

Appendix TPC

M5 Turbo Product Codes FEC Addendum

1.0 Optional Turbo Product Codes FEC Overview

The installation of the optional Turbo Product Codes FEC Card provides the M5 Class modems (PSM-4900/4900H/4900L and variants) with a greater level of functional capability. This optional daughter card is designed to fit onto the main modem assembly and bypass the built-in main Viterbi FEC under software control. Turbo Product Codes offers the maximum coding gain and performance available in Forward Error Correction.

The Turbo Product Codes FEC is described in more detail in the following sections. The abbreviation "TPC" is used interchangeably with "Turbo Product Codes FEC" throughout the rest of this document.

- "**TPC**" This is the short form or abbreviation for Turbo Product Codes. *(Note: There is also a Turbo Convolutional Code FEC which is not block oriented, but generally not currently suitable for satellite communications.)*

For the purposes of the remainder of this appendix the conventions for naming the different rates of data entering and leaving the modem are:

- "**Aggregate**" data rate. The data rate that the modem transmit and receive is operating at. This rate is always the same as or higher than the terrestrial data rate and is the rate that includes the terrestrial rate plus the multiplexer overhead plus the FEC overhead.
- "**Terrestrial**" data rate. The data rate presented on the main modem rear panel data interface connector for connection to the DTE line side.
- "**ES to ES**" or "**ESC**" data rate. The overhead channel rate presented as a service or overhead channel on the modem rear panel connector J4.

Bit time delays introduced by the Turbo Product Codes FEC functions are given in the Unit Specifications, Appendix A.

The Terms "M4" refer to the PSM-512/1500/2100/2100L modems and their variants. The Term "M5" refers to the PSM-4900, 4900H, 4900L and its variants (some yet to be released). The Turbo Product Codes FEC described here is only for use with M5 Modems.

1.1 Overview - Quick Start Guide

The main point to insure in setting up the Turbo Product Codes FEC is that the two ends of the link must be set up in a complementary fashion. That is, whatever parameters are set on the transmit at one end of the link must also be set the same for the receive on the other end.

- If the option card is not already installed see the "Installation" section at the end of this Appendix. The TPC option requires software version 0.62 or greater. Contact Datum Systems if your modem requires a firmware upgrade.
- The Turbo Product Codes FEC (Full or Short Block) can be individually selected in each direction (transmit and receive) via the **<Mod:Data - FEC>** settings for the transmit direction and the **<Dem:Data - FEC>** settings for the receive direction. Then the Code Rate is set in the **<Mod:Data - Code Rate>** settings for the transmit direction and the **<Dem:Data - Code Rate>** The same settings must be used on both ends of the link in each direction.

- Choose a mode of operation suitable for the service desired. In most cases the TPC “Full” mode provides basic full capabilities taking advantage of the special features built into the modem.
- See the Turbo Product Codes FEC Descriptions in Sections 2.1 of this Appendix for more information on refining the settings to optimize them for a particular application.
- The Turbo Product Codes FEC can be used in conjunction with the IBS Multiplexer and RS Option card, but the Reed-Solomon option cannot be enabled with TPC as it could actually decrease performance. The Reed-Solomon is disabled automatically when the TPC is enabled. The IBS Multiplexer options such as AUPC and overhead channels are all still available when used in conjunction with the Turbo Product Codes FEC.

1.1.1 Overview - Modes of Operation

Turbo Product Codes FEC

The TPC option provides the following modes of operation. They are described more fully in later sections of this Appendix.

Mode	Standard/ Compatibility	Overhead Ratio	Notes
Disabled	IESS-308/309		Reverts to Viterbi (or Reed-Solomon) as set.
Full Rate ½	Proprietary	2/1	Performance Optimized
Full Rate ¾	Proprietary	4/3	Performance Optimized
Full Rate 7/8	Proprietary	8/7	Performance Optimized
Short Rate ¾	Proprietary	4/3	Short Block, Delay minimized
Short Rate 7/8	Proprietary	8/7	Short Block, Delay minimized
Legacy ¾ : 7/8	Proprietary	4/3 : 8/7	Full mode, compatible with M5 modems using firmware version lower than 0.76
CT Rate ¾	Comtech	4/3	Full mode, compatible with some Comtech modems operating in QPSK Rate ¾ TPC only.

Note: “Legacy” and “CT” modes only available in firmware versions 0.76 and above.

