DATUM SYSTEMS

Appendix RS

M5 Framing/Multiplexer/Reed-Solomon Codec Addendum

Revision History

Rev 1.0	3-12-2001	Initial Release.
Rev 1.1	9-2-2001	Added change relative to use with Turbo Product Codes.

1.0 Optional Framing/Multiplexer/Reed-Solomon Codec Overview

The installation of the optional Reed-Solomon/Multiplexer Card provides the M5 Class modems (PSM-4900 and variants) with a greater level of functional capability. This optional daughter card is designed to fit onto the main modem assembly and use the J4 “Aux”, (Auxiliary) connector for Input and Output at the rear panel

The option card is provided in one of two possible configurations:

1. Framing and IBS Multiplexer, which provides for both an overhead ESC (Engineering Service Channel) and an available modem-to-modem control channel for AUPC and remote control functions (MCC).
2. Reed-Solomon concatenated codec plus the framing and IBS Multiplexer.

The Framing, Multiplexer and Reed-Solomon codec are each described in more detail in the following sections.

A common clock generator circuit is used to support both the Multiplexer and Reed-Solomon codec. Because of this it is not possible to purchase a Reed-Solomon option by itself. However, either capability may be enabled or disabled independently.

For the purposes of the remainder of this document 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 Reed-Solomon 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 Multiplexer and Reed-Solomon 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 and its variants (some yet to be released). The Reed-Solomon and IBS Multiplexer described here is only for use with M5 Modems.

1.1 Overview - Quick Start Guide

The most important point to insure in setting up the Multiplexer and Reed-Solomon is that the two ends of the link must be set up in a complementary fashion. That is whatever parameters on set on the transmit at one end of the link must also be set the same for the receive on the other end. This is not strictly true for the ESC port rates in all cases, but it is true for most other parameters.

- If not already installed see the “Installation” section at the end of this Appendix.

- The IBS Multiplexer and Reed-Solomon Codec can be individually enabled or disabled in each direction (transmit and receive) via the **<Mod:Mux - Mode>** and **<Mod:RS FEC - Mode>** settings for the transmit direction and the **<Dem:Mux - Mode>** and **<Dem:RS FEC - Mode>** settings for the receive direction. 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 Multiplexer "Enhanced" mode and the RS "IESS"-308" mode provides basic full capabilities taking advantage of the special features built into the modem.
- See the Multiplexer and Reed-Solomon Descriptions in Sections 2.03 and 2.1 of this Appendix for more information on refining the settings to optimize them for a particular application.

1.1.1 Overview - Modes of Operation

IBS Multiplexer

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

Mode	Standard/ Compatibility	Overhead Ratio	Notes
Disabled	N/A	1/1	
Standard	IESS-309	16/15	Fixed synchronous ESC, No AUPC, No MCC
Enhanced	Modified IESS-309	16/15	M4 compatible ESC and AUPC (limited MCC).
Custom	Modified IESS-309	Variable	Full ESC and MCC including AUPC, Remote Modem Control, 2 one=bit control channels. Also variable data load per frame.

Reed-Solomon FEC

The Reed-Solomon FEC provides the following modes of operation. They are described more fully in later sections of this Appendix.

Mode	Standard/ Compatibility	Overhead Ratio	Notes
Disabled	N/A	1/1	
IESS-308	IESS-308	9/8, 45/41, 73/67	M4 compatible up to 1.544 Mbps
IESS-309	IESS-309	73/67	
Custom	Modified IESS-309	Variable	Allows setting the "n", "k" and "depth" values for special requirements. Can also be set for M4 compatibility to max M4 data rate.

1.2 Framing Overview

Framing of data is required both for the Reed-Solomon and Multiplexing functions of this card. That is because both functions are "block" oriented and synchronization to particular locations in the bit stream are necessary. In a standard modem all the bits are considered the same. But for a multiplexer the function must know that certain bits belong to the main terrestrial through data and others belong to the overhead channel and still others are for control purposes. The frame synchronizes the data by placing special detectable flags in the data stream that can be recovered at the receive end to separate or "un-frame" the data.

In contrast to previous Datum Systems' M4 Multiplexer and Reed-Solomon functions, this new M5 unit provides for variable and programmable modes of operation. The multiplexer variability is accomplished by modifying the number of data load bytes within the frame. Thus in "Custom" mode the input to output ratios varying from approximately 1/2 to 255/256 (standard IBS multiplexers use a fixed rate of 15/16). These ratios represent the ratio between the main channel terrestrial data rate and the aggregate rate (exclusive of the Reed-Solomon). Thus a 15/16 ratio means that 15 out of 16 transmitted bits are actual data bits. The 16th bit contains the framing and all the other information multiplexed onto the data stream. Looking at the standard IESS frame structure below you will note that it is actually arranged into bytes, where there are 4 bytes of framing/multiplexer information and 60 bytes of data. The M5 Custom framing allows the number of data bytes per frame byte to vary from 4 to 1020.

2.0 Framing/Multiplexer Description and Operation

The framing convention used in the M5 Multiplexer and Reed-Solomon adheres to the Intelsat IESS-309 standard. Three possible modes of operation are provided for that include various uses for the available framing bits:

1. "Standard" – Provides usage in accordance with the IESS Standard.
2. "Enhanced" – Provides added capabilities proprietary to the M4 and M5 class modems.
3. "Custom" – Provides added capabilities proprietary to the M5 class modem plus variable terrestrial to framing ratios. This mode is not compatible with M4 class modems.

The framing/multiplexer is capable of multiplexing a (usually) low speed overhead channel and pieces of control information onto the terrestrial data stream resulting in a slightly higher combined or "aggregate" data rate through the modem.

