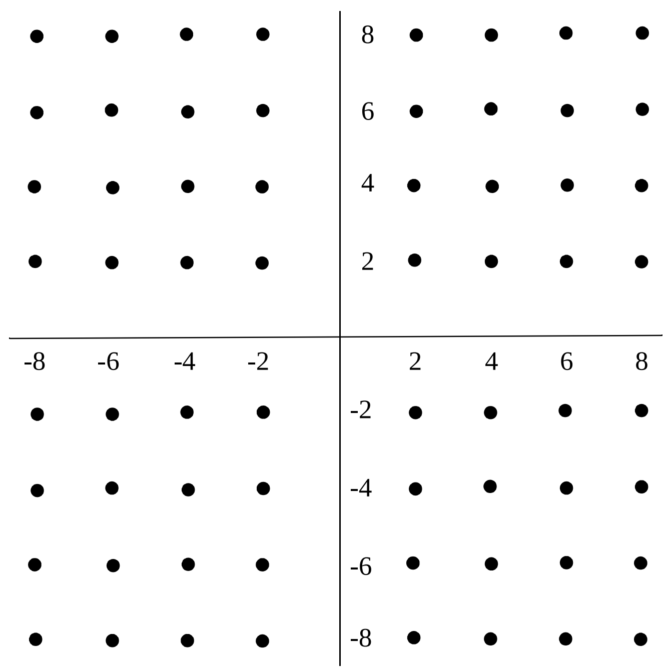


Figure 1-4 Uniform QPSK, 16-QAM and 64-QAM Mapping with an alpha (α) Factor = 1

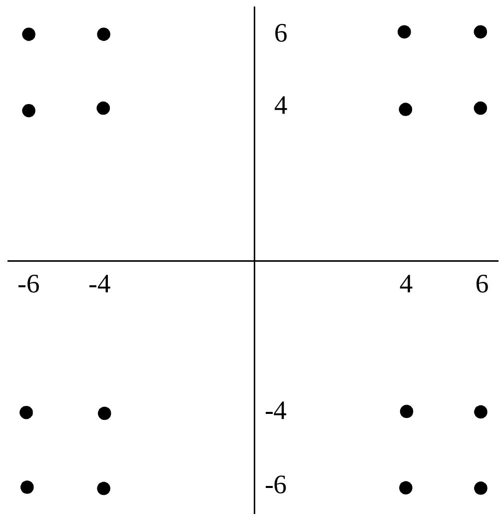


16-QAM, $\alpha = 2$

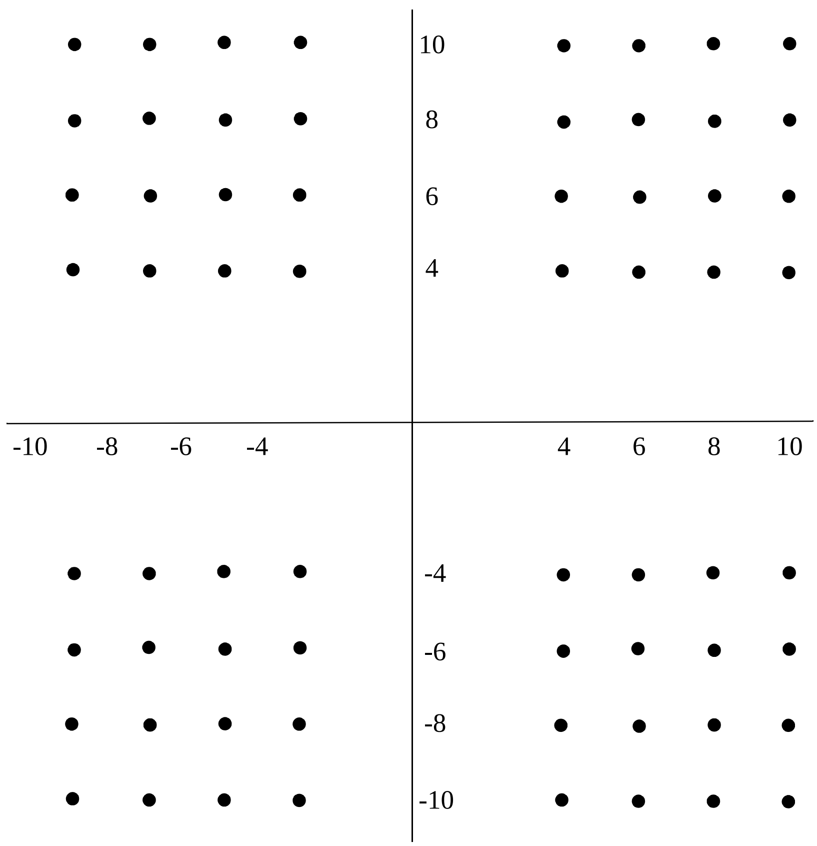


64-QAM, $\alpha = 2$

Figure 1-5 Non Uniform 16-QAM and 64-QAM Mapping with an alpha (α) Factor = 2



16-QAM, $\alpha = 4$



64-QAM, $\alpha = 4$

Figure 1-6 Non Uniform 16-QAM and 64-QAM Mapping With an alpha (α) Factor = 4

1.2.3 Null Packet Usage, DVB-T Setup Screen 4

Figure 1-7 shows the DVB-T MPEG Options Setup screen. This is the fourth of eight DVB-T setup screens. Of particular interest here is the Flow Adaption and Null Packet Removal options. This is important because the incoming transport stream bit rate must match the exciter's transport stream input bandwidth limitation, which is determined by the DVB-T Modulation Parameters of DVB-T Setup screen 2.3.5, shown in Figure 1-3, on page 1-5.