The overhead ratios for the TPC are identical to those for the standard Viterbi/convolutional Codec, i.e. Rate ½, ¾ and 7/8. **Note: Rate ½ is not available in the short block mode.**

1.2 TPC Framing Overview

Framing of data is required for the Turbo Product Codes FEC functions of this card and FEC type. That is because TPC functions are “block” oriented and synchronization to particular locations in the bit stream are necessary. Generally the TPC processor operates on a complete block of data at a time.

Two block sizes are used in the TPC. The standard block size is intended to optimize the TPC performance. The alternate “Short” block is intended for special applications that require minimal bit delay or latency. The latency of the short block is approximately 1/3 of that for the standard block. The FEC decoder in the receive channel is normally the largest bit delay in the end-to-end link.

2.0 Turbo Product Codes FEC Description and Operation

The addition of a Turbo Product Codes FEC places a new Forward Error Correction (FEC) process replacing (in parallel with) the existing Viterbi FEC. The two FECs are considered alternate, and only one or the other can be selected at any one time.

The performance improvement achieved by the Turbo Product Codes FEC is significant, even as compared to concatenated Reed-Solomon plus Viterbi FEC. For example, the BER vs. Eb/No performance of concatenated Viterbi rate 3/4 coding with R-S is better than Viterbi rate 1/2 alone, and it uses less bandwidth than the Viterbi rate 1/2 alone.

Like Reed-Solomon, Turbo Product Codes uses "block" framing which allows the use of a synchronous scrambler and descrambler resulting in slightly improved performance relative to the self-Synchronized scrambler normally used. See the scrambler use in Section 2.2 of this Appendix

A simplified block diagram of the TPC Codec is shown in Figure 1 below.

