SATCOM MODEM

USER'S GUIDE

www.signion.com

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Important notes

Signion Systems (Signion) provides the SATCOM MODEM under the following conditions:

1. This unit, intended for *engineering development*, should not be considered a finished product as it may not be complete in terms of required design, marketing, and/or manufacturing related protective considerations, including product safety measures typically found in the end product. As a prototype, this product does not fall within the scope of the European Union directive on electromagnetic compatibility and therefore may not meet technical requirements of the directive.
2. Should your SATCOM MODEM not meet the specifications indicated in this User's Guide, it may be returned within 30 days from the date of delivery, in its original packing, for a full refund. *This is the exclusive warranty made by the seller to the buyer and is in lieu of all other warranties, expressed, implied or statutory*.
3. The user assumes all responsibility and liability for proper and safe handling of the unit. Further, the user indemnifies Signion from all claims arising from the handling or use of the goods. Please be aware that the unit received may not be regulatory compliant or agency certified (FCC, UL, CE, etc). Precautions with regard to electrostatic discharge, EMI/EMC compliance and electrical safety are the user's responsibility.
4. Except to the extent of the indemnity set forth above, neither party shall be liable to the other for any indirect, special, incidental or consequential damages.
5. Because Signion currently deals with a variety of customers, our arrangement with the user is not exclusive. Signion assumes no liability for applications assistance, customer product design or infringement of patents.
6. Prior to handling the SATCOM MODEM, please read the User's Guide in full, giving special attention to the *Warnings and Restrictions*. For further safety concerns please contact our application engineer at support@signion.com.
7. Persons handling this product must have electronics training and observe good laboratory practice standards.
8. No license is granted under any patent right or other intellectual property right of Signion covering or relating to any machine, process, or combination in which such Signion products or service might be used.

Warnings and restrictions

- Operate this modem within the specified input and output ranges described in the User's Guide.

- Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the modem. If you have any questions regarding the input range, contact support@signion.com prior to connecting the power.

- Applying loads outside the specified output range may result in unintended operation and/or possible permanent damage to the modem. Please refer to the User's Guide prior to connecting any load to the modem output(s). If there is uncertainty regarding the load specification, please contact support@signion.com.

- During normal operation, some circuit components may have case temperature greater than 60°C. Because the modem is designed to operate properly above 60°C, this should not be a problem as long as the input and output ranges are maintained. These components include but are not limited to voltage regulators, modulator IC, DSP, and CPLD. These devices can be identified using the diagram shown in the User's Guide.

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About this document

This manual describes Signion's high speed DSP based SATCOM MODEM, providing details of the following:

- Hardware interface
- Test setup and configuration
- Performance in the presence of AWGN
- System specifications
- Troubleshooting

Introduction

The SATCOM MODEM provides flexible data rates at 70 MHz IF, while supporting a variety of modulation (BPSK/ QPSK/ 8-PSK/ 16-QAM) and coding (Viterbi/ trellis and R-S) options, http://www.signion.com/satradio.pdf. The 16-QAM demodulator's advanced non-decision directed phase acquisition and TCM decoder's constellation adaptation, over a wide amplifier back-off range, allows continuous mode operation, with negligible degradation, for many amplifier types (TWTA, GaAsFET, SSPA, etc.).

It offers state of the art performance and reliability with the best features of a programmable modem, all at the industry's lowest price. Sophisticated digital signal processing eliminates all on board physical adjustments and provides superior performance.

The SATCOM MODEM has an advanced receive acquisition and tracking system. It offers fast acquisition over a wide range of frequency offsets.

Quick start

This section guides you to quick start the process of using the SATCOM MODEM evaluation boards.

What you need to use our modem

- +5V DC linear regulated power supply
- BER (Bit Error Rate) tester (DTE)
- AWGN adder
- Spectrum analyzer

Continuous mode loop-back test setup

- Configure the BER Tester (DTE) to RS449 interface and external clock mode.
- Connect clock and data signals to DTE as per the interface details in Table 1.

Description	37 pin D-type connector pin no.
Modulator CLK+	5
Modulator CLK-	23
Modulator Data+	4
Modulator Data-	22
Demod CLK+	8
Demod CLK-	26
Demod Data+	6
Demod Data-	24
GND	1,19

Table 1. Continuous mode DCE-DTE interface details

- Set the DIP-switch settings (refer Table 4) to choose the data rate, modulation type, FEC, R-S, scrambler and acquisition mode, as required.
- Connect modulator output to demodulator input with the help of a SMA-SMA male RF cable.
- Connect the SATCOM MODEM to the DTE (a cable connecting two 37-pin D-type connectors with one-to-one connections for the pins described in Table 1 is supplied for interfacing SATCOM MODEM to DTE in continuous mode).
- Connect a +5V DC **linear** regulated power supply to turn on the modem.

