Appendix A

Datum Systems PSM-2100/512 Satellite Modem

Technical Specification

PSM-2100 and PSM-512 VSAT / SCPC - Modem Specification

Revision History

Rev 1.0   6-15-97   Preliminary Release.

Rev 1.1   10-10-97   Initial Release.

Rev 1.2   5-5-99   Added "synchronous" to RS-232 name, changed FEC G1 code to 133, added more detail on clock options, added bit delay information.

Rev 1.3   6-10-99   Add revised specifications for PSM-512.

Introduction

This section defines the technical performance parameters and requirements for a low-cost flexible, state-of-the-art VSAT/SCPC Satellite Modem. The PSM-2100 and PSM-512 Modems are designed to meet two application criteria. The first is a remote station VSAT modem which is typically part of a TDMA system. In this mode, incoming RF information is continuously QPSK or BPSK modulated data and the RF output is in "Burst" mode BPSK or QPSK. The second mode of operation, selectable in the field, is as a Single Channel Per Carrier (SCPC) modem where both outgoing and incoming RF data is continuous BPSK or QPSK modulated. The SCPC mode is usable as a stand-alone modem for communications with a companion unit at the other end of a link.

The basic modem design includes separate synthesized transmit and receive interfaces at 70 MHz, flexible clocking options and on-board Viterbi Forward Error Correction (FEC). The standard data interface can be either RS-449, V.35 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.

Data rates are field selectable from 3.6 kbps BPSK or 7.2 kbps QPSK to a maximum dependent upon modulation and FEC coding. Maximum FEC rate 1/2 data rates are 525 kbps BPSK, or 1050 kbps QPSK. Maximum FEC rate 3/4 or 7/8 data rates are 1050 kbps BPSK, or 2.100 Mbps QPSK. The PSM-512 is limited to 525 kbps in any mode. This is the only difference from the PSM-2100.

The modem includes an internal microprocessor for controlling the modulator transmit synthesizer, data rate and modulation, demodulator receive synthesizer, operating and diagnostic measurements 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 devices to reduce the complexity and cost to a minimum while providing full flexibility. The modulation and demodulation is accomplished directly at 70 MHz without heterodyning, eliminating most adjustments and alignment.

Modulator Specifications

IF Output

Output Frequency Range: .... 50.000 to 90.000 MHz.
Tuning Method: .... Via internal synthesizer.
Output Level Control: .... Programmable in 0.1 dB steps over 20 dB from
.... -5 to -25 dBm, @ Front Panel and via the serial
.... control port.
Output Level Stability: .... $\pm$ 0.5 dB over 0 - 50°C
.... $\pm$ 0.25 dB over any 10°C range.
Output Impedance: .... 75 Ohm.
Output Return Loss: .... 20 dB minimum.
Output Burst Control: .... Burst transmission controlled by the incoming SDLC
.... data flags when VSAT mode selected.
Output Burst Off Isolation .... >60 dB
Modulation Technique: .... BPSK or QPSK Selectable @ Front Panel and via serial
.... control port.
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: .... < -50 dBc from 2 to 200 MHz.

Transmit Baseband Processing

Data Rate: .... Selectable via front panel or serial control port for:
     FEC Rate 1/2 .... Any data rate from 3.6 kbps to 525 kbps BPSK.
.... Any data rate from 7.2 kbps to 1050 kbps QPSK.
     FEC Rate 3/4 or 7/8 .... Any data rate from 7.2 kbps to 1050 kbps BPSK.
.... Any data rate from 14.4 kbps to 2100 kbps
.... QPSK.
PSM-512 Any FEC Rate and Mode .... Upper limit of 525kbps, same lower limits.
     Settability .... Any rate settable within 5 ppm, rate 1/2, or 10
.... ppm, rate 3/4 or 7/8, exclusive of internal
.... frequency reference (nominally 2.5 ppm).

