DATUM SYSTEMS

Preliminary Appendix A

Datum Systems PSM-500 Satellite Modem

Technical Specification

PSM-500, 500H and 500L VSAT / SCPC - Modem Specification

Revision History

Rev 0.8	7-10-2007	Preliminary Release.
Rev 0.85	1-10-2008	Preliminary Release added new performance statistics.

Introduction

This document defines the technical performance parameters and requirements for a low-cost flexible, state-of-the-art VSAT/SCPC Satellite Modem. The PSM-500 Modem series is designed to meet the needs of general purpose applications including those as a remote station VSAT modem and as a Single Channel Per Carrier (SCPC) modem where both outgoing and incoming RF data is continuous. Many of the capabilities of this modem series are largly determined by firmware in FPGAs, and are expected to evolve in the future with added functions.

The PSM-500 series includes three basic types defined by their IF frequencies: The standard 70 MHz IF, a special order variation of the standard that uses a 140 MHz IF, and a full L-Band version. A fourth "Hybrid" IF version with 70 MHz transmit IF and L-Band Receive IF may be produced if demand is sufficient. The IF minimum and maximum settings are shown in Table 1 below. All versions are settable in 1 Hz increments via the front panel or remote control interfaces.

Table 1 - PSM-500 Series IF Interface Versions.

Interface Versions	PSM-500S	PSM-500N	PSM-500L	PSM-500H**
IF Transmit	50 ~ 90 MHz	100 ~ 180 MHz	950 ~ 1750 MHz	50 ~ 90 MHz
IF Receive	50 ~ 90 MHz	100 ~ 180 MHz	950 ~ 1900 MHz	950 ~ 1900 MHz

** Note: The Hybrid version production is dependent on demand.

The IF interface is fixed in a particular modem by the design and manufacturing. It is not possible to change the IF interface in a modem either by hardware or software changes.

Any of the PSM-500 IF versions is also available in one of 3 "Feature Sets" versions consisting of Modulation modes and maximum data rates designed to meet the needs of specific applications. The modulation modes and minimum and maximum data rates in each mode are shown below, followed by specific limitations of specific FEC options.

Feature Sets are field software upgradable. Options are field hardware upgradable.

Table 2 - PSM-500 Series Feature and Option Matrix.

	PSM-500S/N/L Series		
Feature	**M505**	**M511**	**M523**
Modulation			
BPSK	✔	✔	✔
QPSK	✔	✔	✔
OQPSK	✔	✔	✔
8PSK/8QAM*	Upgrade →	✔	✔
16QAM/APSK*	Upgrade →	Upgrade →	✔
Max Data Rate			
BPSK	2.5 Mbps	5 Mbps	7.38 Mbps
QPSK/OQPSK	5 Mbps	10 Mbps	28.04 Mbps
8PSK/8QAM*	N/A	10 Mbps	29.52 Mbps
16QAM/APSK*	N/A	N/A	29.52 Mbps

The tables below show the data rate limits depending on specific hardware and user selected operating modes. Rate ½ includes rate 0.453 and 21/44. Rate 0.9x includes 0.922 and 0.95. The modem maximul symbol rate is 14.76 Mega Samples Per Second.

Table 3 – Maximum Data Rates vs. Modulation and Code Rates-Mbps

Modulation	5/16	1/2+	3/5	2/3	3/4	4/5	5/6	7/8	0.9x
BPSK	4.61	7.38	8.86		11.07	11.81	12.3	12.92	14.02
QPSK/OQPSK		14.76	17.71		22.14	23.62	24.6	25.83	28.04
8PSK/8QAM*				29.52	29.52	29.52	29.52	29.52	29.52
16QAM/APSK*		29.52	29.52	29.52	29.52	29.52	29.52	29.52	29.52

Table 4 – Maximum Data Rates vs. FEC Type and Code Rates-Mbps

FEC Type	5/16	1/2+	3/5	2/3	3/4	4/5	5/6	7/8	0.9x
Viterbi		29.52			29.52		29.52	29.52	
TCM				29.52					
TPC-4K	4.61	5			5	5	5	5	5
TPC-16k	4.61	29.52			29.52	29.52	29.52	29.52	29.52
S-Tec - Std		10	10		10	10	10	10	10
S-Tec – HS		20	20		20	20	20	20	20

Table 5 – Minimum Data Rates vs. Modulation and Code Rates-kbps.

Modulation	5/16	1/2+	3/5	2/3	3/4	4/5	5/6	7/8	0.9x
BPSK	1.2	1.2	1.2			N/A	2.4	2.4	2.4
QPSK/OQPSK		2.4	2.4		7.20	8.0	8.0	8.4	8.4
8PSK/8QAM*		4.8	9.6	4.8		9.6	9.6	9.6	9.6
16QAM/APSK*		4.8	19.2			19.2	19.2	19.2	19.2

* 8QAM and 16APSK operating mode not yet available, but may be in the future.

***** Interface Maximum Data Rates *****

The built-in synchronous serial interface selectable for RS-449, V.35, IEA530 and variants is limited to 10 Mbps by cables and available DTE devices. The RS-232 is limited to 128 kbps.

The optional SnIP and HSSI interfaces will operate up to 29.52 Mbps if other selections permit.

Table 6 shows the currently available standard and optional FEC types and code rates. Note that this table changes frequently. The latest version can be seen on the web site.

Table 6 – FEC, Modulation and Code Rates.

PSM-500 Series FEC Option Table Rev. 1.5														
FEC Type	Sel # (T)	FEC Type Option	Sel # (O)	Code Rates Available	Sel # (C)	R-S Option	Modulation Modes (see notes)						
							BPSK 0	QPSK 1	OQPSK 2	8PSK 3	8QAM 4	16QAM 6	16APSK 7
None	0	N/A	0	N/A	0		●	●	●				
Viterbi	1	Normal	0	1/2	0	●	●	●	●			●	·
				3/4	1	●	●	●	●			●	
				5/6	2	●	●	●	●			●	
				7/8	3	●	●	●	●			●	
		Swap C0/C1	1	1/2	0	●	●	●	●			●	
				3/4	1	●	●	●	●			●	
				5/6	2	●	●	●	●			●	
				7/8	3	●	●	●	●			●	
		CT	2	3/4	1	●◆	·	·	·			●	
				7/8	3	●◆						●	
TCM	2		0	2/3	0	●				●			
TPC	4	Advanced	0	0.453-16k	0		●	●	●	·	·	●	
				1/2-16k	1		●	●	●	·	·	●	
				1/2-4k	2		●	●	●	·	·	●	
				3/4-16k	3		●	●	●	●	·	●	
				3/4-4k	4		●	●	●	●	·	●	
				7/8-16k	5		●	●	●	●	·	●	
				7/8-4k	6		●	●	●	●	·	●	
				0.922-16k	7		●	●	●	●	·	●	
				0.950-4k	8		●	●	●	●	·	●	
		M5 Full	1	1/2	0		●	●					
		*TPC4k Only		3/4	1		●	●					
				7/8	2		●	●					
		M5 Short	2				·	·					
				3/4	1		●	●					
		*TPC4k Only		7/8	2		●	●					
		M5 Legacy	3										
				3/4	1		●	●					
				7/8	2		●	●					
		CT	4	5/16	0		●						
				21/44	1		●	●	●				
				3/4	2		●	●	●	●		●	
		*TPC16k only		7/8	3		●	●	●	●		●	
				0.95	4		●	●	●	●		●	

PSM-500 Series FEC Option Table Rev. 1.5													
FEC Type	Sel # (T)	FEC Type Option	Sel # (O)	Code Rates Available	Sel # (C)	R-S Option	Modulation Modes (see notes)						
							BPSK 0	QPSK 1	OQPSK 2	8PSK 3	8QAM 4	16QAM 6	16APSK 7
S-Tec	6	Any	0	1/2	0		●	●	●	●		●	
		Interleaver		3/5	1		●	●	●	●		●	
		Block Size		3/4	2		●	●	●	●		●	
		Option 0~4		4/5	3		●	●	●	●		●	
				5/6	4		●	●	●	●		●	
				7/8									

Notes: 8QAM and 16APSK modes not implemented yet, and will have added options available.
* TPC4k and TPC16 restrictions apply to that line and Code Rate only.
TPC4k M5 Mode Limits: Rate 1/2 = 2.46 Mbps, Rate 3/4 or 7/8 = 4.92 Mbps.
TPC4k CT Mode Limits: Rate 5/16 = 2.048 Mbps, Rate 21/44 = 3.2 Mbps, Rate 3/4 = 5 Mbps, Rate 0.95 = 6.6 Mbps.
The Modulation Modes, FEC Types, Option and Code Rates plus Reed-Solomon selection form a number completely defining that FEC Mode. The acronym for these 5 numbers is "MTOCR".

Table 7 below shows the Spectral Efficiency of the above FEC modes in bits per Hz of occupied bandwidth at the 3 dB occupied bandwidth point.

Table 7 – Spectral Efficiency vs. Modulation and FEC Code Rates.

Modulation Bits/Sym →	BPSK 1	QPSK OQPSK 2	8PSK 8QAM 3	16QAM/16APSK 4
FEC Code Rate	Efficiency in Bits/Hz at 3 dB Bandwidth			
5/16	0.3125	0.625**	0.9375**	1.25**
0.453	0.453	0.906	1.359	1.812
21/44	0.477	0.95	1.43 **	1.91**
1/2	0.50	1.00	1.50	2.00
3/5	0.60	1.20	1.80	2.40
2/3	0.66	1.33	2.00	2.66
3/4	0.75	1.50	2.25	3.00
4/5	0.80	1.60	2.40	3.20
5/6	0.833	1.667	2.50	3.333
7/8	0.875	1.75	2.625	3.50
0.922	0.922	1.844	2.766	3.688
0.95	0.95	1.90	2.85	3.80

** These modes not available in any setting

Each of these FEC Types can operate up to the maximum 20 Mbps, except TPC-4K is limited to 5 Mbps and S-Tec Standard is limited to approximately 10 Mbps at all rates. The S-Tec High speed version is capable of 20 Mbps or more in all modes.

The possible FEC operating modes has exploded in recent years because of the variety of available and common FECs in use. The PSM-500 Series has many current modes and additional ones in development. Below is a table showing the currently available modes depending on modulation.

The basic modem design includes separate synthesized transmit and receive interfaces, flexible clocking options and on-board Viterbi Forward Error Correction (FEC). The on-board standard data interface is programmable for either RS-449, V.35, V.36, EIA-530/A or synchronous RS-232, while a separate Serial Control Port allows external monitor and control of all variable functions and parameters from either a terminal device or control computer. Front panel control and display allows full operation of the unit without external devices.

The modem includes an internal microprocessor for controlling all transmit and receive functions and user display control. The processor also accepts commands from and responds to the Serial Control Port. The processor stores its current configuration in non-volatile EEPROM for proper power-up recovery of the last state. The incorporation of an embedded processor allows intelligent modem features such as smart reacquisition of a lost carrier, real Eb/No and BER display and full interactive monitor and control of the modem on a full screen terminal display.

A second internal Digital Signal Processor, or DSP, gives the modem acquisition capabilities significantly faster than a standard modem at lower data rates. It does this by mathematically determining the location of a carrier based upon sampled data input.

The modem design incorporates a unique combination of reliability, cost and flexibility. The design uses large scale proprietary ASIC/FPGA devices to reduce the complexity and cost to a minimum while providing full flexibility. The modulation and demodulation is accomplished directly at the IF frequency without heterodyning, eliminating all adjustments.