There are two specific channels that the PSM-4900 IBS Multiplexer can add to the terrestrial data stream. The data for the channels is contained within the framing bytes themselves.

- The "ESC" channel available in all modes.
- The control or "MCC" channel available in the proprietary "Enhanced" and "Custom" modes.

The multiplexed channels are recovered and separated from the terrestrial data at the far end of the link.

The ESC channel is termed variously an overhead channel, Engineering Service Channel (ESC), "asynch" channel or in Intelsat IESS terminology an "ES to ES data channel" (for Earth Station to Earth Station). This document and the modem front panel refer to this channel as the "ESC". A simplified block diagram of the data multiplexer is shown in Figure RS-1 below. Normal operation of the multiplexer may be either uni or bi directional and most parameters of the multiplexer may be set independently in each direction. The ESC channel appears at the rear connector J4 on the modem.

In addition to the ESC various other information is transferred between the two ends of the link. This information consists of status represented by fixed bits within the frame structure. The "Frame" is the method used to synchronize information at each end, allowing recovery of the separate channels that are multiplexed or "mixed" together for transmission. The standard Intelsat IESS frame structure is shown below in figure RS-2 below.

The MCC or Modem Control Channel is proprietary to Datum Systems' Modems, and provides added valuable facilities. For the M5 class modems the MCC can provide:

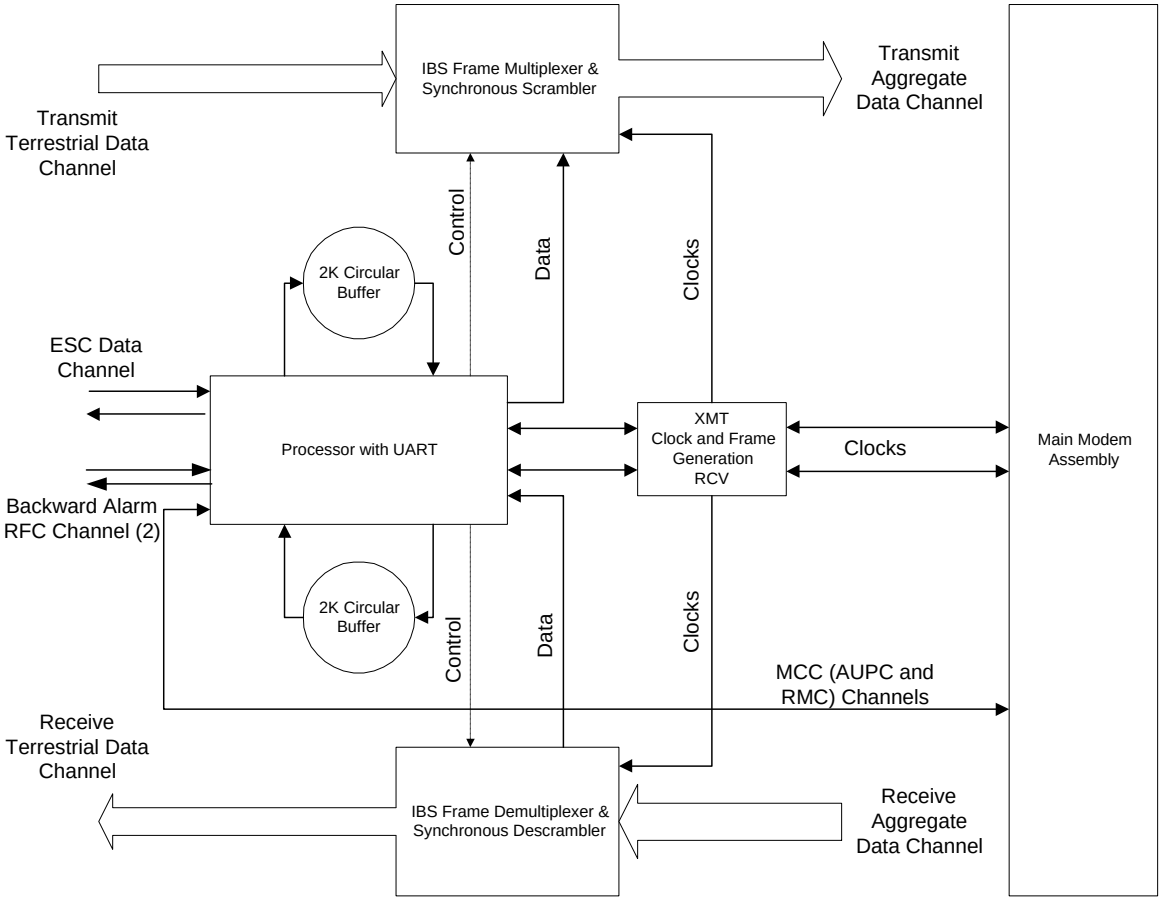
- AUPC – Automatic Uplink Power Control in Enhanced and Custom modes.
- RMC – Remote Modem Control in Enhanced and Custom modes. (Not compatible with M4 Modems)
- RFC – Remote Facility Control in Custom mode only.

The MCC facilities are generated using specific normally unused bits in the framing structure. It provides an independent channel by which the two modems themselves may communicate, providing the capability for Automatic Uplink Power Control (AUPC) and Remote Modem Control (RMC) without the necessity of a separate multiplexer. This document and the modem front panel refer to this channel as the “MCC”, standing for Modem Control Channel.