Forward Error Correction: .... Convolutional encoder, k= 7.
.... Rate 1/2. G0 code = 171 octal,
.... G1 code = 133 octal.
.... Rate 3/4 or 7/8 using punctured code
     NOTE: *Burst Transmit Mode Supports Rate 1/2 only.*
Differential Encoding: .... Selectable On or Off @ Front Panel and
.... via serial control port.
Scrambler: .... Intelsat, V.35 selectable with enable @ Front Panel
.... and via serial control port. IBS and Reed-Solomon are
.... available when these options are installed.

Transmit Synthesizer

Tuning Step Size: .... 1 Hz steps.
Frequency Stability: .... ± 2.5 ppm. (220 Hz @ 88 MHz) internal
.... reference,
.... OR locked to external reference's stability.
         Note: .... The internal frequency reference is a 10 MHz,
.... 2.5 ppm stability oscillator over -10 to +50°C.
.... Higher stability of 1 ppm available as option.
Synthesizer Control: .... @ Front Panel and Via serial control port.
Transition Time: .... < 200 msec. to any frequency including
.... command latency.
Long Term Stability: .... 1 ppm per year maximum including aging over
.... 5 years when using internal reference.
.... NOTE: Higher stability upgrades are optional

Demodulator Specifications

IF Input

Input Frequency Range: .... 50.000 to 90.000 MHz.
Tuning Method: .... Via internal synthesizer.
Input Carrier Level: .... -20 to -60 dBm at any data rate (40 dB AGC
.... range).
Acquisition/Tracking Range: .... Selected @ Front Panel and via serial control
.... port at any value between ± 200 Hz and ± 1.25
.... MHz in 100 Hz increments.
Smart reacquisition: .... The demodulator will search for return of a lost
.... carrier within a specified range for a selected
.... time before reverting to full acquisition range.
.... Operation of this feature is selected via the
.... serial port.
         Reacquisition range: .... ± 200 Hz and ± 1.25 MHz in 100 Hz
.... increments
         Reacquisition sweep time: .... 10 to 65,535 seconds in 1 second increments.
         Carrier Lock time to qualify for
              smart reacquisition: .... 5 to 65,535 seconds in 1 second increments.
Input Impedance: .... 75 Ohm.
Input Return Loss: .... 20 dB.
Modulation Technique: .... Selectable BPSK or QPSK @ Front Panel and
.... via serial control.
Type of demodulation: .... Continuous Coherent.

Receive Baseband Processing

Data Rate: .... Variable under program control
         FEC Rate 1/2 .... Any data rate from 3.6 kbps to 525 kbps
         BPSK.
.... Any data rate from 7.2 kbps to 1050 kbps
.... QPSK.
         FEC Rate 3/4 or 7/8 .... Any data rate from 7.2 kbps to 1050 kbps
.... BPSK.
.... Any data rate from 14.4 kbps to 2100 kbps
.... QPSK.

PSM-512 Any FEC Rate and Mode .... Upper limit of 525kbps, same lower limits.

Settability .... Any rate settable in 1 bit per second increments

Baseband Filter:* .... n=6 Butterworth filter response, electronically
.... variable.
Forward Error Correction: .... Viterbi convolutional decoder, k=7,
.... Rate 1/2. G0 code = 171 octal,
.... G1 code = 133 octal.
.... Rate 3/4 or 7/8 using punctured code
.... Rate 1/2 Coding Gain of 5.2 dB @ BER of 10^{-5}
.... Rate 1/2 Coding Gain of 5.6 dB @ BER of 10^{-7}
BER vs. Eb/No Performance: .... 0.2 dB typical over theoretical.
.... 0.4 dB maximum.
Differential Decoding: .... Selectable On or Off @ Front Panel and via serial
.... control port.
Descrambler: .... Intelsat, V.35 selectable with enable @ Front Panel
.... and via serial control port. IBS and Reed-Solomon are
.... available when these options are installed.
Receive Data Buffering .... 4 bits to 131,070 bits, programmable in 1 bit increments
.... or in time increments. The buffer is a 262,140 bit (maximum)
.... self centering FIFO. Over or under-flow result in re-centering.