Modulator Specifications

IF Output

Output Frequency Range: Standard & Hybrid . 50.000 to 90.000 MHz. (100 to 180 MHz Optional)
L-Band ..... 950 to 1750 MHz
Tuning Method: ..... Via internal synthesizer.
Output Level Control: ..... Programmable in 0.1 dB steps over 40 dB from
..... +5 to -35 dBm, +3 dBm max at 50Ω standard unit
Output Level Accuracy/Stability: ..... ± 0.5 dB over 0 - 50°C @ any level or frequency
..... ± 0.25 dB over any 10°C range.
Output Impedance: Standard..... Programmable 50 or 75Ω.
L-Band ..... 50Ω.
Output Return Loss: Standard & Hybrid ..... 20 dB minimum
L-Band ..... 10 dB minimum, 14 dB typical
Output Burst Control: ..... Contact factory for burst definition and capability.
Output Burst Off Isolation..... >60 dB
Modulation Technique:..... BPSK, QPSK, OQPSK, 8PSK or 16QAM Selectable.
Spectral Density:..... The modulated band shall be -3 dB at the
..... Nyquist frequency of the symbol rate, then
..... approximating an n=8 Butterworth filter
..... response.
Spurious Output: Standard & Hybrid ..... < -50 dBc from 2 to 200 MHz.
L-Band ..... < -50 dBc from 400 MHz to 5000 MHz
Harmonic Output: Standard & Hybrid ..... < -50 dBc.
L-Band ..... < -50 dBc up to –10 dBm out, -40 dBc at +5 dBm.
Phase Balance:..... < 1 degree.

Transmit Synthesizer

Tuning Step Size:..... 1 Hz steps.
Frequency Stability: Standard & Hybrid..... ± 2.0 ppm. (176 Hz max) internal reference
L-Band ..... ± 0.1 ppm. (175 Hz max) internal reference

..... OR locked to external reference's stability.
L-Band Note: ..... The internal 10 MHz OCXO reference can be
..... used to phase lock an external BUC.
Aging: Standard & Hybrid ..... ±1 ppm per year using internal reference.
L-Band ..... ± 0.2 ppm per year using internal reference

Phase Noise: Standard & Hybrid ..... <-87dBc @1kHz.
..... <-93dBc @10kHz.
..... <-108dBc @100kHz.
L-Band ..... Better than IESS-308/309 by 4 dB min, 6 dB typical
Synthesizer Control:..... Via Front Panel and serial control port.
Transition Time: ..... < 100 msec. to any frequency including
..... command latency.

Transmit Baseband Processing

Data Rate:..... Variable under program control and dependent on
..... Feature Set, FEC selected and interface type.
..... See Tables 2 to 5 above.

Note: Maximum rates are limited using Reed-Solomon and IBS Multiplexer Options.

Settability ..... Any rate settable to 1 bps increments. Accurate
..... to 2 PPT at rate 1/2, or 4 PPT, rate 3/4 or 7/8,
..... relative to either internal (nominally 2.0 ppm) or
..... external reference clock as selected.
Data Clock Tracking Range ..... External or Terminal Timing = +/-400 ppm.
..... Reverts to internal clock outside this range.
Data Rate Clock Sources ..... **a**. Internal.
..... **b**. Terminal Timing input on data connector
..... **c**. External input on data connector.
..... **d**. Receive Clock recovered from demodulator.
Forward Error Correction: ..... See Table 6 above for current modes and rates.
Viterbi ..... Convolutional encoder, k= 7.
..... Rate 1/2. G0 code = 171 octal,
.... G1 code = 133 octal.
..... Rate 3/4, 5/6 or 7/8 using punctured code
Trellis Code Modulation (TCM): ..... Rate 2/3 in 8PSK only, may use R-S.
Standard Reed-Solomon Concatenated Codec: Available in Viterbi or TCM.
R-S Rates ..... Disabled, IESS-308, IESS-309, IESS-310,
CT220-200 and custom.
Optional Turbo Product Codes and S-Tec Codecs Available.
Differential Encoding:..... Selectable On or Off @ Front Panel and
..... via serial control port.
Scrambler:..... IESS-308 or 309, Intelsat and V.35 selectable with
..... enable @ Front Panel and via serial control port.
..... IBS and Reed-Solomon specific modes are available
..... when these options are enabled/installed.

Demodulator Specifications

IF Input

Input Frequency Range Standard:..... 50.000 to 90.000 MHz. (100 to 180 MHz Optional)
Hybrid & L-Band): ..... 950.000 to 1900.000 MHz

Tuning Method: ..... Via internal synthesizer.
Input Carrier Level: ..... -20 to -84 dBm total. 40dB range window shifts
..... .with the data rate. Lower levels at lower rates.
Acquisition/Tracking Range: ..... ± 100 Hz and ± 1.25 MHz in 1 Hz increments.
Smart reacquisition: ..... In "Search" mode the demodulator will search
..... for return of a lost carrier within a specified
..... range for a selected time before reverting to full
..... acquisition range.
Reacquisition range:..... ± 100 Hz and ± 1.25 MHz in 1 Hz increments
Reacquisition sweep time: ..... 0.1 to 6000 seconds in 0.1 second increments.
Input Impedance: Standard..... Programmable 50 or 75Ω.
Hybrid & L-Band ..... 75Ω.
Input Return Loss: Standard..... 20 dB. (17 dB with 140 MHz IF option.)
Hybrid & L-Band ..... 10 dB minimum, 14 dB typical.
Modulation Technique:..... BPSK, QPSK, OQPSK, 8PSK or 16QAM Selectable.
Type of demodulation: ..... Continuous Coherent.

Receive Synthesizer

Tuning Step Size:..... 1 Hz steps.
Frequency Stability: Standard & Hybrid..... ± 2.0 ppm. (176 Hz max) internal reference
L-Band ..... ± 0.1 ppm. (175 Hz max) internal reference
..... OR locked to external reference's stability.
L-Band Note: ..... The internal 10 MHz OCXO reference can be
..... used to phase lock an external LNB.
Synthesizer Control:..... Front Panel and via the Serial Control port.

Receive Baseband Processing

Data Rate:..... Variable under program control and dependent on
..... Feature Set, FEC selected and interface type.
..... See Tables 2 to 5 above.

Note: Maximum rates are limited using Reed-Solomon and IBS Multiplexer Options.

Settability ..... Any rate settable in 1 bit per second increments.
Data Clock Tracking Range ..... > +/-400 ppm.
Data Rate Change Settling Time: ..... < 100 mSeconds.

Baseband Filter:..... Digital, n=6 Butterworth filter response.
Forward Error Correction: ..... See Table 6 above for current modes and rates.
Viterbi ..... Convolutional encoder, k= 7.
..... Rate 1/2. G0 code = 171 octal,
.... G1 code = 133 octal.
..... Rate 3/4, 5/6 or 7/8 using punctured code
Trellis Code Modulation (TCM): ..... Rate 2/3 in 8PSK only, may use R-S.
Standard Reed-Solomon Concatenated Codec: Available in Viterbi or TCM.
R-S Rates ..... Disabled, IESS-308, IESS-309, IESS-310,
CT220-200 and custom.
Optional Turbo Product Codes and S-Tec Codecs Available.
BER vs. Eb/No Performance: ..... 0.2 dB typical over theoretical.
..... 0.4 dB maximum. See performance curves below.
Differential Decoding:..... Selectable On or Off.
Descrambler:..... IESS 308 or 309, Intelsat and V.35 selectable with
..... enable @ Front Panel and via serial control port.

	IBS, Reed-Solomon and TPC specific modes are
	available when these options are enabled/installed.
Receive Data FIFO Buffering	4 bits to 524,280 bits, programmable in 1 bit
Plesiochronous or Doppler	increments or in time increments. The buffer is a
Elastic Store	1048,560 bit (maximum) self centering FIFO. Over
	or under-flow result in re-centering. When set to even
	multiples of the number of frame bits the re-centering
	minimizes frame disruption.
Buffer Output Clock Options	**a**. Receive Clock (disables buffer)
	b. Modulator Clock
	c. Internal Clock. Same rate as receive data rate clock
	setting, but accurate to 2 PPT at rate 1/2, or 4 PPT,
	rate 3/4 or 7/8, relative to either internal or external
	reference clock as selected.
	d. External Clock, input on data interface.

L-Band Internal OCXO Reference Specifications – PSM-500L only

Frequency:	10 MHz
Stability and Aging:	$\pm 1 \times 10^{-8}$, $\pm 2 \times 10^{-7}$ per year
Phase Noise:	-110 dBc @ 10 Hz
	-130 dBc @ 100 Hz
	-140 dBc @ 1 kHz
	-150 dBc @ 10 kHz
	-155 dBc @ 100 kHz

Bit Error Rate Performance

The following tables and their associated “waterfall” curves show typical Bit Error Rate vs. Eb/No performance for a modem including the effect of using differential encoding and the appropriate scrambler.

The values shown are typical, but are extremely repeatable since the entire transmit and receive processes that affect the performance are digitally produced.

The volume of measurements required plus the significant data that must be collected to characterize the low error rates achievable by Turbo Product Codes and S-Tec FECs are difficult and time consuming. Therefore all of these measurements are made by carefully calibrated and temperature controlled test equipment under computer control. Single measurements of a BER in the 10^{-9} range may require several days.

Although the tables show Eb/No values at fixed logarithmic BER increments for easy reading, the graphs are created from the actual measurment points. That data and the graph program (GPL open source) used are available from Datum Systems.

The tabular data contains a 5 digit number above each column of Eb/No data. This number is called “MTOCR”. It is a short nemonic acronym for **M**odulation, FEC **T**ype, **O**ption, **C**ode Rate and **R**eed-Solomon selection options. To set the modem for any particular combination of MTOCR you would first select the modulation type (by the number if desired), then the Type, Option and Code Rate for the FEC and then the Reed-Solomon option. The M, T, O and C values for all currently available FEC modes are shown in Table 6.

The Eb/No values shown are those referenced to the customer data rate at the decoder output. Performance would appear improved if measured relative to the decoder input (i.e. at the satellite data rate).

Note that the performance is subject to change. We periodically have improved the performance of multiple options via software revisions.

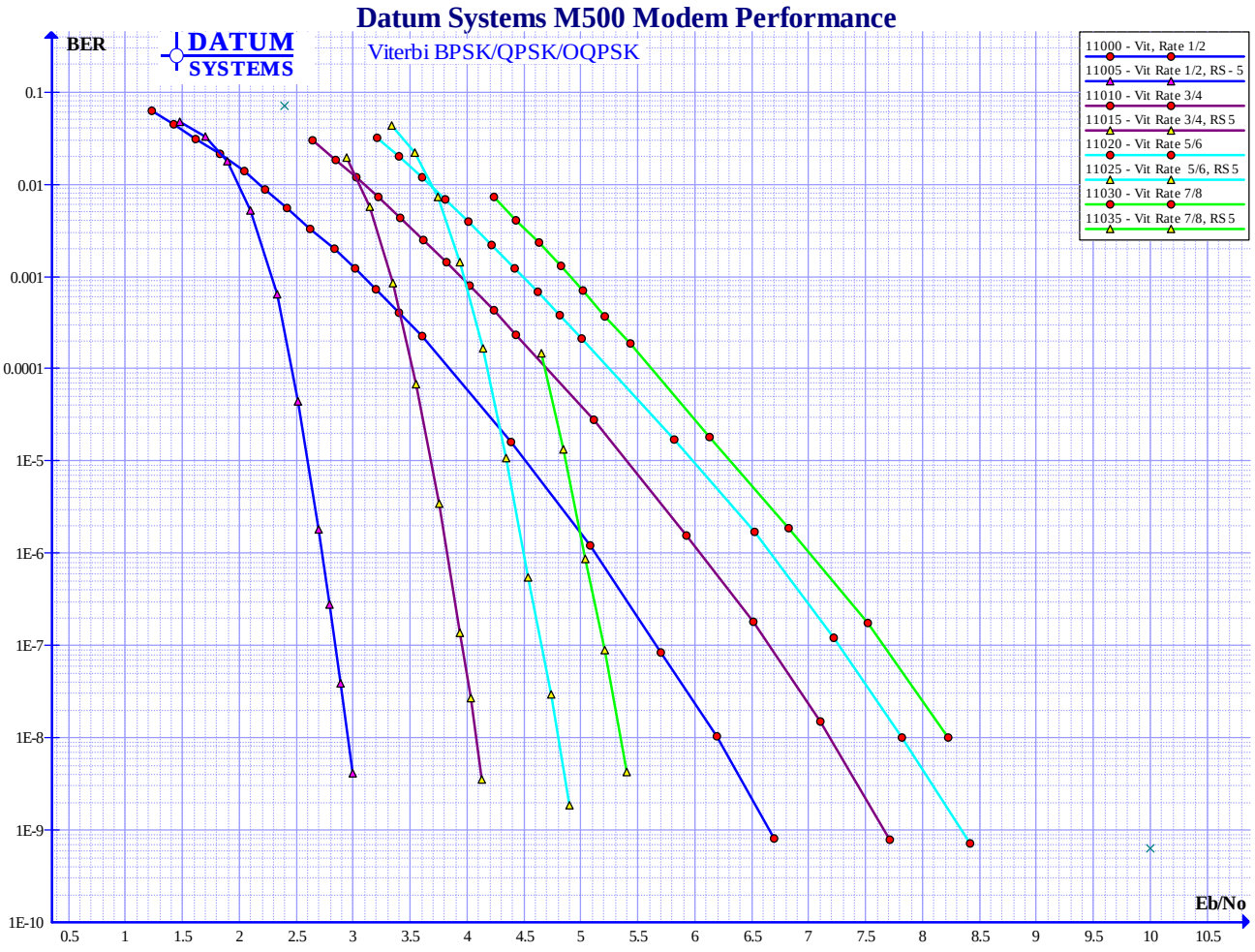
Viterbi FEC and Concatenated Reed-Solomon Performance

The standard Viterbi FEC plus the Viterbi concatenated with Reed-Solomon performance is shown in the following table and the accompanying graph.