The PSM-4900 multiplexer MCC also provides two “single line” backward alarm channels, termed a Remote Facility Control or “RFC”. These two independent RFC channels can accept a voltage or contact closure type input on one end and provide a form “C” relay contact presence on the far end. These can be used for alarms and simple commands. One example might be to light an indicator at a hub site when the door is opened at a remote site. The reverse direction of this bit might be used to lock the door electronically. One other possible use for such data transfer would be to provide a “backward” alarm from an unattended site giving the status of the transmit and receive outdoor converter and amplifier equipment.

The AUPC and RMC information is used internally by the modem and does not appear on the rear panel at J4. The RFC “backward alarm” channels do appear on J4. For the pin connections refer to the “Installation” Section 3 of this Appendix.

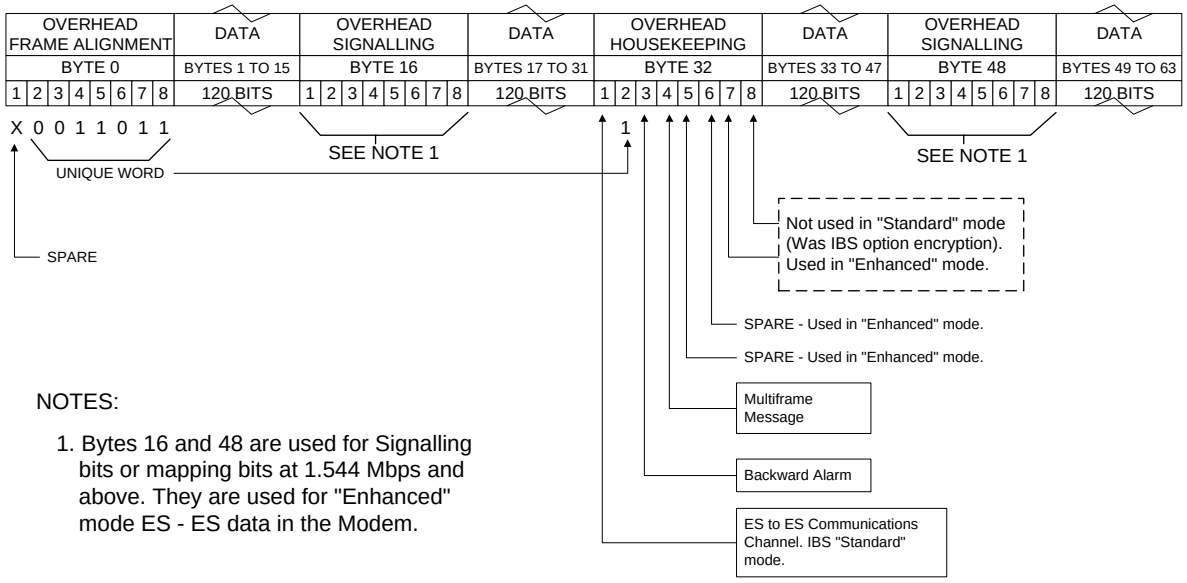
Note: The ESC is available in all modes when the IBS Multiplexer is enabled. The MCC is available only in the Enhanced and Custom Multiplexer modes described below.



IBS Multiplexer Simplified Block Diagram

One advantage of the framing of serial terrestrial data is that a “synchronous” scrambler can be employed. This type of scrambler overcomes the slight loss of performance due to the standard V.35 type self-synchronized scrambler normally used.

The basic frame structure used by the multiplexer is that specified in the IESS-309 standard, Page 60, Figure 10, resulting in a 16/15 aggregate to through data ratio. Most of the IESS Framing Structure diagram is shown here in Figure RS-2 below.



IBS FRAME STRUCTURE

Overhead signaling bytes 16 and 48 are not implemented as signaling or mapping bits. Three software controlled modes are designed into the card to best utilize the available bits; “Standard IBS”, “Enhanced” and “Custom”. The characteristics of the channel interface are also determined by the standard or enhanced mode.

2.0.1 Standard IBS Multiplexer Mode

In the first or "Standard" mode, all bit assignments are per the IBS standard. The bits of Overhead Housekeeping byte 32 are implemented as shown below:

Bit 1 - *ES to ES Data Channel* Channel. Its the	This bit is routed directly to the ES to ES (ESC) Data data rate is 1/512th of the aggregate rate (or 1/480th of through terrestrial data rate), and is normally used to super-sample an asynchronous data channel.
Bit 2 -	Part of the Frame Alignment word.
Bit 3 - *Backward Alarm*	Transmit and Receive with main processor to activate main alarm/LED
Bit 4 - *Multiframe Message*	As per IBS
Bits 5 and 6 - *Spare*	Not currently Utilized
Bits 7 and 8 - *Encryption Utilization*	Not currently Utilized

The ratio of the through terrestrial data channel rate to the aggregate rate is 15/16.

The standard transmit and receive channels of the ESC data channel in standard IBS mode are raw channels operating at the specific bit rate as controlled by the data channel rate, without buffering. Synchronous clocks are provided with the ESC channel in the standard mode when set to RS-232 I/O. The transmit and receive ESC clocks are both outputs from the modem as the timing is specifically set by the IESS standard as a fixed ratio to the terrestrial data rate. These clocks are not provided when operating in the RS-485 mode.

2.0.2 Enhanced Multiplexer Mode

The “Enhanced” Multiplexer mode provides alternate proprietary usage for the basic framing structure allowing enhanced useful capabilities not provided in the standard mode. Note that all of the capabilities of the Enhanced Multiplexer mode are also available in the “Custom” mode described below. One main purpose of the Enhanced mode is to provided backward compatibility with the M4 class (PSM-2100) modems, specifically the operation of the AUPC function.