DTE should sync up and show '0' (zero) BER.

Note: Both modulator and demodulator bit clock timings are internal.

Testing and performance evaluation

Adjudicate modem performance by testing it with AWGN (Additive White Gaussian Noise).

Testing in presence of AWGN

The bit energy (E_b) to noise energy per unit bandwidth (N_0), in any communication channel is given by the relation,

$[E_b/N_0]$ = [(Signal energy/Bit Rate)/ (Noise power/Bandwidth)]

Gaussian distributed random noise, based on desired E_b/N_0, is added to the modulated signal before it is fed to the demodulator for processing. The actual data bits transmitted are compared with the demodulated data to find the probability of bit error (P_e) using the relation,

P_e = [Number of bits in error/ Total number of bits transmitted]

Modem test procedure

1. Continuous mode

- The set up for *continuous* mode modem testing is shown in Figure 1.
- Select DIP-switch options as required (refer Table 4).
- Set the BER tester for random data sequence.
- Feed the modulator signal to the AWGN adder and the composite signal to the demodulator.
- Connect the modem to +5V DC **linear** regulated power supply to start the test.
- As per the selected configuration (i.e. scrambler, data rate, modulation type, Viterbi, R-S), add different levels of noise and record BER.

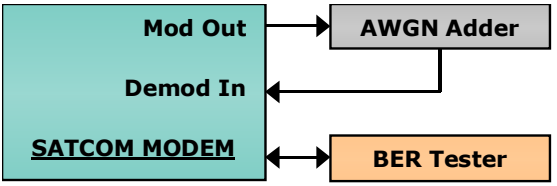


Figure 1. Continuous mode performance test setup

- As Viterbi decoder/ concatenated FEC output errors tend to be bursty, record BER after a minimum of ten error events.

- The observed BER at different E_b/N_0 levels can be tabulated as shown below:

S.No.	E_b/N_0 (dB)	BER
1.	12	8e-9
2.	10	4e-6
3.	8	1.8e-4
4.	6	2.5e-3

Table 2. Theoretical BER performance for uncoded QPSK

2. Burst mode

SATCOM MODEM supports uncoded, convolutional and TCM encoded (K=7, rate ½ FEC) data in *burst* mode, with the following format and timing details:

Burst format:

Burst frame for BPSK/ QPSK/ 8-PSK/ 16-QAM modulations is distributed as follows:

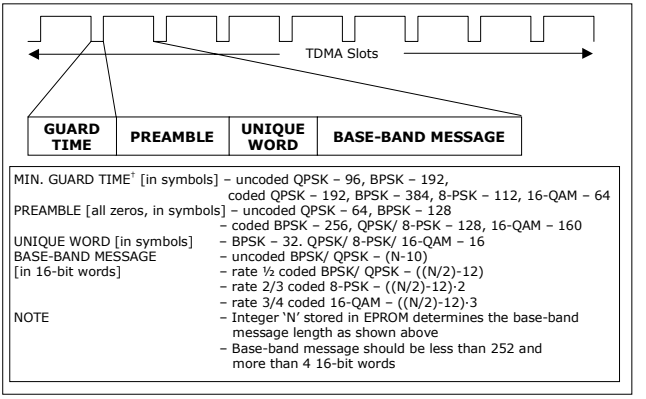


Figure 2. Burst frame structure

†Each mode's guard bits lower limit, determined by demodulator and decoder buffers and delays, applies when the same demodulator receives sequential air-interface bursts. Guard bits may be reduced if your TDMA protocol does not sequentially exercise the same demodulator.

Configuring the SATCOM MODEM's burst length:

Burst length 'N' is specified at address 0x0200 of EPROM. Factory setting of 'N' is 64.

- Read the contents of SATCOM MODEM EPROM (27C010 or 27C020) using an EPROM programmer and save the contents to a file.

- Erase the EPROM, by exposing its window to ultra-violet rays. Load the file that was saved; now edit the byte at address 0x0200 to the desired burst length 'N' and then program the EPROM.
- Place the EPROM in its socket and power ON the SATCOM MODEM. The new configuration is now set.