The typical performance with the optional Reed-Solomon codec (concatenated on the Viterbi codec) is shown in the table below. All values shown are using the standard IESS-308 Reed-Solomon codec values of n = 126, k=112, depth =4, and the synchronous IESS-308 scrambler/descrambler. Significant changes in performance, positive and negative, are achieved using different n, k and depth values.

Viterbi FEC Performance for BPSK, QPSK and OQPSK with and without Reed-Solomon Required Eb/No in dB dB - Typical																
Rate -->	Rate 1/2				Rate 3/4				Rate 5/6				Rate 7/8			
RS Opt-->	None	1	2	5	None	1	2	5	None	1	2	5	None	1	2	5
BER	**11000**	**11001**	**11002**	**11005**	**11010**	**11011**	**11012**	**11015**	**11020**	**11021**	**11022**	**11025**	**11030**	**11031**	**11032**	**11035**
1.00E-03	3.09	2.33	2.36	2.28	3.94	3.36	3.39	3.33	4.49	4.01	4.03	3.97	4.90	4.44	4.52	4.66
1.00E-04	3.84	2.52	2.53	2.46	4.70	3.57	3.58	3.52	5.25	4.23	4.22	4.18	5.62	4.73	4.73	4.68
1.00E-05	4.52	2.67	2.67	2.60	5.40	3.75	3.74	3.68	5.98	4.43	4.41	4.35	6.32	4.94	4.91	4.86
1.00E-06	5.12	2.82	2.80	2.73	6.04	3.91	3.89	3.82	6.66	4.60	4.57	4.50	7.01	5.14	5.10	5.03
1.00E-07	5.66	2.95	2.92	2.84	6.65	4.06	4.03	3.96	7.27	4.78	4.73	4.66	7.66	5.33	5.26	5.20
1.00E-08	6.20	3.08	3.04	2.95	7.19	4.20	4.16	4.08	7.82	4.95	4.89	4.80	8.22	5.52	5.43	5.35
1.00E-09	6.65	3.22	3.14	3.05	7.66	4.35	4.28	4.19	8.35	5.12	5.07	4.94	8.78	5.70	5.61	5.49

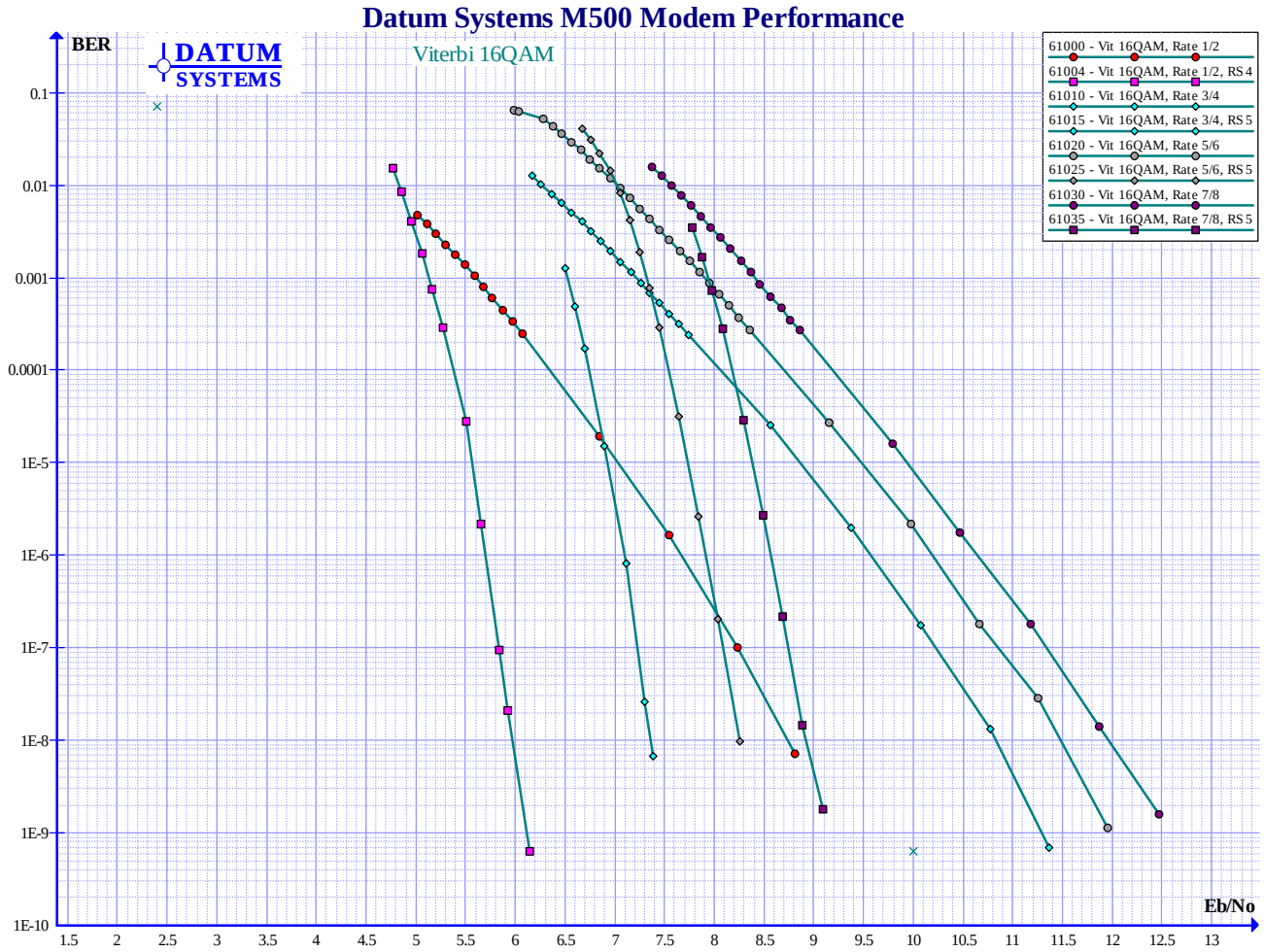
Waterfall curves for the common Viterbi FEC at various Code Rates for BPSK, QPSK, OQPSK modulation modes are shown in the graphs below.



16QAM Modulation Viterbi FEC Performance

Waterfall curves for the common Viterbi FEC at the available Code Rates for 16QAM modulation modes are shown in the graphs below. TPC 16QAM performance is shown with the TPC FEC data later.

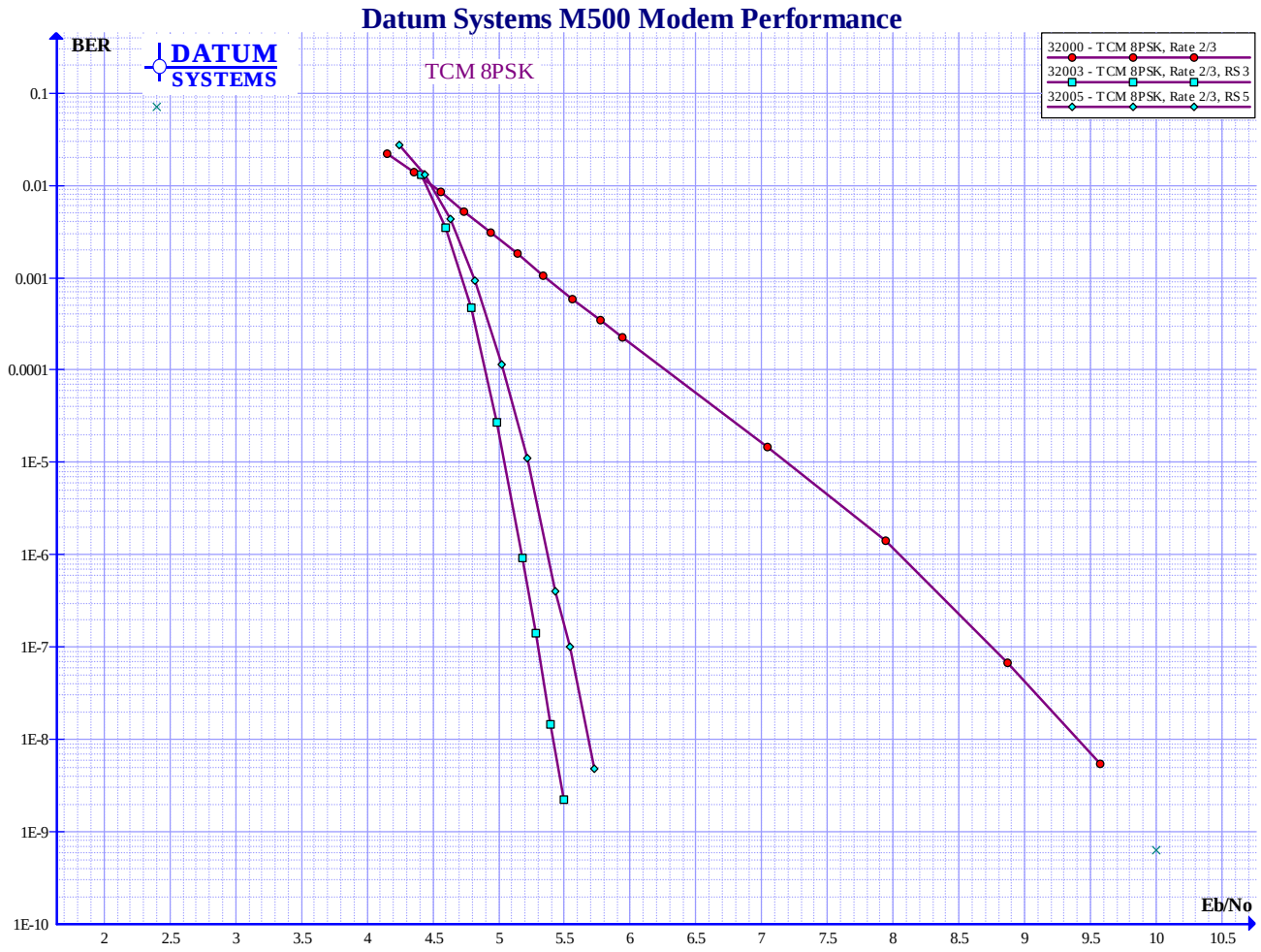
Viterbi FEC Performance for 16QAM with and without Reed-Solomon Required Eb/No in dB dB - Typical										
Rate -->	1/2		3/4			5/6		7/8		
RS Opt-->	None	4	None	4	CT-5	None	4	None	4	CT-5
BER	**61000**	**61004**	**61010**	**61014**	**61215**	**61020**	**61024**	**61030**	**61034**	**61235**
1.00E-03	5.65	5.13	7.24	6.68	6.60	7.92	7.49	8.46		7.96
1.00E-04	6.38	5.38	8.08	6.93	6.79	8.74	7.75	9.24		8.18
1.00E-05	7.02	5.57	8.89	7.15	6.95	9.51	8.00	10.01		8.40
1.00E-06	7.65	5.70	9.62	7.35	7.12	10.23	8.23	10.72		8.60
1.00E-07	8.23	5.84	10.28	7.54	7.26	10.92	8.45	11.33		8.79
1.00E-08	8.75	5.97	10.87	7.72	7.39	11.53	12.15	11.98		8.96
1.00E-09	9.24	6.11	11.47	7.91	7.53	12.02	20.67	12.54		9.13



8PSK Trellis Code Modulation Performance

The Trellis Code Modulation (TCM) codec is designed for and used only with 8PSK modulation. It is not possible to operate TCM at any data rate other than 2/3 or in any modulation mode other than 8PSK. Typical performance of TCM rate 2/3 in 8PSK with and without concatenated Reed-Solomon is shown in the table below. All values shown are using the synchronous IESS-308 scrambler/descrambler. Significant changes in performance, positive and negative, are achieved using different n, k and depth values.