Since many of the frame bits in the standard IBS mode are not used, an "Enhanced" multiplexer mode has been implemented that can be engaged under software control. Since this mode changes the use of many of the framed non-data bits, this mode is only usable when the PSM-4900 or 2100 is at both ends of a link and each is set to the same modes. In this mode, the overhead signaling bytes 16 and 48 can be used to implement a significantly higher speed ESC Data Channel under software control. When implemented, this rate is 16 times that of the normal IBS standard, or 1/30th of the terrestrial data rate (1/32nd of the aggregate rate). In addition, spare bit 1 of Byte 1 and bits 1, 5, 6, 7 and 8 of Byte 32 are typically used to implement a secondary ES-ES modem channel dedicated to communications between the two modems-on a link for Status and Automatic Uplink Power Control (AUPC) applications. This secondary channel is called a Modem Control Channel or MCC.

One of the main advantages to the Enhanced (or Custom) mode of multiplexer operation is to provide buffering of the ESC, which then allows using standard asynchronous format and rate operation.

> ***NOTE: The Enhanced or Custom IBS mode MUST be selected for true Asynchronous channel operation to be available.***

The main processor and the option card logic performs software/hardware assignment of bits to specific purposes in the enhanced mode and buffers the ESC Data Channel to standard asynchronous data rates. The secondary or MCC modem control channel should normally be at 300 bps minimum in order to maintain a sufficient loop response time when using Automatic Uplink Power Control. Therefore, if the aggregate rate results in an MCC modem channel rate less than 300 bps minimum (approximately 25 Kbps aggregate) then the Overhead Signaling bytes are commandeered for this purpose. The primary ESC channel then uses the six spare and unused bits, which is still six times the rate of standard IBS. Note that this occurs in the enhanced mode whether the AUPC is enabled or not.

The processor-controlled ESC channel contains both transmit and receive data buffers which are 2048 bytes in length. These act as long FIFOs on the data in each direction. No data is lost if the actual ESC data channel and the buffered user data rates are different unless the sustained user data rate causes the buffer to overflow. Buffer overflow results in purging the entire buffer contents. Gaps between characters or messages do not use the buffer and thus can be used to prevent overflow. If the user data rate is less than the data channel rate, then there are simply gaps between characters, which is normal in asynchronous communications. The transmit and receive data rates at either end do not have to be the same, so one end of the link could, for example, have 19.2 kbps transmit and receive while the other end may have 1.2 kbps transmit and receive rates. Note that this could easily result in overflow if the sustained rate exceeded 1.2 kbps.

The MCC channel also contains buffers, 1024 bytes in this case, that allow the processor to write AUPC and Remote Modem Control messages which flow at the normal MCC overhead rate. If

the buffers are full the processor receives a message to that effect and can resend the message later.

2.0.3 Custom Multiplexer Mode

This is the most flexible mode available in the multiplexer. In both the Standard and Enhanced modes the ratio of framing bytes to data bytes are fixed at 1 framing byte per 15 data bytes, and a frame length of 64 bytes total. Note that there are 4 framing bytes per complete frame. In the Custom mode the framing bytes remain as previously described, but the number of data bytes in a frame is variable from 4 to 1020. Thus the ratio of data to framing bytes variable from 1 to 255 yielding mux ratios of 1:2 to 255:256. Like the "Enhanced" multiplexer mode the “Custom” mode uses the unused frame bits in the standard IBS mode. It also provides all of the features of the “Enhanced” mode, plus the variable data “load”. In addition the Custom mode provides for two single line control or backward alarm type channels, complete with logic inputs and relay outputs. These are termed Remote Facility Control (RFC) channels.

> ***NOTE: The Custom IBS Multiplexer mode is NOT compatible with M4 class modems.***

The Custom Multiplexer Mode provides the capability of very low overhead penalty at one extreme of setting to the capability for an overhead channel that is close to the rate of the through data channel at the other extreme of its settings.

> ***NOTE: The Custom or Enhanced IBS mode MUST be selected for true Asynchronous ESC channel operation to be available.***

> ***NOTE: Both ends of a link (in each direction) MUST be set to the same mode, that is the transmit on one end of the link and receive at the other end. The two directions may be set to different modes.***

The processor on the main board performs software/hardware assignment of bits to specific purposes in the Custom mode. The ESC Data Channel is buffered to standard asynchronous data rates.

The user does not have to compute data framing variables to use the Custom Multiplexer Mode. When placed in this mode the entry parameters are the ESC and MCC channel “overhead” rates selected from standard asynchronous data rates (300 to 38,400 bps). The modem then computes the proper relationship between the framing and terrestrial data rates to achieve the proper operation. The modem also displays the terrestrial data to aggregate ratio.

The Custom ESC and MCC Overhead rates determine the frame resources that are allotted to the ESC and MCC channels. The overhead rate selected is different from the ESC port rate, which determines the rate that the rear panel ESC port actually operates at. The difference between the two in Custom mode must be absorbed by the ESC transmit and receive buffers, just as in the Enhanced mode.

The ESC channel and the MCC channel can be individually disabled by setting the **<Mod:Mux – ESC Overhead>** or **<Mod:Mux - MCC Overhead>** to “Disable”. The companion Demodulator settings must be used on the other end of the link.

2.0.3.1 Custom Multiplexer Mode Setup Guide and Example

In the Custom mode it can be difficult to determine how to properly set the ESC/MCC overhead rates and port rates to efficiently use the satellite link. Several guidelines are set out here as a sequence to arrive at good initial settings, using a hypothetical case as an example.