Burst mode timing:

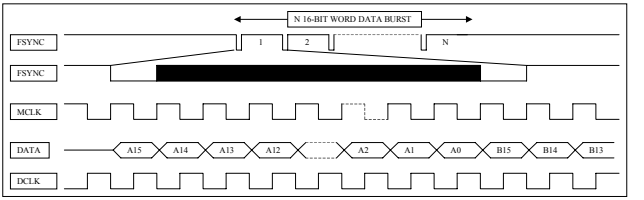


Figure 3. Burst/ continuous mode timing diagrams

The timing diagram in Figure 3 depicts the phase relationship between:

- M(D)CLK and DATA in *continuous* mode
- M(D)CLK, FSYNC and DATA in *burst* mode

M(D)CLK, FSYNC and DATA are generic names used to explain the timing diagram (MCLK is modulator input clock, DCLK is demodulator output clock and FSYNC is the burst timing). In the MODEM interface connector description, these signals are referred to as Modulator CLK+, Modulator Data+ and Modulator FSYNC+ at the modulator input and as Demod CLK+, Demod Data+ and Demod FSYNC+ at the demodulator output. Refer Table 3 for interface details.

In *continuous* mode, modulator input is sampled on the falling edge of the data transmit clock and demodulator output is updated on the falling edge of the data receive clock (for sampling on the rising edge, by an external device). FSYNC at modulator input should be left open (pulled high inside the box).

In *burst* mode, in addition to the phase relationship between M(D)CLK and DATA described above, FSYNC provides start of burst information and word synchronization. At the modulator input and the demodulator output, the FSYNC signal will remain inactive (high) immediately after power-on and during the inter-burst interval (which is typically much greater than a word duration). The data is valid (MSB first) once FSYNC becomes active (i.e. sampled low by the falling edge of MCLK, or rising edge of DCLK, whichever the case may be). The FSYNC signal is an input to the modulator and an output from the demodulator. It is the user's responsibility to synchronize the demodulated burst with the first FSYNC.

Burst mode test procedure:

- Connect the data source, which provides the data bursts and burst timing (FSYNC, highlighted in Table 3), as in Figure 2.
- Test setup is the same as described in Figure 1 except for the burst source
- Select DIP-switch options as required (refer Table 4).
- Connect the modem to +5 V DC **linear** regulated Power supply to start the test.
- As per the selected configuration, add different levels of noise and record the burst loss

Description	37 pin D-type connector pin #	Input (I)/ output (O) information[1]
Modulator CLK+	5	O
Modulator CLK-	23	O
Modulator Data+	4	I
Modulator Data-	22	I
Modulator FSYNC+	2	I
Modulator FSYNC-	3	I
Modulator FSYNC (TTL)	7	I
Demodulator CLK+	8	O
Demodulator CLK-	26	O
Demodulator Data+	6	O
Demodulator Data-	24	O
Demodulator FSYNC+	13	O
Demodulator FSYNC-	31	O
Demodulator FSYNC (TTL)	21	O
GND	1,19	

Table 3. Burst/ continuous interface details

MODEM performance

SATCOM MODEM continuous mode performance, evaluated as described in the previous section, for various modulation/ coding schemes, is shown in Figure 4.

The SATCOM MODEM adapts (with a time constant of about 128ksymbols) automatically, in continuous mode only, to amplifier back-off (see http://www.signion.com/qam16.pdf) and its performance under two different back-offs (IBO's) are shown in Figure 5.

SATCOM MODEM burst-mode performance (for 0.5ms bursts) for various modulation/ coding schemes is shown in Figure 6.