8PSK TCM FEC Performance for 8PSK Required Eb/No in dB dB - Typical			
Rate -->	2/3	2/3 with R-S, IESS-310	2/3 with R-S, CT 220,200
BER	**32000**	**32003**	**32005**
1.00E-03	5.36	4.72	4.81
1.00E-04	6.26	4.90	5.03
1.00E-05	7.19	5.05	5.23
1.00E-06	8.04	5.18	5.37
1.00E-07	8.75	5.30	5.54
1.00E-08	9.40	5.41	5.68
1.00E-09	10.05	5.55	5.83



Turbo Product Codes Performance

The typical performance with the optional Turbo Product Codes FEC is shown in the tables below. The Eb/No values shown are those referenced to the customer data rate at the decoder output. Performance would appear improved if measured relative to the decoder input (i.e. at the satellite data rate). All values shown are using the synchronous TPC scrambler.

TPC M5 Compatible Modes

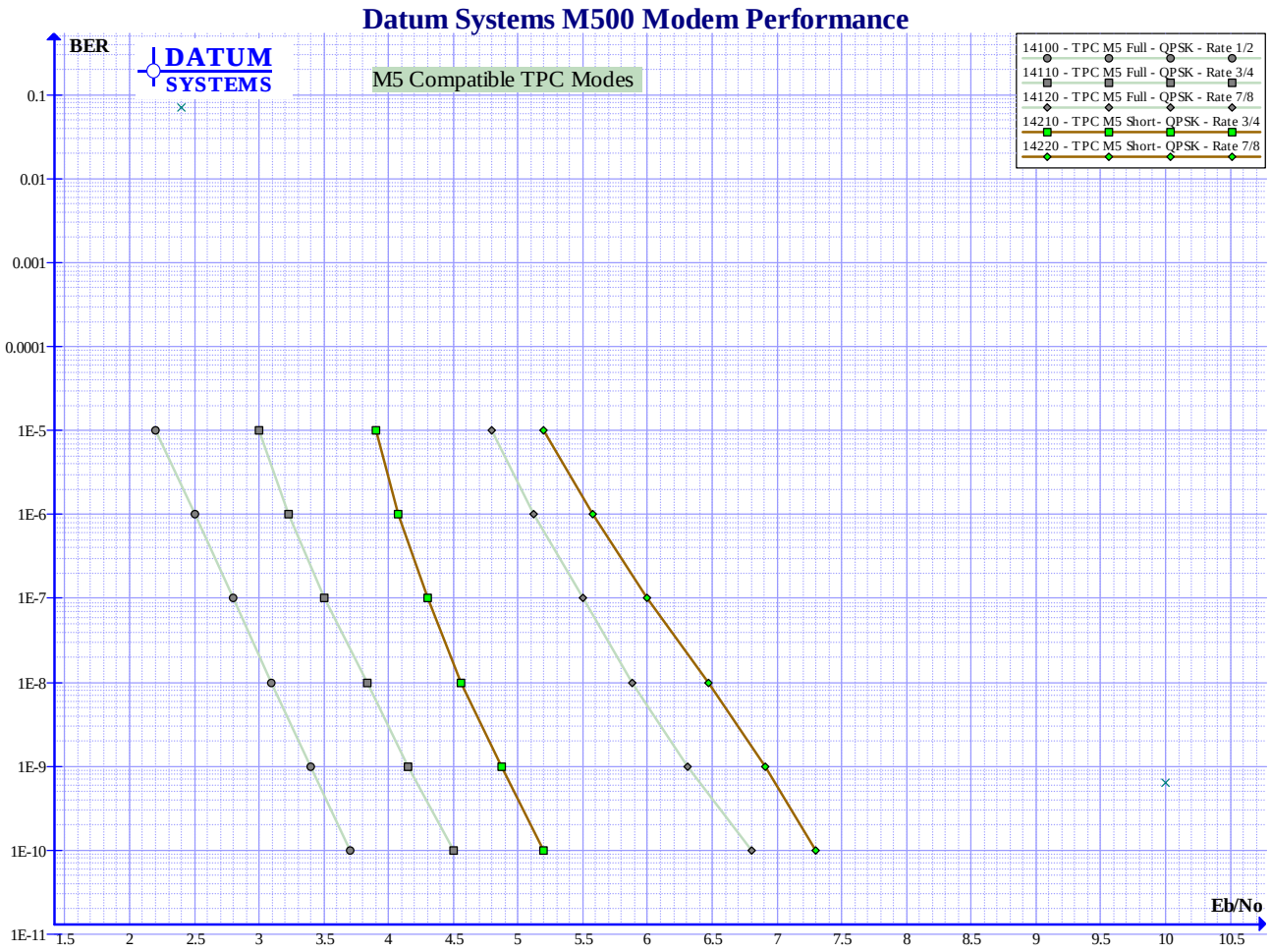
Turbo Product Codes FEC M5 Full Mode Typical Performance Data			
	Rate ½	Rate ¾	Rate 7/8
MTOCR	14100	14110	14120
BER	Eb/No	Eb/No	Eb/No
10^{-4}			
10^{-5}	2.20	3.00	4.80
10^{-6}	2.50	3.23	5.12
10^{-7}	2.80	3.50	5.50
10^{-8}	3.09	3.84	5.88
10^{-9}	3.40	4.15	6.31
10^{-10}	3.70	4.50	6.80

Turbo Product Codes FEC M5 Short Block Mode Typical Performance Data			
	Rate ½	Rate ¾	Rate 7/8
MTOCR	14200	14210	14220
BER	Eb/No	Eb/No	Eb/No
10^{-4}			
10^{-5}		3.90	5.20
10^{-6}		4.07	5.58
10^{-7}		4.30	6.00
10^{-8}		4.56	6.47
10^{-9}		4.87	6.91
10^{-10}		5.20	7.30

Turbo Product Codes FEC M5 Legacy Mode Typical Performance Data			
	Rate ½	Rate ¾	Rate 7/8
MTOCR	14300	14310	14320
BER	Eb/No	Eb/No	Eb/No
10^{-4}			
10^{-5}		3.2 dB	4.6 dB
10^{-6}		3.3 dB	4.7 dB
10^{-7}		3.5 dB	4.8 dB
10^{-8}		3.6 dB	5.0 dB
10^{-9}		3.7 dB	5.3 dB
10^{-10}		3.9 dB	5.5 dB

TPC M5 Compatible Modes Waterfall Curves

Note: M5 Legacy mode not shown

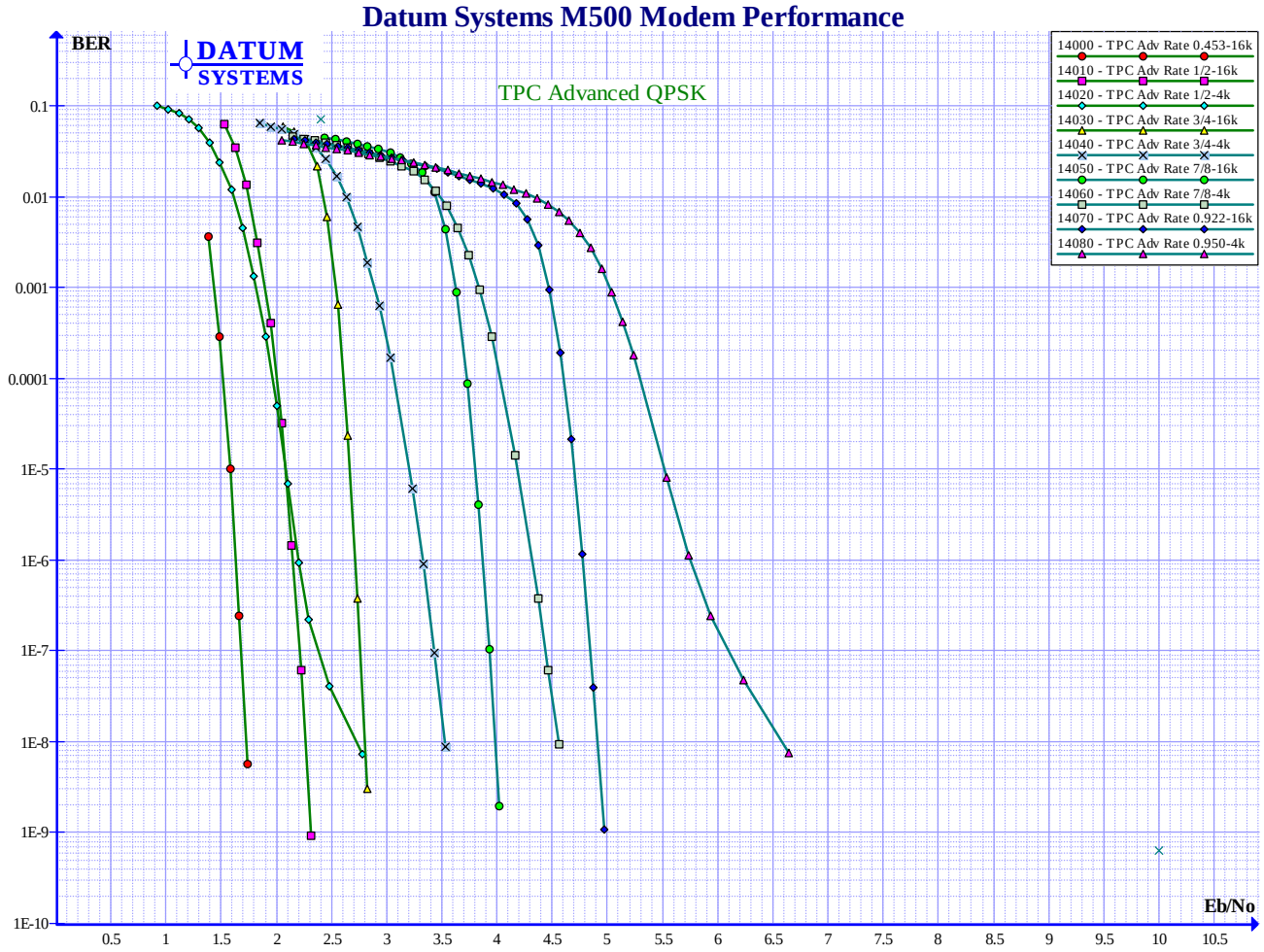


TPC Advanced Performance Mode

The TPC Advanced FEC option is a new TPC implementation proprietary to Datum Systems. These specific modes were optimized for optimized performance covering a broad range of system needs. They will typically outperform any TPC modes by any modem manufacturer.