1. Determine that an ESC and MCC are required.
   We assume here that it is.
2. Determine the desired ESC port rate.
   Example – two computers that will talk at 9600 baud
3. Determine the approximate duty cycle of the ESC.
   Example – our computers only communicate approximately 25% of the time.
4. Compute approximate required ESC and MCC Overhead rates.
   The ESC overhead rate would be 9600 times 25% = 2400 bps. AUPC and very occasional remote modem control are required; therefore the MCC is set at the minimum needed by the AUPC, 300 bps.

When the above settings are combined with several terrestrial data rates the resulting ratios of terrestrial data to aggregate rates are shown in the table below:

ESC Configuration Example with Percentages of Overhead Used						
ESC Port Rate in bps.	Approx. Activity %	ESC Overhead Rate in bps	Terrestrial Data Rate (kbps)	Mux Ratio Including 300 bps MCC	Overhead percentage of Terr. Rate	Aggregate Rate
9600	25%	2400	9.6 kbps	2:3	50%	14.4 kbps
9600	25%	2400	32	7:8	14.3%	36.57143
9600	25%	2400	64	14:15	7%	68.57143
9600	25%	2400	128	29:30	3.5%	132.4138
9600	25%	2400	256	58:59	1.7%	260.4138
9600	25%	2400	1000	229:230	.4%	1004.367

As a first estimate formula for the total overhead percentage of the terrestrial data rate this could be expressed as:

Overhead % = ((ESC Port Rate X ESC Activity Factor) + (MCC Overhead Rate) +2000) / Terrestrial Rate

The Aggregate data rate is then approximately 1 + Overhead percentage times the terrestrial data rate. The aggregate rate is exactly the terrestrial data rate times 1/Mux ratio (as read from modem front panel). In the example above, at 128 kbps the aggregate rate would be 128 X (30/29) or 132.4138 kbps.

In practice the maximum rate of ESC plus MCC cannot be greater than approximately 68% of the through terrestrial data rate.

The ESC activity factor is obviously just a guess in most cases, but often the usage can be very low, as in the case of occasional command information. Since the buffers on the ESC channel are relatively large (2 kbytes at both the transmit and receive ends), the ESC Overhead rate can be set very low to minimize the aggregate data rate. The transmit and receive ESC buffers are circular, thus If the buffer(s) overflow the oldest ESC data is overwritten.

2.0.4 ESC Channel Port Characteristics

The ESC (ES to ES) Data Channel can be set under software-control to operate in either RS-232 mode, or RS-485 4 Wire mode, RS-485 Drvr On or 485 2 Wire mode. The pin assignments for both modes are shown in the Installation section of this Appendix. The RS-485 Transmit Data Drivers can be set to “RS-485 4 Wire” or “RS-485 Driver ON” when in “Enhanced” or “Custom” mode. The “ON” setting forces the driver continuously on while the “RS-485 4 Wire” setting controls the output into tri-state when the modem is not transmitting data, allowing multiple modem outputs to be connected together typical of a multi-drop control system. In the standard IBS mode only the “RS-485 ON” mode is available.

In Enhanced or Custom mode the RS-485 2 Wire receive operating mode can be selected for the receive data into the ESC channel. In this mode the receive input is muted while the transmit data output is active. In 4 wire mode the receive is always enabled. In the standard IBS mode only the 4-wire mode is available. Note that the transmit and receive pairs are physically separate wires and must be connected together if true RS-485 2 wire connectivity is desired.

Note that the RS-232 connection in standard IBS mode is synchronous. This is due to the IBS frame structure resulting in unbuffered data at a fixed rate relative to the terrestrial data rate. The Enhanced and Custom modes offer full transmit and receive buffering allowing true asynchronous operation at standard data rates. These modes also offer full control signals.

The Mux - ESC port rate, port (RS-232/RS-485 and 2 wire/4 wire) and format controls appear in both the Mod and Demod pages and are coupled. A change in one side results in the same change in the other. The driver/receiver selected is a physical device and must be the same in both ESC transmit and receive.

2.0.4.1 ESC Flow Control Operation

When using the RS-232 ESC I/O mode it is possible to activate (or ignore) the standard asynchronous control signals under front panel or remote control. These control signals are normally used for flow control of the ESC, and include RTS/CTS, DSR/DTR.

The RTS/CTS are normally used on the sending end to prevent buffer overflow. When the buffer on sending end of the ESC reaches ¾ full (1536 bytes) then the CTS control line is dropped. It is raised again when the buffer is reduced to ¼ or less (512 bytes).

DSR/DTR are normally used on the receiving end to notify the end equipment of traffic status. If the user drops the DTR the receive data output will stop and the buffer will start filling. The DTR can be used for flow control but the buffer is the responsibility of the user. The DSR control line operation is similar to that of a DCD. That is when data is incoming the DSR goes active meaning that data is present and being transmitted.

Control options allow forcing the Modulator ESC CTS active, while Normal permits flow control. The Demodulator ESC DSR can be forced active or set to Normal, which follows the DTR line and shows the presence of data. The Normal DSR setting will also drop on loss of lock or Multiplexer hardware alarm. With the DTR set to Nrormal it is used for receive flow control, while ignore will ignore the DTR line, eliminating flow control.

2.0.5 Modem Control Channel (MCC)

The MCC is available in both the Enhanced and Custom Multiplexer modes. In the Enhanced mode the MCC provides for an AUPC and Remote Modem Control channel. In the Custom mode the MCC provides for the AUPC plus the Remote Modem Control (RMC) Channel and the Auxiliary Remote Facility Control lines or RFC (sometimes called backward alarms).