Manipulating the null packet count is one way to match the two bit rates, this is accomplished by setting the Flow Adaption to On. There are some limits to the two bit rates, they will be discussed later.

The other way, with the Flow Adaption set to off, is to carefully set the ASI encoder output bit rate to the exact rate required by the exciter, or to set the exciter's required ASI transport stream bit rate of the value set by the ASI encoder. In either case, the two bit rates must match or the exciter will mute.

Setup-DVB-T-2,3,4.jpg (310)

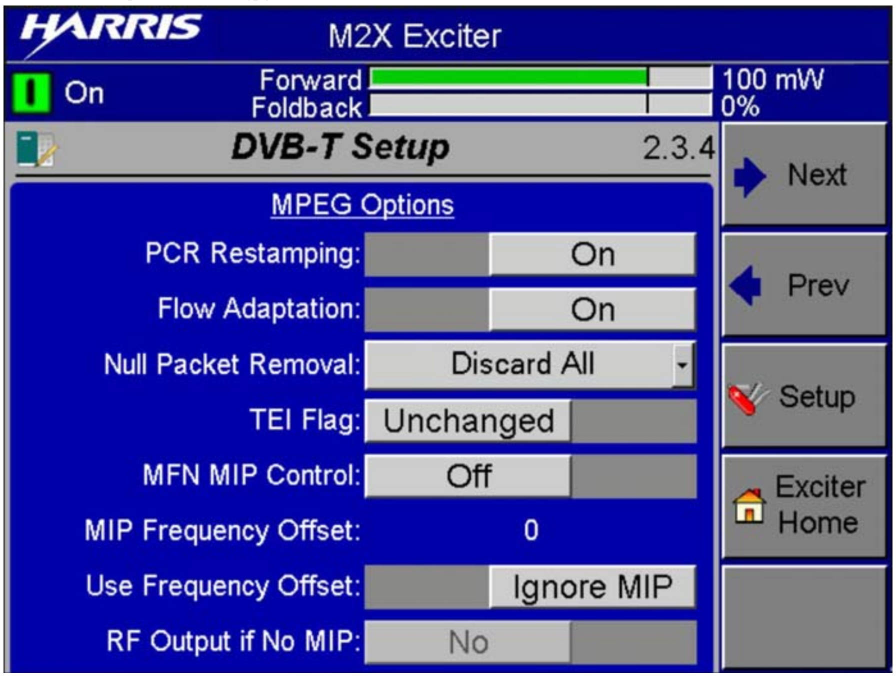


Figure 1-7 DVB-T Setup Screen 4, MPEG Options

1.2.3.1 MPEG Options Functions

Refer to Figure 1-7. The MPEG Option Control programming can only be changed by GUI when in MFN mode. These settings affect the transport stream bit rate into the modulator and must be set to keep it at or below the maximum rate determined by the modulation settings.