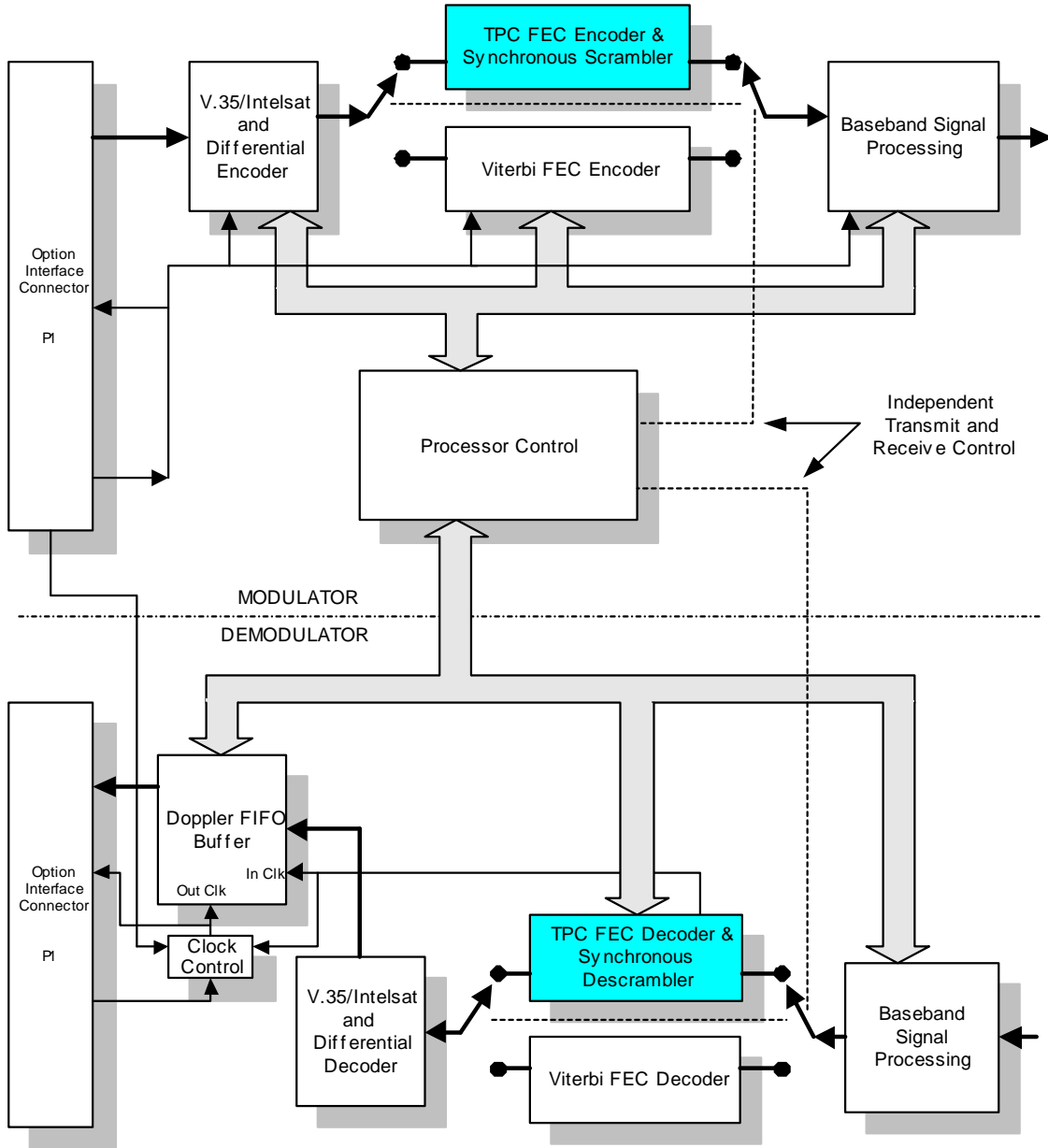


Figure 1 - M5 Modem TPC Diagram

The Turbo Product Codes FEC function can be turned on and off under software control from either the front panel or remote control.

2.1 Controlling the Optional Turbo Product Codes FEC Functions

The PSM-4900 Modems automatically recognize the presence of the optional capabilities when this option card is installed. Any of the Turbo Product Codes FEC properties can be programmed from the front panel or remote control interface. Like other properties of these modems the latest configuration of the TPC are saved in non-volatile memory and re-instated on power up.

The TPC FEC function is designed to replace or serve as an alternate to the modem's built-in Viterbi/convolutional Codec. The TPC option actually allows one of two alternate TPC functions to be used; the standard "Full" and a low latency "Short" version. The user now has the choice between 3 main FEC options in the Mod and Demod Data FEC parameter. These are Viterbi, TPC Full and TPC Short in each direction (Transmit and Receive).

The same FEC Code Rate parameters options of Rate $\frac{1}{2}$, $\frac{3}{4}$ and $\frac{7}{8}$ apply to any of these codecs just as with the standard Viterbi Codec. Rate $\frac{1}{2}$ is not available with the "Short" block version of TPC. The occupied bandwidth of the RF signal is identical between a Viterbi and TPC Codec at the same FEC "Rate".

The performance of the Full Block TPC in rates $\frac{3}{4}$ and $\frac{7}{8}$ were further improved in modem firmware revision 0.76, resulting in the need for a "Legacy" mode which allows modems with this firmware revision or later to communicate properly with TPC modes used in prior firmware equipped modems. The legacy modes should only be used in this case as the best performance is achieved using the latest firmware.

Firmware revision 0.76 also includes a "CT" compatibility mode in TPC Rate $\frac{3}{4}$ when operating with QPSK modulation. This mode provides specific compatibility with some Comtech modems equipped with TPC. Currently these include the CDM550T, which only operates in TPC Rate $\frac{3}{4}$, QPSK, and the CDM600, which includes that specific mode among others (other CDM600 TPC modes are not compatible because of differences in the TPC chip used).

NOTE:

The user does not have to compute aggregate data rates for operation with the TPC options. The terrestrial data rate is maintained when features that require adjusting the aggregate rate are added or deleted. The modem internal software automatically computes the proper aggregate rate and sets the modem accordingly.

NOTE:

The data rate entry at the front panel or remote control is the "Terrestrial" or user data rate that the physical interface operates at, not the modem's aggregate rate.

The TPC function has the same restrictions on maximum data rate as the standard Viterbi Codec does at each FEC Code Rate. Attempts to program the data rate higher than possible at each FEC Code Rate results in the modem sounding a warning beep and setting the data rate to the maximum possible.

2.1.1 Scrambler Selection

The M5 modems have had a preferred scrambler setting in the "IESS 308" or "IESS-309" modes for the modulator and demodulator. These modes automatically select the proper scrambler to use when in any standard Intelsat IESS 308 or 309 modes. There is no IESS Standard covering the new Turbo Product Codes FEC, and this auto mode no longer optimum in certain cases with the TPC installed and enabled. Following is the guideline to use with the TPC:

- When TPC is either not installed or not enabled the preferred scrambler and descrambler is "IESS 308" or "IESS 309". See below for the difference.
- When TPC is enabled but the IBS multiplexer option is not installed or not enabled use the new Scrambler and Descrambler option #7 "TPC Sync". This mode uses a synchronous scrambler specific to the TPC Codec. . **Note with Software Version 0.73+:** *Each time that TPC is enabled the modem automatically sets the TPC Sync scrambler mode. To override, change to the desired scrambler after enabling TPC.*
- When both TPC and IBS multiplexer are installed and enabled use the "IESS 308" option.