2.0.5.1 AUPC Control Channel (part of MCC)

When the modem is placed into either the “Enhanced” or “Custom” modes the AUPC control channel becomes available. The AUPC operation itself is under control of the modem while the AUPC facility in the MCC provides the channel for the information. This channel provides a minimum 300 baud control channel in each direction to allow the modems at two ends of a link to interactively maintain the receive Eb/No by controlling the power output at the transmit site.

Refer also to the AUPC operation description of the main manual in section 3.8 titled “*Automatic Uplink Power Control (AUPC)” Operation.*

2.0.5.2 Remote Modem Control Channel (RMC)

When the modem is placed in the “Enhanced” or “Custom” mode the Remote Modem Control channel becomes available. This channel allows the control of a far end modem from the near end site. This control is not however allowed from the near end front panel, but only via the remote control interface port. The command protocol for remote unit control is explained in Appendix B*, “Remote Control Protocol”.*

Note: Remote Modem Control is only available between two M5 class modems.

Note that the Automatic Configuration Recovery or ACR is partially designed as a safety feature to be used with the remote programming of modems. It can help prevent “losing” the modem at an unattended site. Refer to the ACR section of the main manual in 3.14 “*Automatic Configuration Recovery”.*

2.05.3 Remote Facility Control Channels (RFC)

When the Multiplexer is placed into the “Custom” mode the auxiliary control RFC channels becomes available. These consist of two single line or “one-bit” control channels that can be used to send control information independently in both directions over the link. The input signals on these channels can be either a contact closure or a logic type signals while the output is a form C relay contract set whose state depends on the state of the input signal. The low input logic level is 0 to 0.8 VDC, while the logic high level can be from 2.0 to approximately 5 VDC. This includes normal “TTL” logic levels. The input is current limited to accept temporary inputs up to approximately 20 VDC without damage. Higher voltages may damage the inputs however and caution should be exercised.

The RFC input has an approximate 1 mA pull-up and can therefore also accept a contact closure as the input signal.

When modem power is removed or the demodulator is unlocked the output relay state will be in the Normally Open state. When locked a logic 1 input will result in a Normal Open state. A logic 0 or contact closure on the input will result in the output relay being driven to the Normally Closed state.

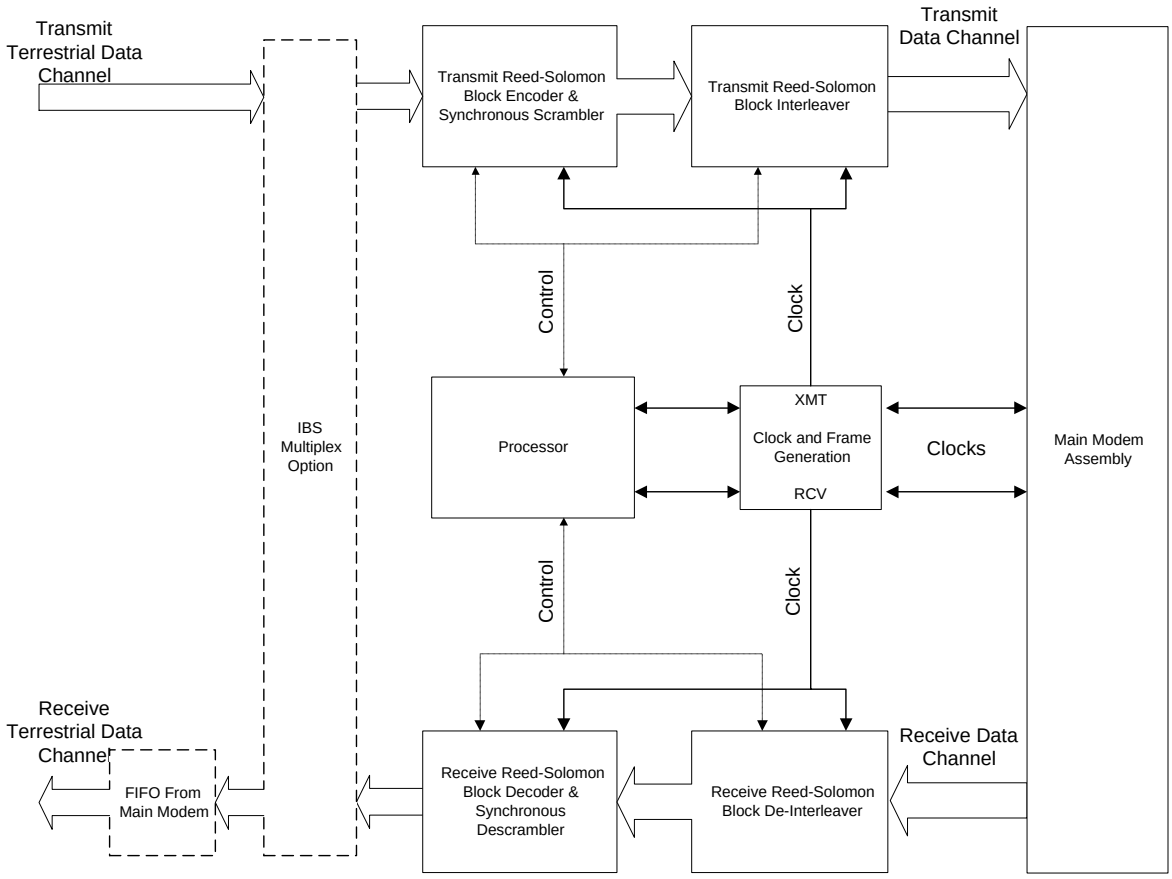
2.1 Reed-Solomon Codec Description and Operation

The addition of a Reed-Solomon codec places a second Forward Error Correction (FEC) process outside of and in series with the existing Viterbi FEC. The two FECs are considered "Concatenated". In addition, the data between the Reed-Solomon and Viterbi encoder is "interleaved". When the same bit stream is de-interleaved at the receive end any bursts of consecutive errors are spread out which effectively reduces the possibility of multiple consecutive errored block symbols, thus improving the Reed-Solomon Codec performance.