- **Flow Adaption,** choices are Off (disabled) or On (enabled).

  Flow Adaptation enables or disables the transport stream flow (bit rate) adaptation by the addition or deletion of null packets.
  For a SFN, this function can not be changed and is disabled per default.
  Either setting is valid in MFN mode, but it is usually enabled.

- **Null Packet Removal,** choices are Keep All or Discard All.

  Keep All = All incoming null packets are kept.
  Discard All = Discard all incoming null packets.

  For a SFN, this function can not be changed manually, it is set to Keep All per default. Any setting is valid in MFN mode, but Discard All is usually selected.

  Keeping or discarding the excess Null packets effects the maximum allowable M2X ASI transport stream input bandwidth (in Mbps). The maximum allowable ASI transport stream input bandwidth (in Mbps) is determined by the settings selected in Figure 1-3, DVB-T Setup Screen 5, Modulation Parameters, on page 1-5.

  The ASI transport stream input bit rate can be calculated by referring to the explanations for the ASI Input Packets and Nulls associated with Figure 1-8, DVB-T Modulator Status Screen 2, on page 1-20.

1.2.3.2 Flow Adaption and Null Packet Removal Settings

As mentioned above, the incoming transport stream contains data packets and null packets. The purpose of the null packets is to keep the ASI encoder transport stream bit rate at the level set by the encoder while allowing the program bandwidth to vary slightly. This is accomplished by setting the program stream bit rate slightly lower than the encoder bandwidth limit. The encoder raises the output transport stream bit rate up to the required encoder output rate by adding an appropriate number of null packets. The null packet bandwidth typically ranges from 100 kbps to 1.5 Mbps. Multiple program streams within a transport stream are likely to require more data rate headroom and therefore may contain more null packets than a transport stream with a single program stream.

An example may be helpful. This example is a transport stream which contains multiple program streams.

Data Bandwidth - - - - -18.9 Mbps

Null Bandwidth- - - - - - -6.0 Mbps

Total Bandwidth - - - - -24.9 Mbps

In the exciter, the 24.9 Mbps transport stream data rate would result in a higher C/N (receiver carrier to noise ratio) and therefore reduce the distance which the signal could be received.

By setting the Null Packet Removal entry of Figure 1-7 to Discard All (its normal setting), the transport stream null packets are removed, causing the transport stream bit rate to drop to 18.9 Mbps. By Removing the null packets, the maximum allowable M2X ASI transport stream input bandwidth can be reduced from slightly greater than 24.9 Mbps to slightly greater than 18.9 Mbps. This may reduce the C/N and increases the distance which the signal can be received, if the exciter’s modulation or code rate settings are changed in the process of reducing its maximum input rate.

Next, the exciter modulation parameters are set to produce a transport stream maximum input bandwidth which is equal to or slightly greater than that of the bit rate of the transport stream.

If the Flow adaption, of Figure 1-7, is set to Off, the two bit rates would have to be exactly the same. If they differed slightly, the exciter would mute.

If the Flow adaption is set to On (its normal setting), and the transport stream maximum input limit was set slightly higher than the transport stream data rate, null packets would automatically be added to or taken from the data rate so that is would be exactly equal to the exciter’s transport stream input maximum bandwidth setting.