Remember that the scrambler and descrambler may be set independently in each link direction.

The synchronous TPC scrambler is synchronized to the processed block itself. No lock time or bit latency penalty is incurred by use of the synchronous scrambler, but a performance gain of approximately 0.2 dB is realized relative to the self-synchronizing "V.35/Intelsat" scrambler.

IESS-308 Scrambler Mode Operation

- With no mux or RS then the self-synchronizing Intelsat scrambler is enabled.
- With just the IBS Mux enabled then the IBS synchronous scrambler is used
- With just the R-S enabled then the R-S synchronous scrambler is used
- With both IBS Mux and R-S enabled then the IBS synchronous scrambler is used.

IESS-309 Scrambler Mode Operation

The operation is the same as the IESS-308 option with the exception that

- With just R-S enabled then the self-synchronizing Intelsat scrambler is used.

Fixed Scrambler Mode Operation

The V.35 and Intelsat scrambler modes use the V.35 and Intelsat self-synchronizing scramblers respectively in all modes.

Alternate Scrambler Mode Operation

The alternate V.35 and alternate Intelsat scrambler mode performs a data inversion required by some "Comstream" modems.

2.2 Turbo Product Codes FEC Performance

Turbo Product Codes performance is the best possible of any currently available FEC. TPC offers a significant performance improvement over even concatenated Reed-Solomon FEC performance.

Turbo Product Codes FEC Highlights:

- TPC Rate 1/2 has performance approximately 3 dB better than normal Viterbi Rate 1/2. TPC Rate 7/8 will perform better than Viterbi Rate 1/2, but uses approximately 57% of the bandwidth.
- TPC Rate 3/4 has performance approximately equal to a concatenated Viterbi Rate 1/2 plus Reed-Solomon Codec, but uses approximately 60% of the bandwidth. In addition the bit delay for the TPC link would be 44 ms at 64 kbps, while the Reed-Solomon/Viterbi coding would result in a 75 ms end-to-end delay. (Some other manufacturers spec over 200 ms of delay in the same case).
- Datum Systems' selectable "Short Block TPC" uses a smaller block size optimized for low latency. The Short Block delay in the above example of Rate 3/4, 64 kbps is approximately 14.8 ms.
- Datum Systems' implementation of TPC outperforms other manufacturers performance by 0.3 to 2 dB depending on the Code Rate settings.