Receive Synthesizer

Tuning Step Size: .... 1 Hz steps.
Frequency Stability: .... +/- 2.5 ppm. (220 Hz @ 88 MHz). Locked to
.... the internal reference,
.... OR locked to external reference's stability.
Synthesizer Control: .... @ Front Panel and via the Serial Control port.

Bit Error Rate Performance

The following 3 tables show typical and guaranteed performance as measured against theoretical performance for a modem including the effect of using differential encoding and a V.35 scrambler. The FEC coding gain at high Eb/No is not well specified by manufacturers and the given values at a BER of 10^{-7} are extrapolated from available curves by Qualcomm, Inc.

FEC Rate 1/2 Performance Data			
BER	Uncoded Eb/No	Rate 1/2 Coding Gain	Typical Eb/No with differential encoding and scrambler
10^{-4}	8.4 dB	4.7 dB	4.3 dB
10^{-5}	9.6 dB	5.2 dB	4.9 dB
10^{-6}	10.5 dB	5.5 dB	5.5 dB
10^{-7}	11.4 dB	5.6 dB	6.0 dB

FEC Rate 3/4 Performance Data			
BER	Uncoded Eb/No	Rate 3/4 Coding Gain	Typical Eb/No with differential encoding and scrambler
10^{-5}	9.6 dB	4.1 dB	5.6 dB
10^{-6}	10.5 dB	4.2 dB	6.4 dB
10^{-7}	11.4 dB	4.2 dB	7.0 dB

FEC Rate 7/8 Performance Data			
BER	**Uncoded Eb/No**	**Rate 7/8 Coding Gain**	**Typical Eb/No with differential encoding and scrambler**
10^{-5}	9.6 dB	2.9 dB	6.7 dB
10^{-6}	10.5 dB	3.1 dB	7.5 dB
10^{-7}	11.4 dB	3.2 dB	8.2 dB

Acquisition Performance

The following table shows typical acquisition performance for the Fast Acquisition mode using the DSP processor. The times shown are for 95% acquisition probability at a 6.0 dB Eb/No.

Fast Acquisition Times				
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)**
9.6	QPSK	1/2	1.13	1.3
9.6	BPSK	1/2	.56	.67
16	QPSK	1/2	.61	.71
16	BPSK	1/2	.32	.40
32	QPSK	1/2	<.4	<.5
32	BPSK	1/2	<.3	<.4
64	QPSK	1/2	<.4	<.5
64	BPSK	1/2	<.3	<.4

Fast acquistion performance is optimized in 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.

Data Interface Specifications

Data Input

Type: .... RS-449/422 or V.35 or RS-232 with separate
.... Clock and Data signals.
.... G.703, ADPCM and others optional via
.... interchangeable interface assembly.
.... Flexible clock options allow the transmit timing
.... to be supplied by:
.... a. An internally generated ± 2.5 ppm reference
....   clock or external reference, if supplied.
.... b. The demodulator RCV clock as output from
....   the modem.
.... c. A Terminal Timing input as supplied to the
.... modem TT interface pins.

Termination: .... 120 Ohm. Terminal Timing and FIFO output
.... clock.

Data Output

Type: .... RS-449/422 or V.35 or synchronous RS-232
....   with separate Clock and Data signals.
.... G.703, ADPCM and others optional via
....   interchangeable interface assembly.
.... Additional clock options allow the demodulator
.... RCV clock to be supplied by:
....   1. The actual received bit rate.
....   2. The user selected transmit clock source.
....   3. A user supplied FIFO output clock source.