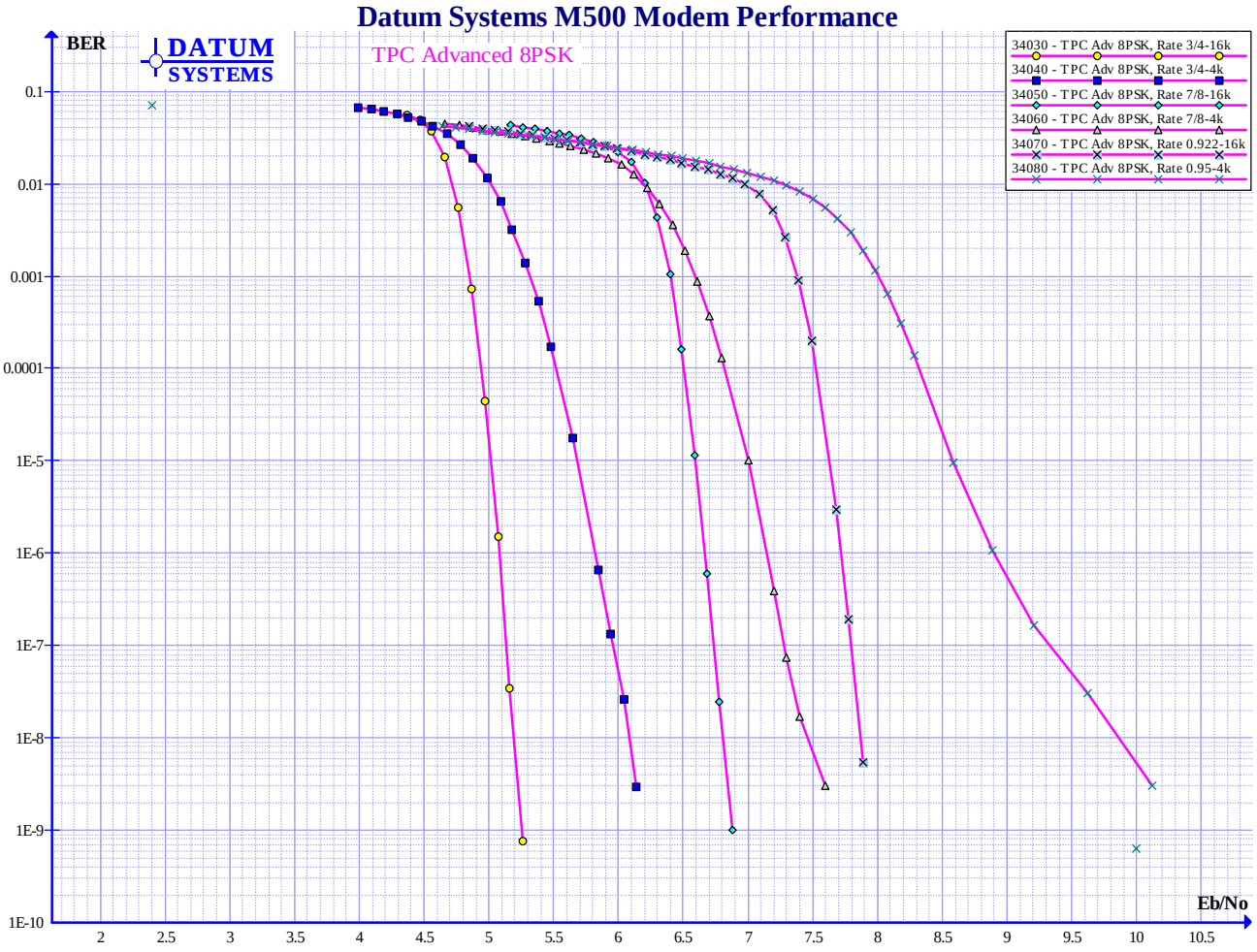
TPC-Advanced BPSK/QPSK Performance

TPC Advanced FEC Performance for BPSK, QPSK and OQPSK Required Eb/No in dB - Typical									
Rate -->	**0.453-16k**	**1/2-16k**	**1/2-4k**	**3/4-16k**	**3/4-4k**	**7/8-16k**	**7/8-4k**	**0.922-16k**	**0.95-4k**
BER	**14000**	**14010**	**14020**	**14030**	**14040**	**14050**	**14060**	**14070**	**14080**
1.00E-03	1.44	1.90	1.82	2.54	2.89	3.62	3.83	4.47	5.02
1.00E-04	1.51	2.01	1.97	2.61	3.06	3.72	4.02	4.60	5.30
1.00E-05	1.58	2.08	2.09	2.67	3.20	3.80	4.18	4.70	5.52
1.00E-06	1.63	2.15	2.20	2.72	3.32	3.87	4.31	4.77	5.75
1.00E-07	1.68	2.22	2.38	2.76	3.43	3.93	4.44	4.84	6.10
1.00E-08	1.73	2.27	2.72	2.81	3.52	3.98	4.56	4.91	6.59
1.00E-09	1.78	2.32	3.12	2.85	3.62	4.04	4.68	4.97	7.10



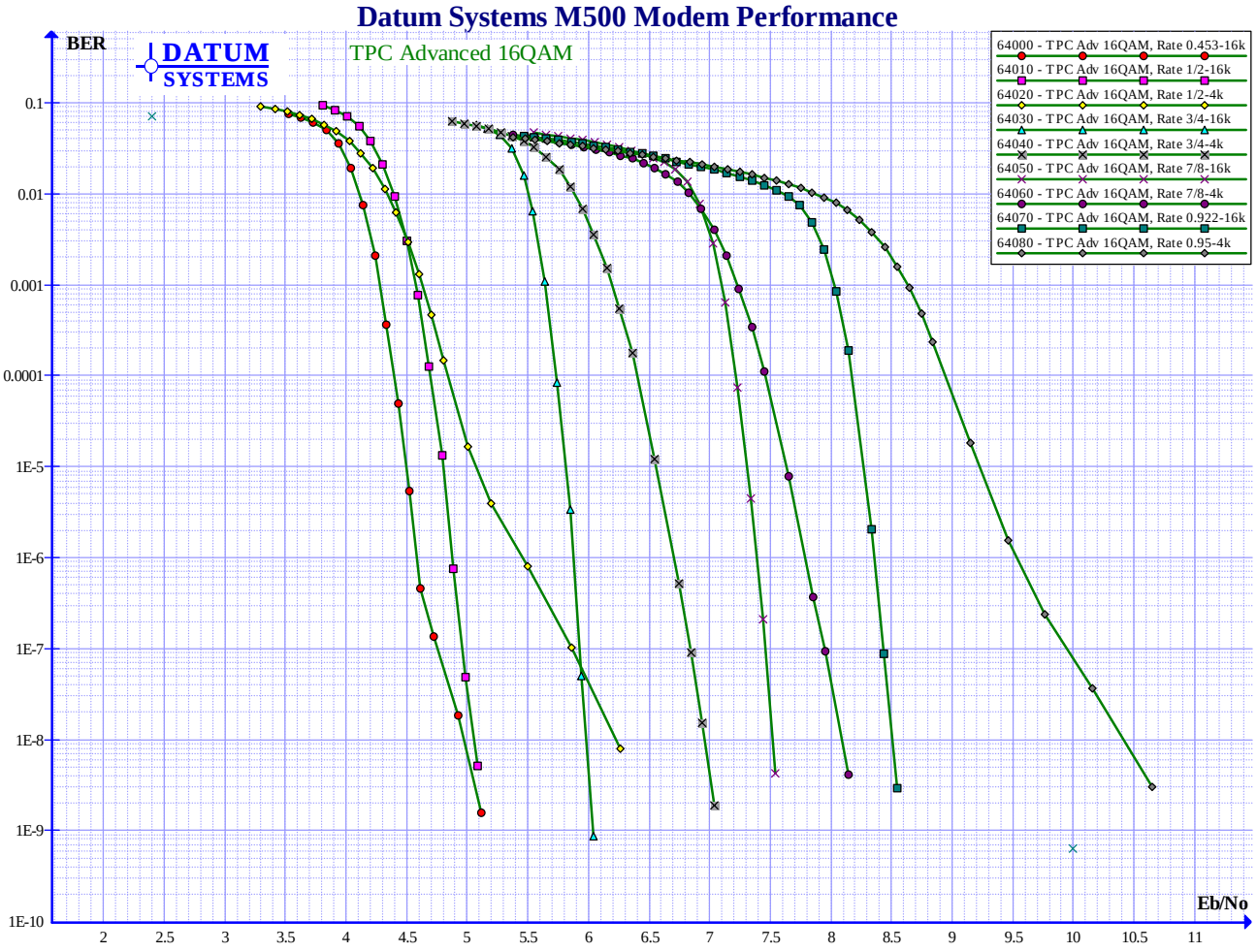
TPC-Advanced 8PSK Performance

TPC Advanced FEC Performance for 8PSK Required Eb/No in dB dB - Typical						
Rate -->	**3/4-16k**	**3/4-4k**	**7/8-16k**	**7/8-4k**	**0.922-16k**	**0.95-4k**
BER	**34030**	**34040**	**34050**	**34060**	**34070**	**34080**
1.00E-03	4.85	5.31	6.40	6.59	7.38	8.00
1.00E-04	4.94	5.52	6.51	6.82	7.52	8.32
1.00E-05	5.01	5.68	6.59	7.00	7.63	8.58
1.00E-06	5.08	5.82	6.66	7.14	7.72	8.90
1.00E-07	5.13	5.96	6.74	7.28	7.80	9.33
1.00E-08	5.19	6.08	6.81	7.46	7.87	9.86
1.00E-09	5.25	6.19	6.88	7.73	7.94	10.36



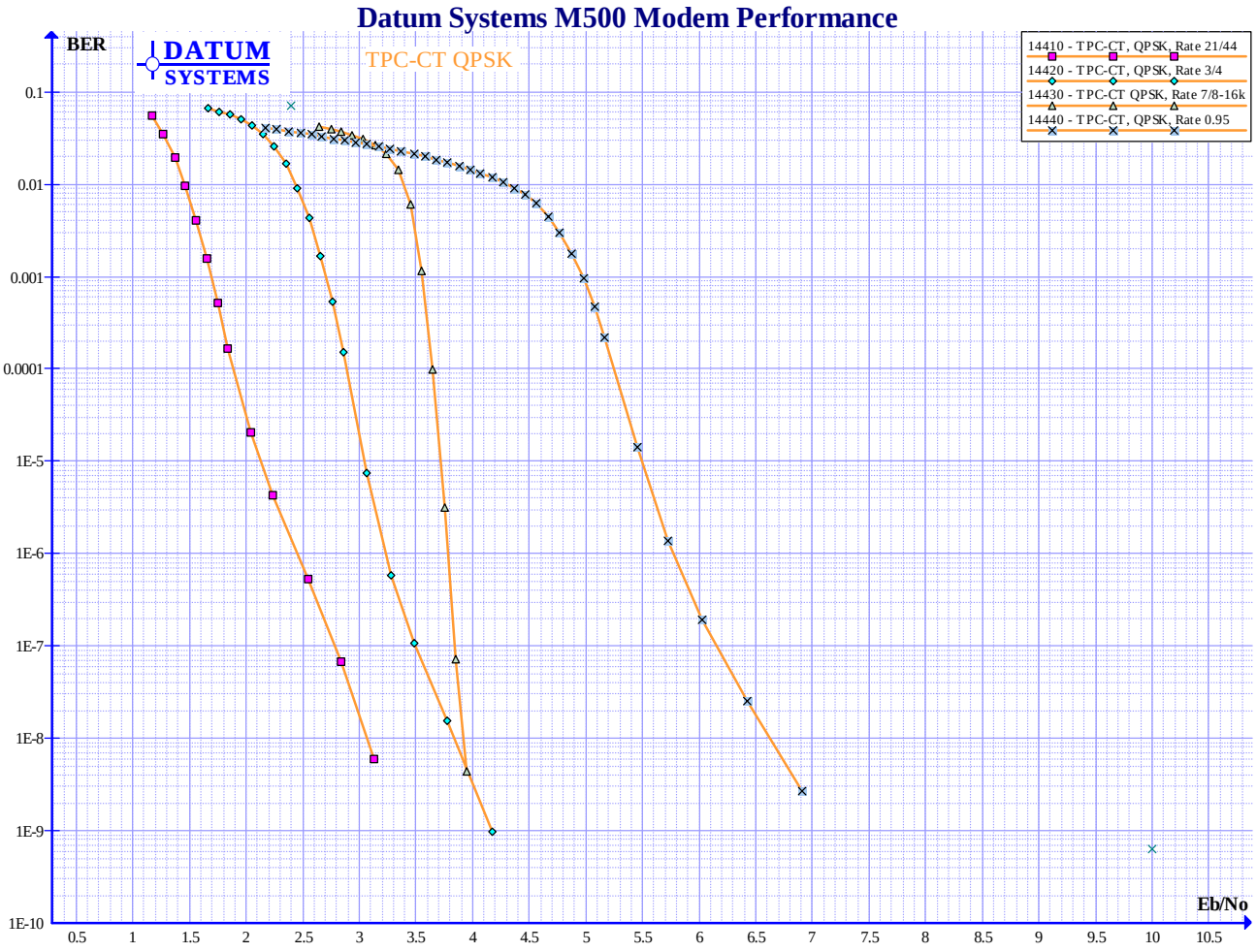
TPC-Advanced 16QAM Performance

TPC Advanced FEC Performance for 16QAM Required Eb/No in dB dB - Typical									
Rate -->	**0.453-16k**	**1/2-16k**	**1/2-4k**	**3/4-16k**	**3/4-4k**	**7/8-16k**	**7/8-4k**	**0.922-16k**	**0.95-4k**
BER	**64000**	**64010**	**64020**	**64030**	**64040**	**64050**	**64060**	**64070**	**64080**
1.00E-03	4.28	4.57	4.63	5.64	6.19	7.10	7.23	8.02	8.63
1.00E-04	4.40	4.69	4.84	5.73	6.40	7.22	7.46	8.17	8.94
1.00E-05	4.49	4.80	5.08	5.81	6.56	7.31	7.63	8.27	9.23
1.00E-06	4.58	4.88	5.46	5.88	6.71	7.39	7.78	8.36	9.53
1.00E-07	4.75	4.96	5.86	5.93	6.84	7.46	7.95	8.44	9.94
1.00E-08	4.98	5.06	6.22	5.98	6.96	7.52	8.09	8.51	10.41
1.00E-09	5.15	5.16	6.59	6.04	7.07	7.58	8.23	8.59	10.86