1.2.3.3 Interaction of Flow Adaption and Null Packet Removal

Four possible settings of the Flow Adaption and Null Packet Removal parameters are possible, each of which places demands on the incoming transport stream data rate and the exciter's maximum data rate settings. They are as follows:

- **SFN (single frequency network) Setting: Flow Adaption Off and Null Packet Removal set to Keep All.**

  For this setting, the exciter's maximum transport stream bit rate must be set exactly equal to the incoming transport stream total bit rate. This setting produces a higher bit rate but with no bit rate flexibility.

  In a single frequency network, the transport streams sent to each transmitters should be identical, therefore, the transmitter modulation parameters are set at a common location (for example, by a Synchrony) upstream from all transmitter sites and sent down to each transmitter in the MIP of the transport stream.

  For this setting, the source (Synchrony) and exciter clocks must be locked by 1pps or GPS.

- **MFN (multiple frequency network) Normal Setting: Flow Adaption On and Null Packet Removal set to Discard All.**

  In this setting, the exciter's maximum transport stream bit rate limit is set slightly greater than the incoming transport stream data rate. Flow Control automatically makes the two rates equal. This provides a lower bit rate with some flexibility.

  For this setting, the transport stream source and exciter clocks do not need to be locked.

- **Setting should be avoided for MFN: Flow Adaption On and Null Packet Removal set to Keep All.**

  In this setting, the exciter's maximum transport stream bit rate limit is set slightly higher than the input transport stream's total bit rate. Flow Control automatically makes the two rates equal. This setting produces a higher bit rate with some flexibility. This setting can cause RF mutes in case of large input data variation.

  For this setting, the transport stream source and exciter clocks do not need to be locked.

- **Setting Usually Avoided, for MFN: Flow Adaption Off and Null Packet Removal set to Discard All.**

  For this setting, the exciter's maximum transport stream bit rate must be set exactly equal to the incoming transport stream data bit rate. This setting produces a lower bit rate with no bit rate flexibility.

  For this setting, the transport stream source and exciter clocks must be locked by 1pps or GPS.

- **Setting Usually Avoided, for MFN: Flow Adaption Off and Null Packet Removal set to keep All.**

  For this setting, the exciter's maximum transport stream bit rate must be set exactly equal to the incoming transport stream total bit rate. This setting produces a higher bit rate with no bit rate flexibility.

  For this setting, the transport stream source and exciter clocks must be locked by 1pps or GPS.

1.2.4 DVB-T Modulator Status Screen 2

Figure 1-8 shows the DVB-T modulator status screen, the second of two screens. Of particular interest here is the Packets (total transport stream packet count) and the Nulls (transport stream null packet count) for the incoming transport stream. These counts represent the number of 188 byte packets for the two categories, and are taken before the Flow Adaption and Null Packet Removal options, previously discussed, and is not effected by their settings.

The total and null packet count are useful because they can be used to determining the transport stream input bit rates for its total, null and data components. This process is described below.

Status-DVB-T-3.3.2.jpg (310)