The performance improvement achieved by the serial combination of Reed-Solomon and Viterbi coding is significant. 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 the multiplexer, the Reed-Solomon uses framing which allows the use of a synchronous scrambler 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 Reed-Solomon Codec is shown in Figure RS-3 below.



Reed-Solomon Codec Simplified Block Diagram

The Reed-Solomon Codec function can be turned on and off under software control, and is independent of the IBS Multiplexer.

Previous M4 R-S codecs used a single standard block format of 126,112,4 per IESS 308. In that scheme the ratio of encoded to un-encoded transmission is 9/8. This M5 type R-S Codec is capable of operating in multiple standard and custom modes as shown in Table RS-2 below.

Mode	Compatibility	Terrestrial Data Rate	Overhead Ratio	n, k and depth Values
Disabled	N/A		1/1	
IESS-308	IESS-308	1.2 kbps to <1.544 Mbps	9/8	126, 112, 4 (M4 modem compatible up to 1.544 Mbps)
	IESS-308	1.544 Mbps to <2.048 Mbps	45/41	225, 205, 4
	IESS-308	>2.048 Mbps	73/67	219, 201, 4
IESS-309	IESS-309	All	73/67	219, 201, 4
Custom	Modified IESS-308/309	All	Variable 255/253 to 2/1	Allows setting the “n”, “k” and “depth” values for special requirements. Can also be set for M4 compatibility to max M4 data rate.

2.1.1 Reed-Solomon "n", "k" and "depth" Rules

There are specific limitations or "rules" placed on values in the "Custom" mode of operation. Specifically:

1. The values of "n" must be between 22 to 255 and "k" must be between 20 to 253.
2. The value of k must always be 2 to 20 less than n.
3. The value of the "depth" parameter is either 4 or 8 independent of n and k.

For full IESS-308 compatibility the modem's scrambler and descrambler should also be set to "IESS- 308" mode. (**<Mod:Data – Scrambler>** and **<Dem:Data – Descrambler>**)

For full IESS-309 compatibility the modem's scrambler and descrambler should also be set to "IESS- 309" mode. (**<Mod:Data – Scrambler>** and **<Dem:Data – Descrambler>**)

2.1.2 Reed-Solomon "n", "k" and "depth" Custom Values

The PSM-4900 Custom Reed-Solomon codec values result in improved compatibility with other modems and allow tradeoffs of power vs. bandwidth to optimize link performance. In addition to the two standard IESS modes the table below shows some possible settings for the "n", "k" and "depth" factors for specific requirements. Generally the values chosen affect three areas; overhead factor, performance and delay. The overhead factor is **n/k**.

n	k	depth	Standard	Overhead Factor	Delay (bits)
126	112	4	IESS 308	9/8, 12.5%	5632
219	201	4	IESS 309	219/201, 8.95%	9384
254	250	4	None	127/125, 1.6%	10672
120	100	4	None	6/5, 20%	5440
126	112	8	None	9/8, 12.5%	9664

Another factor often used with Reed-Solomon codecs is "t". "t" is the number of bytes that can be corrected within a block of size "n". The value of "t" is equal to **(n-k)/2.**

One reason for changing to a non-standard set of R-S values would be to minimize the delay normally encountered with Reed-Solomon concatenated coding. Changing the interleave factor "depth" from 4 to 8 will almost double the delay. Intelsat recommendations are to use an interleaver depth of 4 for terrestrial data rates less than 1.544 Mbps and a depth of 8 for data rates of 1.544 Mbps and above.

2.1.3 Reed-Solomon Eb/No Options with Reed-Solomon Enabled

There are two possible methods of computing the Eb/No when using Reed-Solomon: Both are listed in different sections of the IESS standards, so the facility to use either method is provided for use with the PSM-4900 R-S. The selection is strictly at the preference of the user, and does not change the performance, only the method used to compute Eb/No. These methods are to determine the Eb/No based on the modem's data rate either at the Reed-Solomon decoder input or the decoder output. The data rate selected by these options are thus either the customer data rate (decoder output) or satellite channel rate (decoder input). Since the total energy in the carrier is the same and the decoder input has a higher data rate then the Eb/No would be lower referenced to this point than referenced to the decoder output. Depending on the specific Reed-Solomon mode selected the difference in reading can be approximately 0.5 dB.

To select the decoder input or output as the reference data rate the **<Dem:RS FEC – Eb/No>** parameter is used. Note that there is no complementary Modulator function.

> *Note that when AUPC is used the demodulator Eb/No used will be the Eb/No as set using this option.*

2.2 Controlling the Optional Multiplexer and R-S Functions

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

Optional parameters for operation of the multiplexer and R-S are added to the front panel display as required. For example if both multiplexer and R-S are disabled then the only parameter available is the one to enable these functions, as well as the Unit Status read only parameter that indicates that the modem is so equipped. When the multiplexer is enabled new options become available in the front panel matrix allowing setting of the “Standard”, “Enhanced” or “Custom” multiplexer operating modes, and the optional ESC channel format. Parameter settings for the Multiplexer and Reed-Solomon functions appear in the “RS FEC” and “Mux” columns when either the “Mod” or “Dem” front panel buttons are pressed.