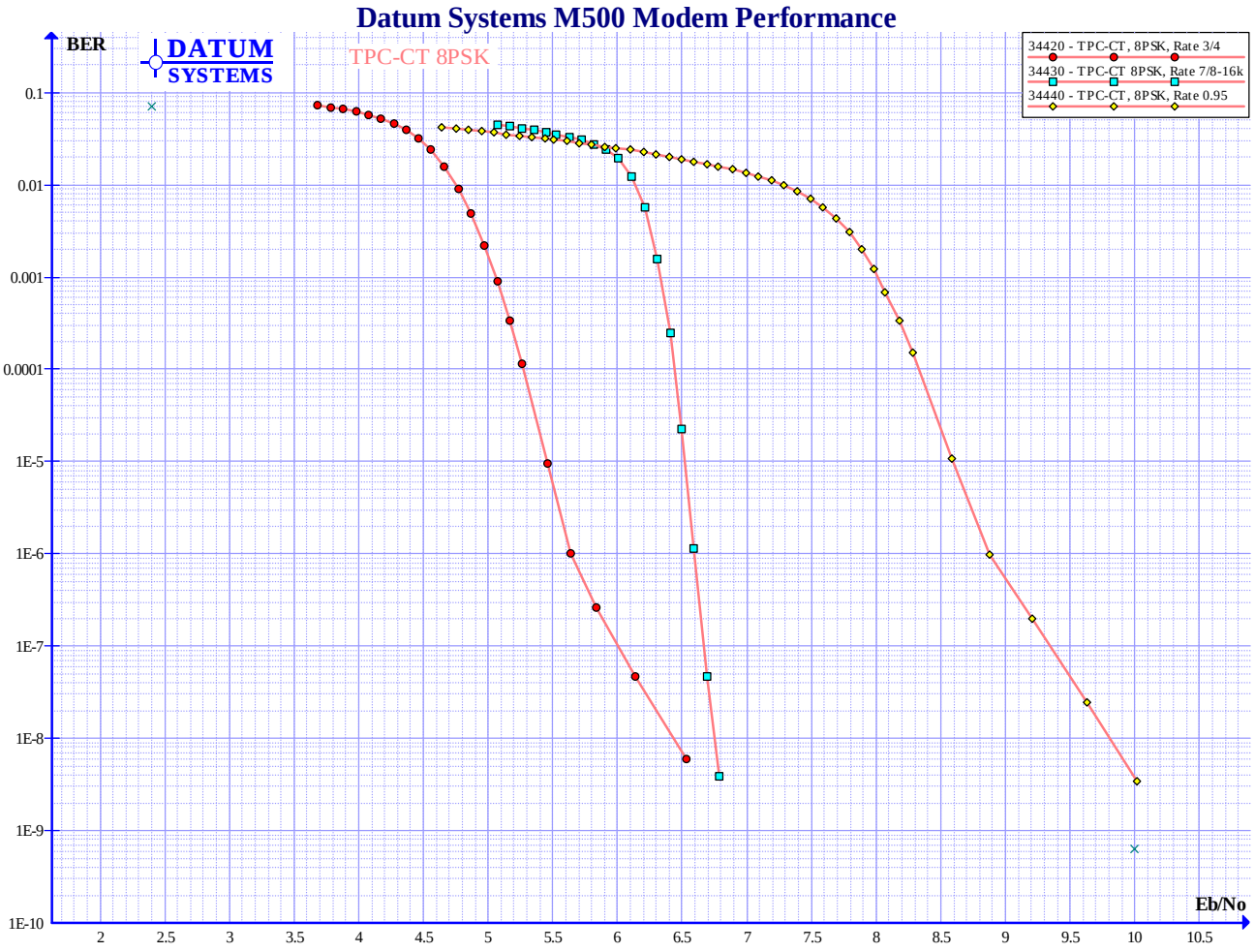
TPC-CT BPSK/QPSK Performance

TPC CT FEC Performance for BPSK, QPSK and OQPSK Required Eb/No in dB dB - Typical					
Rate -->	5/16	21/44	3/4	7/8	0.95
BER	14400	14410	14420	14430	14440
1.00E-03		1.69	2.70	3.56	4.97
1.00E-04		1.89	2.89	3.65	5.25
1.00E-05		2.13	3.05	3.72	5.50
1.00E-06		2.45	3.24	3.78	5.78
1.00E-07		2.79	3.49	3.84	6.16
1.00E-08		3.07	3.84	3.92	6.63
1.00E-09		3.34	4.17	4.00	7.12



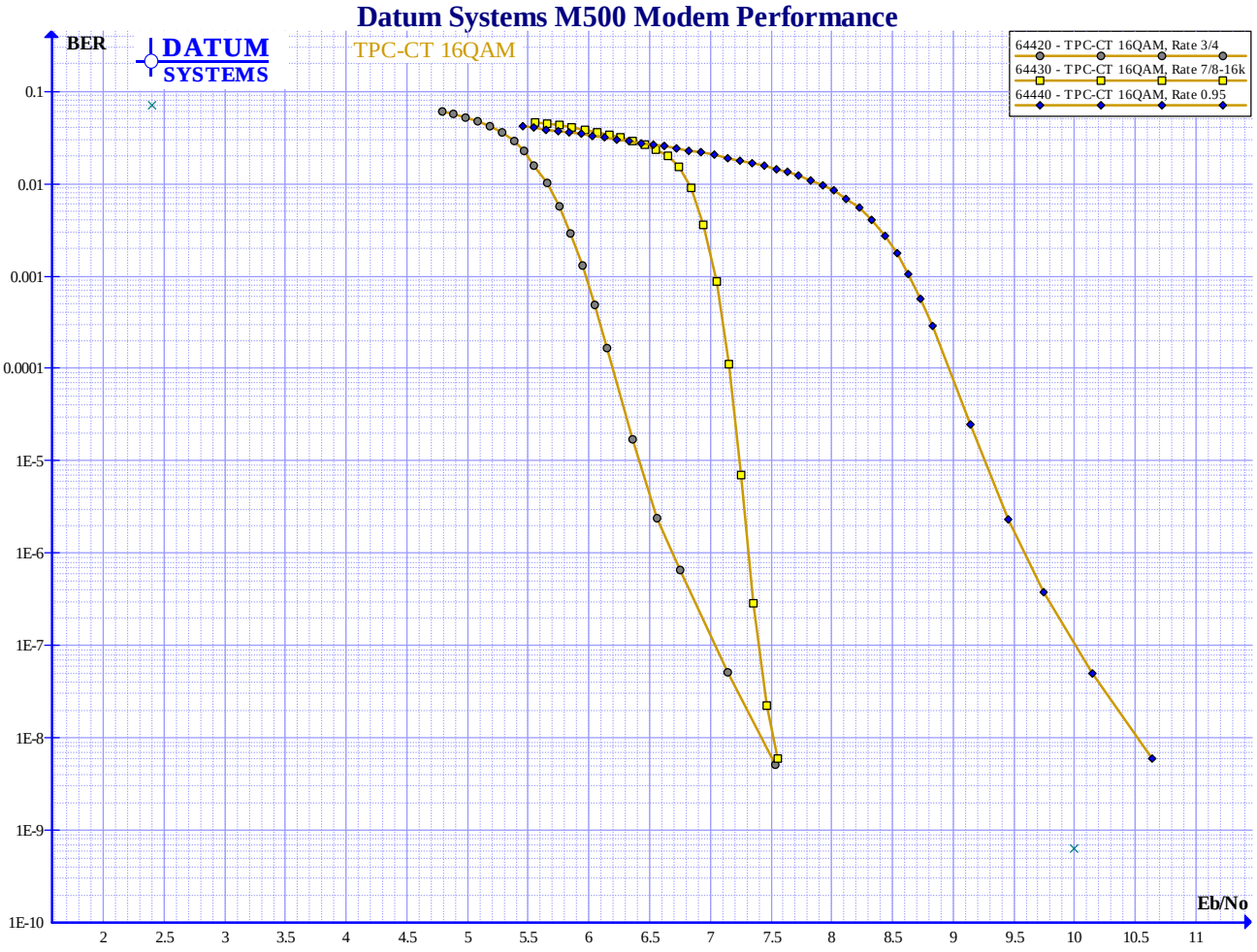
TPC-CT 8PSK Performance

TPC CT FEC Performance for 8PSK Required Eb/No in dB dB - Typical			
Rate -->	3/4	7/8	0.95
BER	34420	34430	34440
1.00E-03	5.06	6.33	8.01
1.00E-04	5.27	6.44	8.33
1.00E-05	5.45	6.52	8.60
1.00E-06	5.64	6.59	8.88
1.00E-07	6.01	6.67	9.35
1.00E-08	6.43	6.75	9.81
1.00E-09	6.87	6.85	10.27



TPC-CT 16QAM Performance

TPC CT FEC Performance for 16QAM Required Eb/No in dB dB - Typical			
Rate -->	3/4	7/8	0.95
BER	64420	64430	64440
1.00E-03	5.98	7.04	8.64
1.00E-04	6.20	7.15	8.96
1.00E-05	6.42	7.24	9.26
1.00E-06	6.69	7.31	9.59
1.00E-07	7.04	7.40	10.01
1.00E-08	7.42	7.52	10.52
1.00E-09	7.80	7.70	11.05