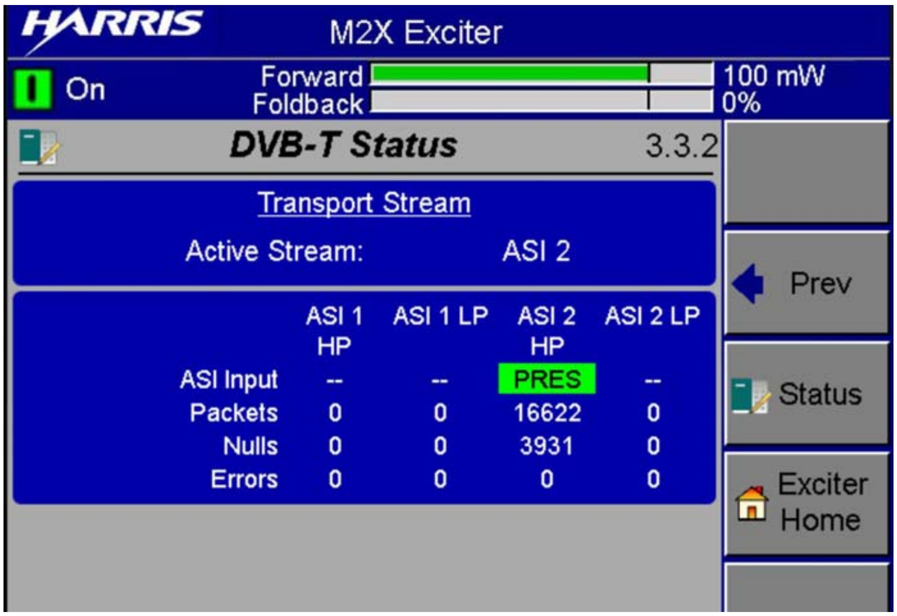


Figure 1-8 DVB-T Modulator Status Screen 2

1.2.4.1 Transport Stream Input Functions Status

There are 4 rows of statuses for each ASI input column:

- **ASI Input:** (top row): Background is green with PRES written if present, and the background is blue (plain) with no writing if not present.
- **Packets:** (2nd row) = the total number of transport stream packets received in one second.

  Total Transport Stream Input Bandwidth (Bit Rate) in bits per second: Obtained by multiplying the above number of packets received in one second times 188 (bytes per packet, without Reed Solomon coding) times 8 (bits per byte).

  OR

  Obtained by multiplying the above number of packets received in one second times 204 (bytes per packet, with Reed Solomon coding) times 8 (bits per byte). See Section 1.2.4.2 for further information concerning the addition of Reed Solomon parity bytes to the ASI encoder transport stream packets.

- **Nulls:** (3rd row) = the number of transport stream null packets received in one second.

  Transport Stream Input Null (packet) Bandwidth (Bit Rate) in bits per second is obtained by multiplying the above number of Nulls (null packets) received in one second times 188 (bytes per packet) times 8 (bits per byte).

  Transport Stream Data Bandwidth in bits per second is obtained by subtracting the null bandwidth bit rate from the total transport stream bit rate.

  An example using the values given in Figure 1-8 may be helpful.

$$\text{Total Number of Transport Stream Packets} = 16622$$

$$\text{Total Number of Transport Stream Null Packets} = 3994$$

$$\text{Total Number of Transport Stream Data Packets} = 16622 - 3994 = 12628$$

$$\text{Transport Stream Total Bit Rate} = 16622 \times 188 \times 8 = 24.9\ \text{Mbps}$$

$$\text{Transport Stream Null (packet) Bit Rate} = 3994 \times 188 \times 8 = 6\ \text{Mbps}$$

$$\text{Transport Stream Data (packet) Bit Rate} = 25 - 6 = 18.9\ \text{Mbps}$$

- **Errors:** (bottom row) = the number of transport packets with errors received in one second. This readout will be zero if the incoming transport stream does not include the 16 Reed Solomon parity bytes per packet. The M2X exciter uses the incoming Reed Solomon parity bytes (if present) to calculate the incoming transport stream error rate.

  See Section 1.2.4.2 for further information concerning the addition of Reed Solomon parity bytes to the ASI encoder transport stream packets.

1.2.4.2 Input Transport Stream With and Without RS Parity Bytes

The ASI transport stream encoder and some transport stream players have the option of adding 16 Reed Solomon parity bytes to each 188 byte packets, for total packet content of 204 bytes. The purpose of these parity bytes is to provide error protection for the encoder to transmitter link.

The exciter uses the incoming parity bytes (if present) to calculate and correct incoming transport stream byte errors, and displays the count of the number of incoming packets with errors in the screen shown above. Once this is done, the exciter deletes these parity bytes before the data stream reaches the modulator.

If calculating the transport stream bandwidth (with Reed Solomon parity bytes) to determine the maximum link transport stream digital bandwidth, then the calculation would use the 204 bytes per packet value.

If the calculation is to determine the bandwidth, required by its modulator, (the exciter maximum input transport stream bandwidth) then the 188 byte per packet value would be used even if the incoming transport stream bandwidth included the 16 Reed Solomon parity bytes per packet.