Modem Bit Delays

Modulator Transmit Delays

Modulation Processing .... 8 channel rate bits
FEC Encoder
    Rate ½ .... 11 channel rate bits
    Rate ¾ or 7/8 .... 11 to 19 channel rate bits
    Rate 7/8 .... 11 channel rate bits
Scrambler Enabled .... 1 channel rate bits
Reed-Solomon Encoder .... 910 user rate bits + 300 us delay
IBS Multiplexer .... 8 user rate bits
R-S/IBS Option Installed .... 5 user rate bits

Demodulator Receive Delays

Demodulation Processing .... 1 channel rate bits
FEC Encoder
    Rate ½ .... 183 channel rate bits
    Rate ¾ or 7/8 .... 183 to 191 channel rate bits

        Rate 7/8 .... 11 channel rate bits
        Descrambler Enabled........................ 1 channel rate bit
        FIFO Buffer (enabled)....................... 1 user rate bit plus bit setting
        Reed-Solomon Encoder .... 3598 user/IBS rate bits + 300 us delay
        IBS Multiplexer................................. 0 user rate bits
        R-S/IBS Option Installed................... 4 user rate bits

Bit Rate definition:
   "User" bit rate = "Terrestrial" interface rate
   "Channel" bit rate = User bit rate X (1/FEC rate) X 16/15 (if mux enabled) X 9/8 (if R-S enabled)

   Example: A modem with R-S and IBS mux is running at a user rate of 128 kbps. The
       Channel bit rate is then = 128 kbps X 2 X 9/8 X 16/15 = 307.2 kbps.
       The time/channel bit is 3.3 uS. The time/user bit is 7.8 uS.
       The modulator delay is 20 channel rate bits x 3.3 uS plus 923 user rate bits x 7.8 uS
           plus 300 uS, for a total delay of 7,565.4 uS or 7.565 mS.

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. The onboard processor controls all operations required for demodulator carrier acquisition and re-acquisition, Eb/No measurement, transmit and receive frequency synthesizer control and alarm reporting.

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

Eye Patterns .... Analog test points on Demodulator.
AGC Level .... Analog test point on Demodulator.
        .... Also available @ Front Panel and via the Serial
        .... control port.
Carrier Lock .... Digital test point
Demodulator Lock: .... PCB edge LED indicator and also available
        .... @ Front Panel and via Serial Control port.
Recovered Symbol Clock: .... Test point on Demodulator.
Transmit Bit Rate Synthesizer Fault: .... Internal LED indicator and available
        .... @ Front Panel and via Serial Control port.
Transmit RF Synthesizer Fault: .... Internal LED indicator and available
        .... @ Front Panel and via Serial Control port.
Receive RF Synthesizer Fault: .... Internal LED indicator and available
        .... @ Front Panel and via Serial Control port.
Eb/No: .... @ Front Panel and Via Serial Control channel.
Operating LED indicators .... 12 Front Panel LED indicators:
        Unit
                Power .... Green - Lit when power applied
                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.
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

Receive Frequency Select: .... @ Front Panel and Via the Serial Control port.
Transmit Frequency Select: .... @ Front Panel and Via Serial Control port.
Modem Reset Control: .... Via Serial Control port. Causes reset
.... of both modulator and demodulator to
.... power up state.
Burst Envelope Signal: (Burst Mode) .... Derived from data flags SDLC. RTS signal held
.... inactive deactivates.
Mute Control:.. @ Front Panel and Via serial control port
.... .Overrides all other controls to disable transmit
.... output.
Continuous Wave Control: .... @ Front Panel and Via serial control port. When
.... this command is activated the modem transmits
.... an unmodulated signal only at the selected
.... carrier frequency.
Miscellaneous:.. Other selectable options as indicated @
.... Front Panel and via the serial control port.