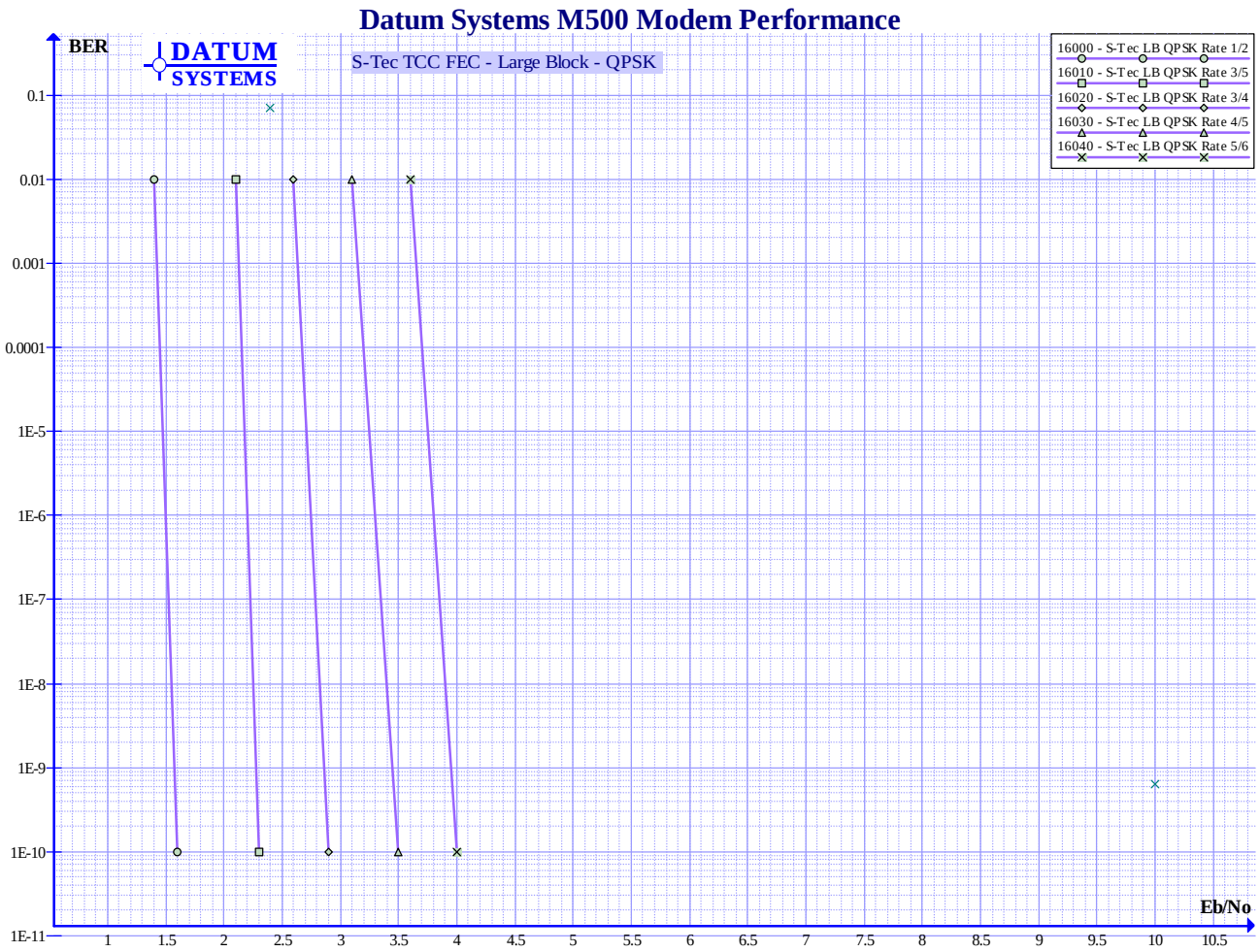
S-Tec Turbo Convolutional Codes Performance

The typical performance with the optional S-Tec FEC is shown in the tables below. The Eb/No values shown are those referenced to the customer data rate at the decoder output. Performance would appear improved if measured relative to the decoder input (i.e. at the satellite data rate). All values shown are using the synchronous TPC scrambler/descrambler and version 0.63 or greater modem firmware.

S-Tec TCT FEC Typical Performance Data for 10^{-10} BER								
	BPSK		QPSK		8PSK		16QAM	
Code Rate	Bits/Hz	Eb/No	Bits/Hz	Eb/No	Bits/Hz	Eb/No	Bits/Hz	Eb/No
1/2	0.50	1.60 dB	1.00	1.60 dB	1.50	3.30 dB	2.00	4.20 dB
2/3	0.67	2.30 dB	1.33	2.30 dB	2.00	4.20 dB	2.67	5.30 dB
3/4	0.75	2.90 dB	1.50	2.90 dB	2.25	5.60 dB	3.00	6.30 dB
4/5	0.80	3.50 dB	1.60	3.50 dB	2.40	6.20 dB	3.20	7.00 dB
5/6	0.83	4.00 dB	1.67	4.00 dB	2.50	7.00 dB	3.33	7.60 dB
7/8	0.90	- dB	1.80	- dB	2.63	- dB	3.50	- dB

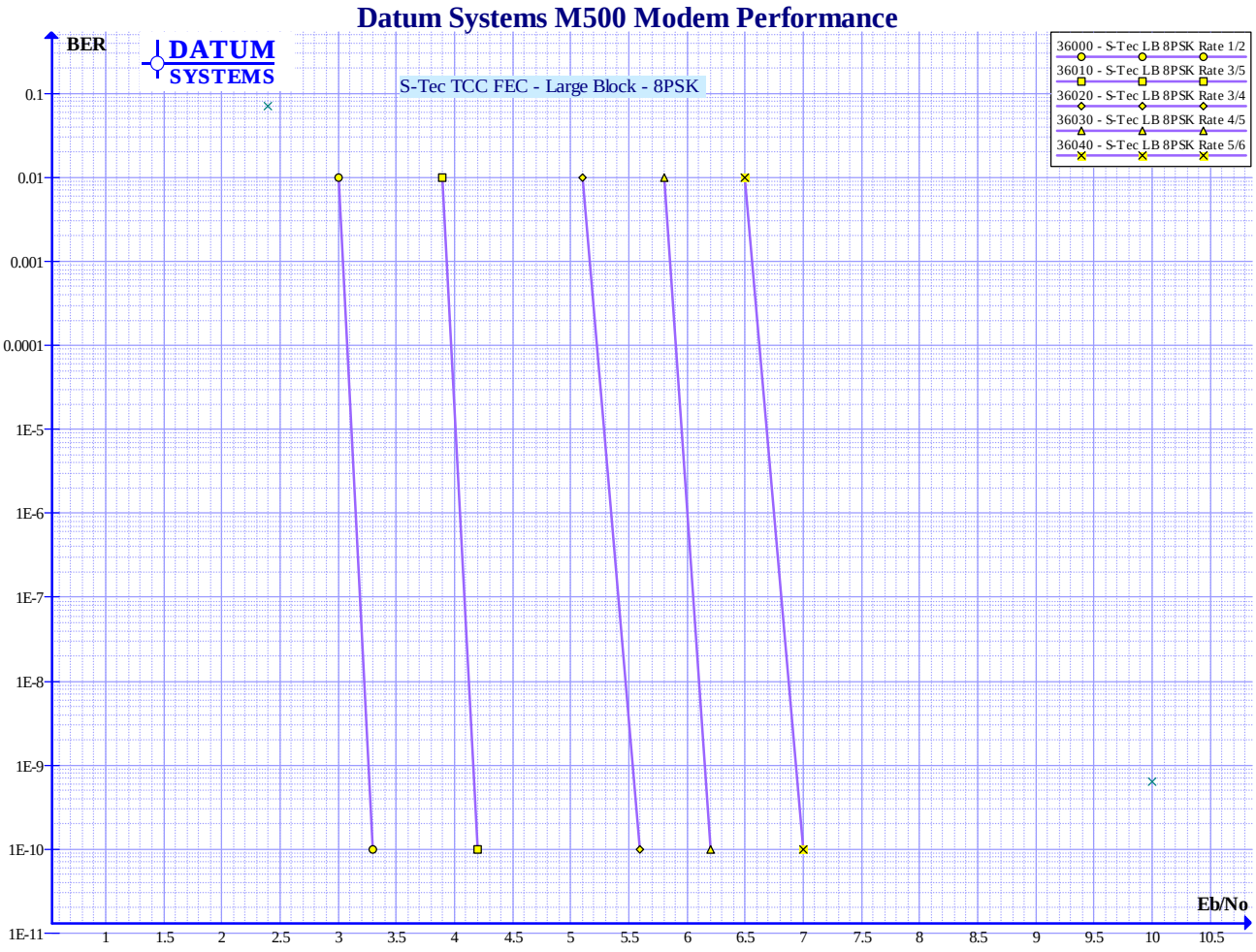
S-Tec Large Block QPSK/BPSK Performance

S-Tec FEC Performance for BPSK, QPSK and OQPSK Required Eb/No in dB dB - Typical					
Rate -->	**1/2**	**3/5**	**3/4**	**4/5**	**5/6**
BER	**16000**	**16010**	**16020**	**16030**	**16040**
1.00E-02	1.40	2.10	2.60	3.10	3.60
1.00E-03					
1.00E-04					
1.00E-05					
1.00E-06	1.44				
1.00E-07	1.48				
1.00E-08	1.52				
1.00E-09	1.56				
1.00E-10	1.60	2.30	2.90	3.50	4.00



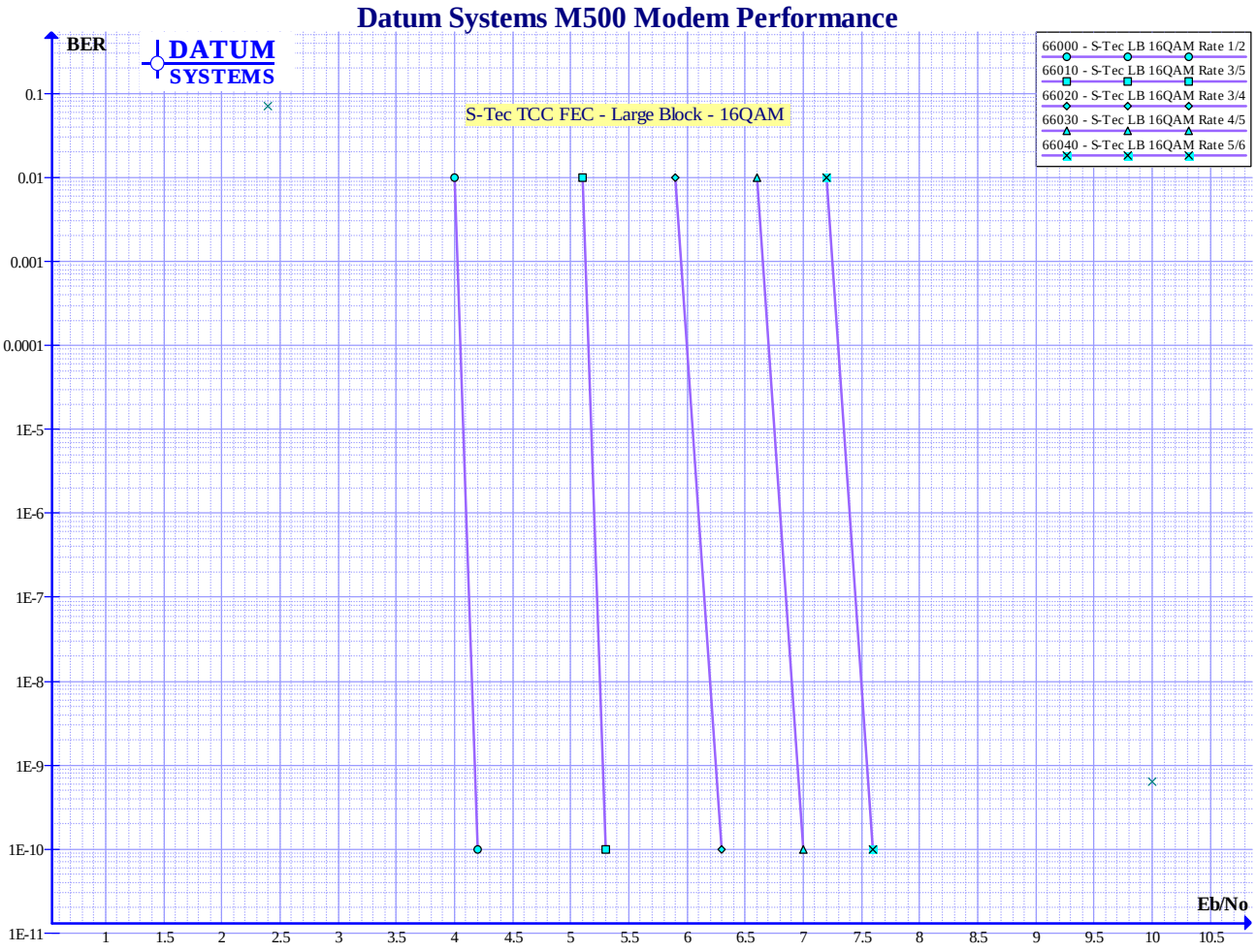
S-Tec Large Block 8PSK Performance

S-Tec FEC Performance for 8PSK Required Eb/No in dB dB - Typical					
Rate -->	**1/2**	**3/5**	**3/4**	**4/5**	**5/6**
BER	**36000**	**36010**	**36020**	**36030**	**36040**
1.00E-02	3.00	3.90	5.10	5.80	6.50
1.00E-03					
1.00E-04					
1.00E-05					
1.00E-06					
1.00E-07					
1.00E-08					
1.00E-09					
1.00E-10	3.30	4.20	5.60	6.20	7.00



S-Tec Large Block 16QAM Performance

S-Tec FEC Performance for 16QAM Required Eb/No in dB dB - Typical					
Rate -->	**1/2**	**3/5**	**3/4**	**4/5**	**5/6**
BER	**66000**	**66010**	**66020**	**66030**	**66040**
1.00E-02	4.00	5.10	5.90	6.60	7.20
1.00E-03					
1.00E-04					
1.00E-05					
1.00E-06					
1.00E-07					
1.00E-08					
1.00E-09					
1.00E-10	4.20	5.30	6.30	7.00	7.60



Acquisition Performance

The following table shows typical acquisition performance for the Fast Acquisition mode using the standard Viterbi FEC and the DSP acquisition processor. The times shown are for the average and 95% of acquisition probability at a 6.0 dB Eb/No. These times are measured over 1000 acquisitions.