> *NOTE:*
> *The user does not have to compute aggregate rates for operation with either of these 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.*

There is an exception to automatic setting; that is when the aggregate rate would exceed the maximum data rate capacity of the modem. For example, if a PSM-4900 is operating at 4.8 Mbps and the multiplexer is enabled in either standard or Enhanced mode then the aggregate rate required would be 4.8 Mbps times 16/15 or 5.12 Mbps. Since this exceeds the maximum aggregate rate of 4.92 Mbps then the modem will sound 4 quick beeps and set the modem to the maximum possible terrestrial rate of 4.92 times 15/16 or 4.6125 Mbps.

2.2.1 Scrambler Selection

Four main scrambler options are provided in the M5 modem plus some alternatives for special cases. In normal operation we recommend the “IESS-308” option, which adjusts automatically for the types of features enabled in the Reed-Solomon as shown below.

The synchronous scrambler is synchronized by a special “multi-frame” bit that occurs every 64 frames, or approximately every 32 k bits. If the synchronous scrambler is turned off the IBS decoder can usually lock in 2 frames. If the synchronous scrambler is enabled then frame lock will take 64 times as long. At low data rates and in the custom mode this can take significantly longer to lock the modem.

IESS-308 Scrambler Mode Operation

- With no mux or RS then self-synchronizing Intelsat scrambler is enabled.
- With just IBS mux then the IBS synchronous scrambler is used
- With just R-S 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 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 Using the Optional Multiplexer and R-S Functions with the Turbo Product Codes Option

The PSM-4900 Modems automatically recognize the presence of the optional capabilities when any option cards are installed. If both the TPC option and the IBS Multiplexer/Reed-Solomon option are installed only one of the FECs may be enabled simultaneously. There is no restriction on the use of the IBS Multiplexer with either FEC.

3.0 Installation

The IBS Multiplexer Option or the Reed-Solomon and IBS Multiplexer Option is normally factory installed, but can be field installed by technical personnel. The option card itself is an approximate 3.5-inch by 3.8 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. Unlike the RS/IBS option on the PSM-2100 modems the PSM-4900 option card is completely independent of the interface circuitry.

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 some early versions of main modem software do not support the Reed-Solomon/IBS Multiplexer card. New software must be downloaded into the modem’s flash memory to update it to the latest standard.*

3.1 Installing a Multiplexer/Reed-Solomon Option Card

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

Place the unit on a flat surface and remove the 8 flathead screws holding the cover to the main chassis. 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 three sockets on the option card. This will require firm pressure directly over the connector pins. Do not press on the lower right 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.

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.

3.2 Adding Reed-Solomon to a Multiplexer Option Card

RS/IBS cards originally configured as Multiplex only can be converted to add Reed-Solomon codec capability by adding the proper ICs to the interface card. These parts are fairly specialized and can be obtained as a “kit” from Datum Systems. The following figure shows the Integrated Circuits concerned, U3 and U5.

Unplug the modem unit and remove the power cord from the rear. Then remove the cover and locate the option card.

Carefully install the ICs into their respective sockets, insuring that they are correctly oriented and fully seated. Double check your work, then reinstall 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 parts by showing “IBS & RS Interface”. The modem is now ready to be put into service.

3.3 Connector J4 Pin Assignments with IBS Multiplexer Installed

The IBS Multiplexer function requires connections for the ESC overhead communications channel and the available RFC one-bit transfer/alarm input and output. These are brought out on the “AUX” DB37 male connector, J4, on the modem’s rear panel as shown below. Note that when the multiplexer is used in the “Standard” IBS mode no buffering is provided and therefore the only way to synchronize the data is via the provided clocks. The proprietary “Enhanced” and “Custom” modes provide buffering to standard asynchronous data rates and therefore do not require clocks.

RS-232 Standard Mode Connection (synchronous)
- RS-232 Transmit on pin 4 (input to modem, sampled on rising clock edge)
- RS-232 Receive Clock on pin 13 (output from modem)
- RS-232 Receive on pin 6 (output from modem, changes on falling clock edge)
- RS-232 Transmit Clock on pin 7 (output from modem)

RS-232 Enhanced/Custom Mode Connection:
- RS-232 Transmit on pin 4 (input to modem)
- RS-232 Receive on pin 6 (output from modem)
- RS-232 CTS on pin 7 (output from modem)
- RS-232 RTS on pin 9 (input to modem)
- RS-232 DSR on pin 11 (output from modem)
- RS-232 DTR on pin 12 (input to modem)
- RS-232 DCD on pin 13 (output from modem)

RS-485 Connection:
- RS-485 Transmit A on pin 11 (output from modem)
- RS-485 Transmit B on pin 6. (output from modem)
- RS-485 Receive A on pin 12 (input to modem)
- RS-485 Receive B on pin 4. (input to modem)

User Remote Facility Control channel A
- Pin 33 - RFC channel A Input (TTL, Internal 1mA Pull-Up)
- Pin 34 - RFC channel A Form-C Common
- Pin 35 - RFC channel A Form-C N.C.
- Pin 16 - RFC channel A Form-C N.O.

User Remote Facility Control channel B

Pin 15 - RFC channel B Input (TTL, Internal 1mA Pull-Up)
Pin 17 - RFC channel B Form-C Common
Pin 18 - RFC channel B Form-C N.C.
Pin 36 - RFC channel B Form-C N.O.

Grounds

Pins 14, 19, 20, 32, 37

Caution: The RFC relay outputs are designed for low voltage control signals and are not intended for AC or power line switching.