M5 Satellite Modem Turbo Product Codes FEC

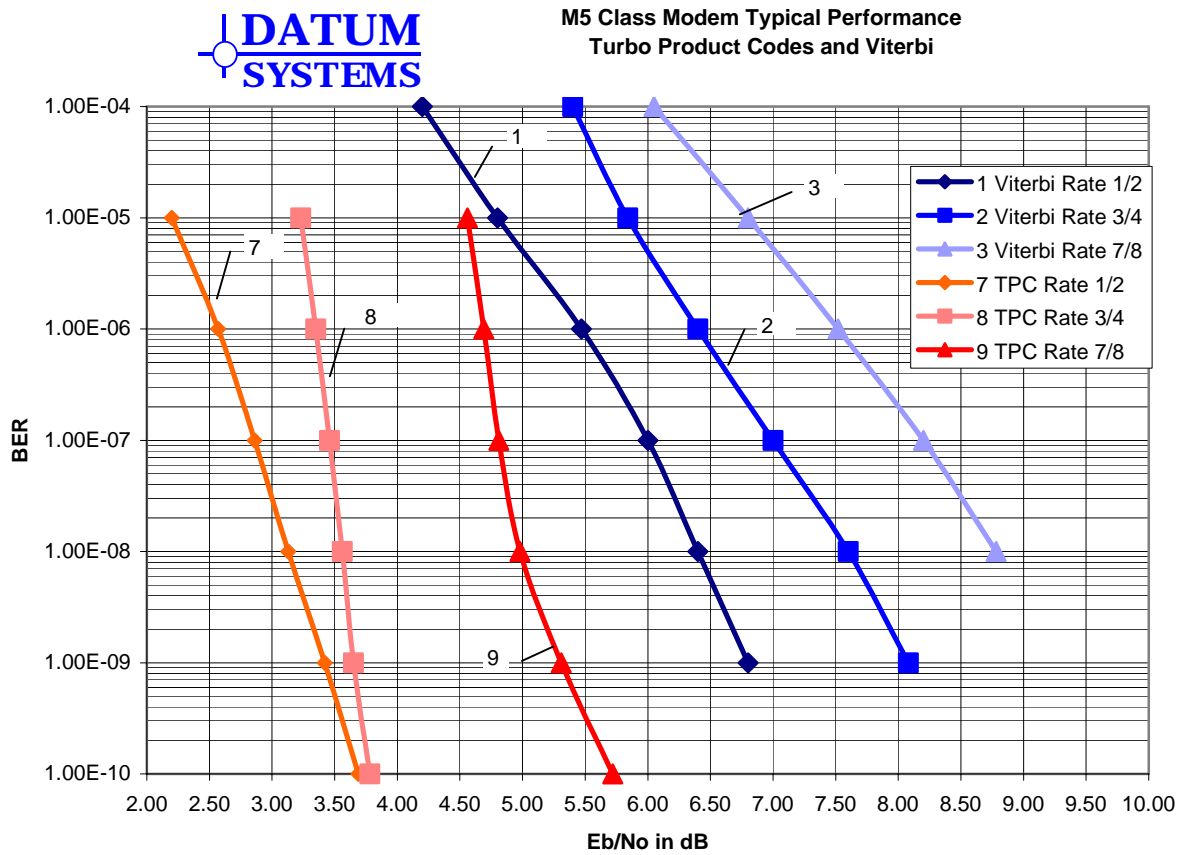
- TPC can provide better performance than 8PSK with Trellis Code Modulation and concatenated Reed-Solomon as per IESS-310. For example TPC in QPSK mode at Rate 7/8 uses less than 5% more bandwidth but 1.2 dB less power at a BER of 1 part in 10⁻⁷. QPSK is also much less sensitive to phase noise and can operate successfully at lower data rates than 8PSK.

The data and graphs below shows the typical performance of a Turbo Product Codes equipped M5 class modem as compared to the typical performance of the standard Viterbi FEC.

Turbo Product Codes BER vs. Eb/No Performance								
BER	1 Viterbi Rate 1/2	2 Viterbi Rate 3/4	3 Viterbi Rate 7/8	7 TPC Rate 1/2 Full Block	8 TPC Rate 3/4 Full Block	9 TPC Rate 7/8 Full Block	10 TPC Rate 3/4 Short Block	11 TPC Rate 7/8 Short Block
1.00E-04	4.20	5.40	6.05					
1.00E-05	4.80	5.84	6.80	2.20	3.23	4.56	3.90	5.20
1.00E-06	5.47	6.40	7.52	2.57	3.35	4.69	4.07	5.58
1.00E-07	6.00	7.00	8.20	2.86	3.46	4.81	4.30	6.00
1.00E-08	6.40	7.60	8.78	3.13	3.56	4.98	4.56	6.47
1.00E-09	6.80	8.08		3.42	3.65	5.31	4.87	6.91
1.00E-10				3.69	3.78	5.72	5.20	7.30

Measurement Notes:

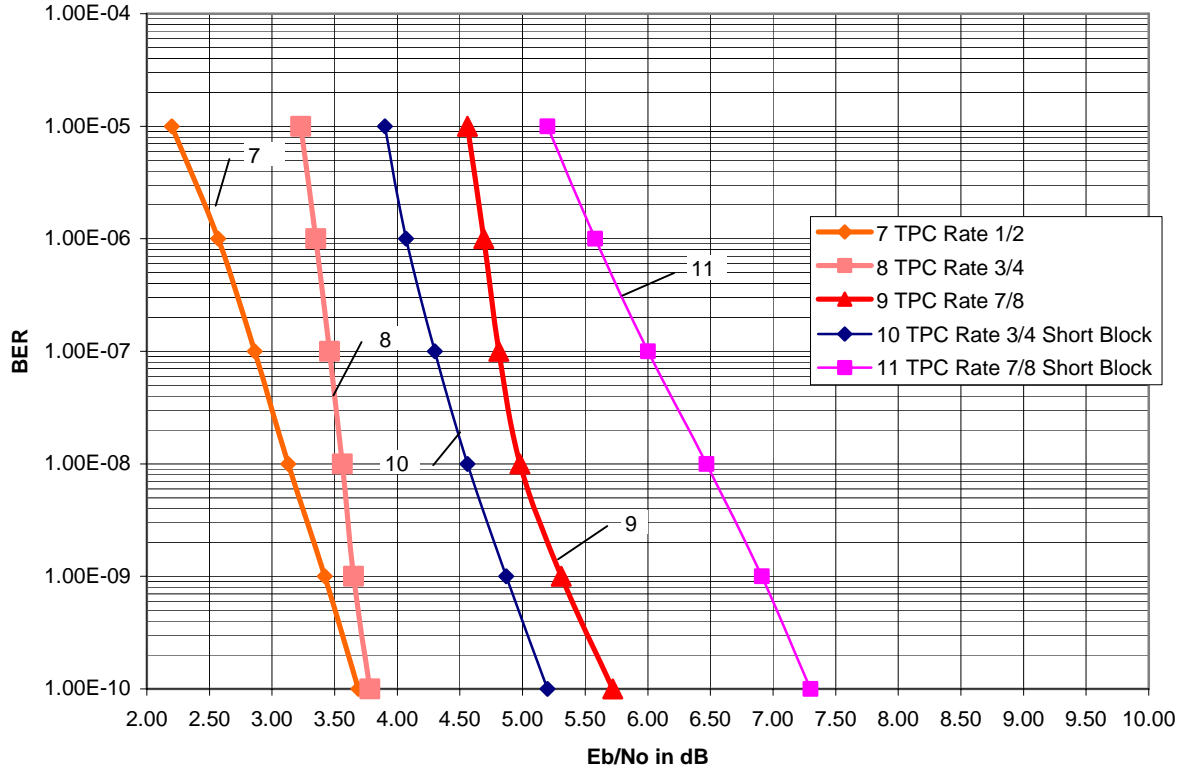
- Viterbi measurements are all made with differential encoding enabled and the standard V.35 scrambler.
- TPC measurements are all made with the Turbo specific synchronous scrambler and no differential encoding.
- The graphs and data are measured in accordance with the IESS 308/309 standard methods.
- The data for TPC Full Block Revised using Firmware Revision 0.74 and above.
- Data for TPC "Legacy" and "CT" modes of Firmware Revision 0.76 are not shown.



The graph below shows the performance of the standard “Full Block” TPC FEC and the low latency “Short Block” TPC FEC. The short block modes trade off performance for low delay achieved by using a smaller block size.



M5 Class Modem Typical Performance
Standard and Short Block Turbo Product Codes



3.0 Installation

The Turbo Product Codes FEC Option is normally factory installed, but can be field installed by technical personnel. The option card itself is an approximate 2.1-inch by 3.9 inch printed circuit board, which plugs onto available header pins on the main modem assembly. Installation requires removal of the modem unit cover, plugging the option card onto the main modem assembly and then replacing the modem unit cover.

When installed the PSM-4900 main processor automatically recognizes the presence of the card and its capabilities. It also adds appropriate front panel and remote control settings to allow programming the added functionality provided. This is transparent to the user, who needs take no action other than installation and setting for desired parameters.

Note that versions of main modem software prior to 0.62 do not support the Turbo Product Codes FEC card. New software must be downloaded into the modem's flash memory to update it to the latest standard.

3.1 Installing a Turbo Product Codes FEC Option Card

Remove the modem unit from service before installation of the TPC option. Unplug the modem unit and remove the power cord from the rear for safety.

WARNING: Failure to remove power from the modem unit before removal of the cover can expose the operator to hazardous voltages and result in harm to personnel and equipment.

Place the unit on a flat surface and remove the 8 flathead screws holding the cover to the main chassis using a number 2 Philips screwdriver. The location for the option card installation is shown in the diagram below.

Position the connectors on the bottom of the option card over those on the main board and gently push the pins on the main PWB into the two sockets on the option card. This will require firm pressure directly over the connector pins. Do not press on the top and bottom of the option card as it is unsupported here and may damage the board. When fully seated the top of the option PCB surface is approximately even with the top edge of the connector plastic shroud to the right of the option card.

Use extreme care in insuring that the pins are properly aligned between the option card and the main board header.

Re-install the cover and plug the unit in. Using the front panel arrow keys scroll down to the interface parameter and verify that the modem recognizes the newly installed card. The modem is now ready to be put into service.