Fast Acquisition Timing				
Bit Rate in kbps	**Modulation**	**FEC Rate**	**Typical Average Fast Acquisition Time for ±30 KHz (seconds)**	**Typical 95% Probability Fast Acquisition Time for ±30 KHz (seconds)**
2.4	QPSK	Vit 1/2	1.230	1.453
2.4	BPSK	Vit 1/2	0.750	0.819
9.6	QPSK	Vit 1/2	0.315	0.371
9.6	BPSK	Vit 1/2	0.174	0.183
16	QPSK	Vit 1/2	0.196	0.231
16	BPSK	Vit 1/2	0.144	0.163
32	QPSK	Vit 1/2	0.116	0.135
32	BPSK	Vit 1/2	0.097	0.110
64	QPSK	Vit 1/2	0.071	0.082
64	BPSK	Vit 1/2	0.050	0.057
	8PSK	TCM 2/3		
	16QAM	Vit 1/2		

Fast acquistion performance is optimized in Viterbi FEC rate ½. When changing to rate ¾ or 7/8 the penalty is approximately 3.5 to 4 times the acquisition time. This is due to the decreased symbol rate and the FEC and acquisition processors having to deal with twice the number of ambiguities in determining signal type and lock. Acquisition times with the Turbo Product Codes FEC are 2 to 4 times that of the Viterbi FEC. Fast acquisition is optimized under normal noise conditions, where the absence of noise adds time for AGC operation.

Data Interface Specifications

Data Input

Type: ..... Synchronous, Programmable for RS-449/422,
..... V.35, V.36, EIA-530, EIA-530A or Synchronous
..... RS-232 with separate Clock and Data signals.
..... G.703, Ethernet and others optional via
..... option interface assembly.
..... Flexible clock options allow the transmit timing
..... to be supplied by:
..... **a**. An internally generated ± 2 ppm reference
..... clock or external reference, if supplied.
..... **b**. The demodulator RCV clock as recovered
..... from the receive carrier.
..... **c**. A Terminal Timing input as supplied to the
..... modem TT interface pins.
..... **d**. A Separate Send Timing input as supplied to
..... the modem Ext. Timing interface pins.

Termination: ..... Per applicable interface specification.
..... Termination can be removed in RS-449 mode.

Data Output

Type: ..... Synchronous, Programmable for RS-449/422,
..... V.35, V.36, EIA-530, EIA-530A or Synchronous
..... RS-232 with separate Clock and Data signals.
..... G.703, Ethernet and others optional via an
..... option interface assembly.
..... Additional clock options allow the demodulator
..... RCV clock to be supplied by:
..... **a**. The actual received bit rate.
..... **b**. The modulator transmit clock source.
..... **c**. An internally generated timing clock source.
..... **d**. A user supplied FIFO output clock source.
..... Using b, c or d enables the receive FIFO buffer.

Modem Bit Delays

Modulator Transmit Delays

Modulation Processing ..... 1 user rate bits.

Viterbi FEC Encoder:
Rate ½ ..... 12 channel rate bits.
Rate ¾ ..... 15 channel rate bits.
Rate 7/8 ..... 17 channel rate bits.

Reed-Solomon Encoder ..... (8·k)+10 user/IBS output rate bits
..... + fixed 500 us delay.

TPC FEC Full Encoder:
Rate ½ ..... 1094 user rate bits.
Rate ¾ ..... 573 channel rate bits.
Rate 7/8 ..... 482 channel rate bits.
TPC FEC Short Encoder:
Rate ¾ ..... 208 channel rate bits.
Rate 7/8 ..... 164 channel rate bits.

IBS Multiplexer: ..... 12 user rate bits.

Demodulator Receive Delays

Demodulation Processing ..... 1 user rate bits.

Viterbi FEC Decoder
Rate ½ ..... 184 channel rate bits.
Rate ¾ ..... 186 to 188 channel rate bits.
Rate 7/8 ..... 186 to 190 channel rate bits.

TPC FEC Full Decoder:
Rate ½ ..... 2025 user rate bits + fixed 751 uS delay.
Rate ¾ ..... 2196 channel rate bits + fixed 446 uS delay.
Rate 7/8 ..... 3593 channel rate bits + fixed 447 uS delay.
TPC FEC Short Decoder:
Rate ¾ ..... 729 channel rate bits + fixed 218 uS delay.
Rate 7/8 ..... 1087 channel rate bits + fixed 290 uS delay.

FIFO Buffer (enabled) ..... 3 user rate bits plus bit setting.

Reed-Solomon Decoder depth = 4: $32 \cdot k+(24 \cdot k \cdot (4 \cdot D-n))/n+11$ User/IBS Demux
..... Input Rate Bits + Fixed 500us Delay
..... where D is the smallest integer >=(n-1)/4
depth = 8: .. $64 \cdot k+(24 \cdot k \cdot (4 \cdot D-n))/n+11$ User/IBS Demux Input
..... Rate Bits + Fixed 500us Delay
..... where D is the smallest integer >=(n-1)/8

IBS Multiplexer ..... 4 user rate bits.

Bit Rate definition:
"User" bit rate = "Terrestrial" interface rate.
“Channel” bit rate is the Convolotional Encoder Input Data Rate for the Modulator.
“Channel” bit rate is the Viterbi Decoder Output Data Rate for the Demodulator.
"Channel" bit rate = User bit rate X (1/Mux rate) (if mux enabled) X (1/RS rate) (if RS enabled).

Delay Examples:
Reed-Solomon Example 1, if n=126, k=112 and Depth=4 then
Total R-S Encoder Delay=906 User/IBS Mux Output Bits + Fixed 500us Delay
D=32, Total R-S Decoder Delay=3,638 User/IBS Demux Input Bits + Fixed 500us Delay

Reed-Solomon Example 2, if n=201, k=219 and Depth=4 then
Total R-S Encoder Delay=1,618 User/IBS Mux Output Bits + Fixed 500us Delay
D=55, The Total R-S Decoder Delay=6,465 User/IBS Demux Bits + Fixed 500us Delay

Reed-Solomon Example 3, if n=205, k=225 and Depth=4 then
Total R-S Encoder Delay=1,650 User/IBS Mux Output Bits + Fixed 500us Delay
D=56, The Total R-S Decoder Delay=6,549 User/IBS Demux Bits + Fixed 500us Delay

Link Calculation Example:

A modem with R-S and IBS mux is running at a user rate of 128 kbps with rate ½ FEC and no buffer. The Reed-Solomon is set as example 1 above: The IBS multiplexer is set to 2400 bps ESC Overhead and 300 bps MCC Overhead yielding a Mux ratio of 29/30.

The channel bit rate is then = 128 kbps X 9/8 X 30/29 = 148.9655 kbps. (Note 9/8 is n/k.)

The time/channel bit is 6.7 uS. The time/user bit is 7.8 uS.

The modulator delay is 13 channel rate bits x 6.7 uS plus 906 user rate bits x 7.8 uS plus 500 uS, for a total delay of 7,653.9 uS or 7.65 mS.

The demodulator delay is 185 channel rate bits x 6.7 uS plus 3638 user rate bits x 7.8 uS plus 500 uS, for a total delay of 30,115.9 uS or 30.116 mS.

The total end to end delay is then 37.766 mS plus the approximate 250 mS for the path delay.

Alarm, Monitor and Control Signals

All monitor and control functions are controllable via the front panel and the remote RS-232/RS-485 serial control port.

During station setup and normal operation the modem can output either the AGC, receive Eb/No or transmit power level to the rear panel via a digital to analog converter.

Alarm:

Summary: ..... Two summary form-C dry contact alarms, each
..... represents the OR'd condition of individually
..... programmed on-board fault sensors.
Indicator ..... Front panel LED indicator.
Timing ..... Alarm activated by any fault condition with 1/2
..... second hold before removal.

Monitor

AGC Level ..... Front Panel and via Remote Control port.
Carrier Lock ..... Green LED on internal PWB.
Demodulator Lock: ..... Front panel LED indicator.
Transmit Bit Rate Synthesizer Fault: ..... Internal LED indicator.
Transmit RF Synthesizer Fault: ..... Internal LED indicator.
Receive RF Synthesizer Fault: ..... Internal LED indicator.
Eb/No: ..... Front Panel and via Remote Control.

Operating LED indicators ..... 12 Front Panel LED indicators:

Unit
Power ..... Green - Lit when power applied
Summary Alarm ..... Red - if summary fault condition
Local ..... Green - Unit set to accept local (front panel)
..... commands.
Remote ..... Green - Unit set to accept remote commands.

Modulator
Transmit On ..... Green - Lit when transmit output is on.
..... Green Flashing – Indicates carrier off, but
..... internal carrier on only for loop-back test.
Major Alarm ..... Red - Indicates transmit traffic is lost.
Minor Alarm ..... Yellow - Warning - Indicates a marginal
..... condition.
Test Mode ..... Yellow Flashing - Modulator currently in test
..... mode.

Demodulator
Lock ..... Green - Indicates RCV lock to incoming CXR.
Major Alarm ..... Red - Indicates receive traffic is lost.
Minor Alarm ..... Yellow - Warning - Indicates a marginal
..... condition.
Test Mode ..... Yellow Flashing - Demodulator currently in test
..... mode.

Control

All parameters are controllable from either the front panel or via the remote control interface. Information and control access to the on-board processor is provided by an asynchronous serial

interface. The interface is selectable as either RS-232 three line interface (transmit, receive and ground) or RS-485 interface to a 4 wire bus with 3 state transmit operation. The modem address and operating mode is settable via the front panel or from terminal mode. The serial command mode control interface only responds to commands from its associated controller when properly addressed.

Refer to the associated "Remote Command Interface Specification" for details of the serial link command structure, protocol and available commands.

General Unit Specifications

Mechanical

IF connection type:..... 75Ω BNC female connectors, 1 XMT, 1 RCV
..... Located on Rear Panel
Reference Input: ..... 50Ω BNC female located on Rear Panel.
Data and Digital I/O connector :..... 37 pin female D type rear panel connector.
Controller Interface: ..... 9 pin "D" type female for RS-485 and RS-232
..... interface located on Rear Panel.
Alarm Interface:..... 9 pin “D” type male with 2 form C contacts.
..... interface located on Rear Panel.
Auxiliary Interface ..... 37 pin male D type rear panel connector.
Power Connector: ..... IEC 3-pin male with switch located on rear
..... panel.
Main Board Size:..... Approximately 9.5 x 11 X 1.2 inches.
Option Interface Board Size:..... Approximately 3.5 x 7 X 1.5 inches.
Packaged Modem Size:..... 1 Rack Mounting Spaces by 12 inches deep.
..... Approximately 19.0 x 12 X 1.75 inches.

Electrical Power Requirements

Prime Power:..... 90 to 260 Vac, 47-63 Hz, 50 Watts maximum
70/140 MHz Unit typical ..... Less than 25 Watts.
L-Band Unit typical ..... Less than 30 Watts exclusive of BUC power.
Internal Voltages: ..... +5 Volts DC ± 5% at 1.5 Amp max.
..... +12 Volts DC ± 5% at 0.8 Amps max.
..... -12 Volts DC ± 5% at 0.3 Amp max.
Note: Options may increase internal current draw.

Environmental

Operating: ..... -10 to +50°C, to 95% humidity, non-condensing.
Non-Operating: ..... -20 to +70°C, to 99% humidity, non-condensing.

Burst Mode Operation

A standard modulator burst mode has not been implemented in the PSM-500 modem yet. This is because of the lack of a standard or available burst demodulators. The circuitry is capable of perfoming this function based on a burst specification. Please contact Datum Systems for specifics of implementing this function and available burst protocols.