General Unit Specifications

Mechanical

IF connection type:.. 75 Ohm BNC female connectors, 1 XMT, 1 RCV
.... Located on Rear Panel
Reference Input:.. 50 Ohm BNC female located on Rear Panel.
Data and Digital I/O connector : .... RS-449 37 pin female 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.. Redundancy information on an RJ-11
.... for RS-232 interface located on Rear Panel.

Power Connector:..IEC 3-pin male with switch located on rear
....panel.
Main Board Size: ....Approximately 10.5 x 15 X 1.5 inches.
Interface Board Size:.......................................Approximately 4 x 8 X 1.5 inches.
Packaged Modem Size: ....1 Rack Mounting Spaces by 17 inches.
....Approximately 19.0 x 17 X 1.75 inches.

Electrical Power Requirements

Prime Power:...90 to 260 Vac, 47-63 Hz, 50 Watts maximum
Internal Voltages: ....+5 Volts DC $\pm$ 5% at 1 Amp max.
....+12 Volts DC $\pm$ 5% at 1.5 Amps max.
....-12 Volts DC $\pm$ 5% at 0.5 Amp max.

Environmental

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

Monitor/Control Processor

An on-board processor provides the functions of monitor and control of the modem. During power-up the processor tests itself and the modem alarm and operating information, and sets default software controlled configuration parameters from EEPROM storage. The power-up diagnostics aid a technician in fault isolation of the processor and its peripherals. An extensive operating parameter terminal display and on board LEDs aid a technician in modem unit diagnostics.

During station setup the Receive Eb/No may be used to indicate relative signal strength/quality for antenna alignment. During normal operation the processor measures the present Receive Signal Eb/No. The processor is also be used to set the operating frequency for the transmit and receive synthesizers. All configurable parameters and an ID number for the unit can be held in non-volatile storage and reported upon request.

Processor Serial 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.

Front Panel Control Interface

The built in front panel permits complete monitor and control of all functions and parameters of the modem without any external control required. The front panel consists of 12 status LEDs, a two line LCD alphanumeric display and a 16-key keypad for user entry.

Burst Mode Operation

The modulator burst mode is controlled by the RS-422 interface RTS/CTS and data flag signals. The sequence of events for the burst mode is as follows:
1. The RTS from the DTE is normally active. The idle character from the DTE is continuous SDLC flag characters.
2. The modulator responds to the DTE when ready to transmit by activating the CTS signal.
3. Any time after the CTS is received by the DTE, the DTE starts transmitting flags and/or data. The first non-SDLC flag character received by the modulator is the start of transmission signal, causing the modem to generate a preamble and initiate the carrier ON command.
4. The next SDLC flag received by the modulator is the end of transmission signal. The modem maintains a 56 bit buffer which allows placement of the closing flag exactly 56 bits prior to the final data bit. This protocol is specific to the CP-101 hub station burst demodulator.
5. When the closing flag is detected by the modulator it drops the CTS indicating that a new data message cannot be started. When the last data bit is sent the modulator will reassert the CTS signal, and turn the carrier OFF.

Data Interface Clock Options

The modem incorporates flexible clocking options for either VSAT or SCPC operation as explained below:

VSAT Mode

The master station reference is used to synchronize the master station transmit data clock. The VSAT terminal receive data clock maintains this synchronization. The DTE equipment may use the receive data clock to synchronize itself and generate the transmit data clock for input to the VSAT modulator. Alternately it may use an accurate clock to generate the transmit data clock.

SCPC Mode

A. Independent - Each station of two linked SCPC modems is considered independent. The transmit data clock is either an input to or output from each station modulator. The far end station receive data clock maintains this synchronization. The clocking in each direction is independent and follows the same transmit to receive synchronization.

B. Master/Slave - One station of two linked SCPC modems is considered the master and the other station is considered the slave. The master transmit data clock is either an input to or output from the master station modulator. The slave station receive data clock maintains this synchronization. The receive data clock is used to generate a contra-directional transmit data clock (from modulator to DTE) of the same frequency, but not necessarily phase, as the receive data clock.