[1] w.r.t. DCE

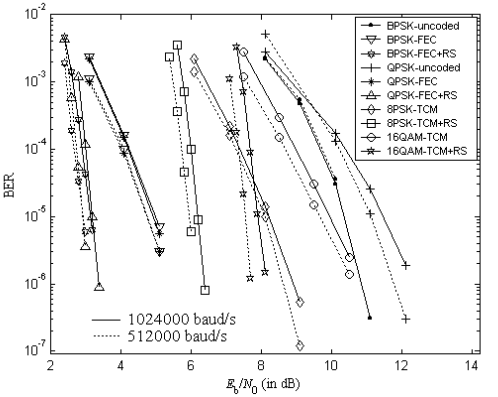


Figure 4. Continuous mode performance

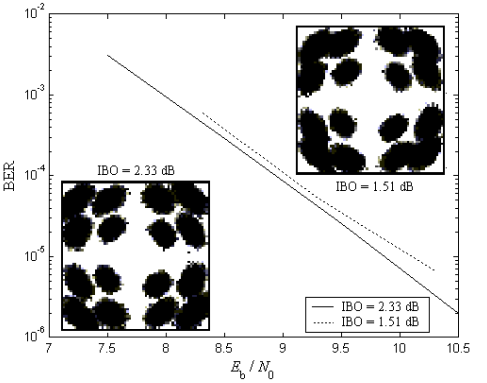


Figure 5. 16-QAM TCM (synchronized manually) at 2 IBO's

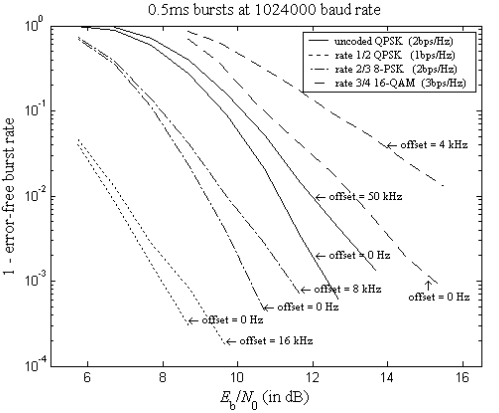


Figure 6. Burst mode performance[2]

[2] 16-QAM burst-mode performance is data dependent; to obtain Figure 5's typical performance, ensure input data is randomized (scrambled) in 16-QAM burst-mode.

Modulator spectrum

Figures 6 and 7 show calculated pulse shaped QPSK and 8-PSK/16-QAM modulator spectra at 1Msymbols/s baud rate.

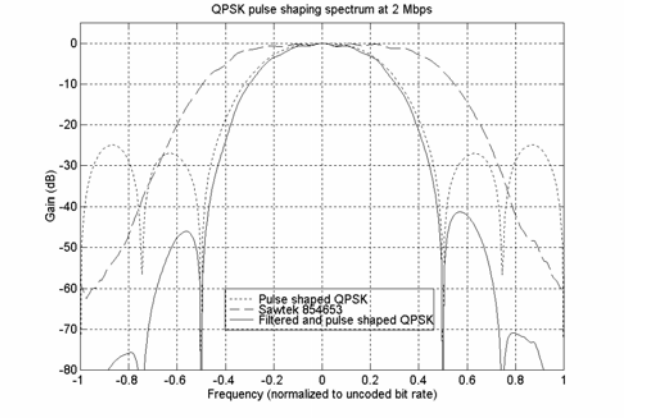


Figure 7. 2 Mbps channel-rate QPSK spectrum

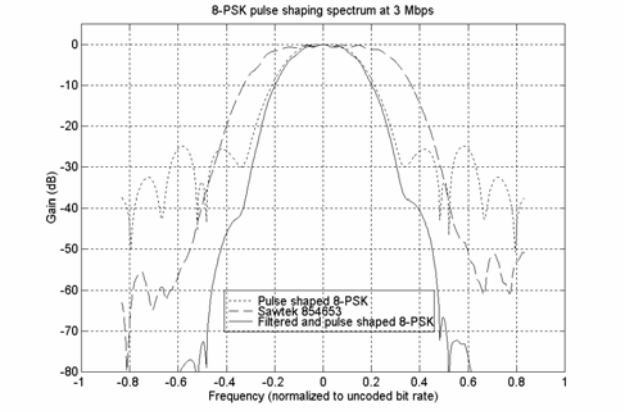


Figure 8. 3/4 Mbps channel-rate 8-PSK/16-QAM spectra

Appendix C shows pulse shaped modulator spectra of all modulation schemes and baud rates.

Configuration details

SATCOM MODEM has options for user selectable modulation type, data rate, acquisition type, FEC & R-S codes selection, scrambler selection etc.

NOTE: Since DIP-switch settings are read only on power-on, any change in settings will take effect ONLY when the MODEM is rebooted (by removing and restoring power)

DIP-switches (S0:S7)

Switch	Function
S0:S1	Baud rate selection (Table 5)
S2:S3	Modulation type selection (Table 5)
S4	Convolution encoder selection (FEC)
S5	R-S outer code selection
S6	Scrambler selection
S7	Acquisition mode selection

Table 4. DIP-switches

Modem switch settings

- Scrambler OFF is supported only when both FEC (S4) and R-S (S5) are OFF.
- Uncoded 8-PSK and 16-QAM are not supported.
- Acquisition mode (S7) is for *continuous*/ *burst* carrier acquisition mode selection:
  - ON indicates *continuous* mode, in which differential encoder is always ON, for modes other than 16-QAM.
  - OFF indicates *burst* mode, in which differential encoder, scrambler and RS encoding are OFF.

S0:S1	Baud rate
00	1024000
01	512000
10	256000
11	128000

S2:S3	Modulation scheme
00	QPSK
01	BPSK
10	8-PSK
11	16-QAM

Table 5. Baud rate and modem modulation type selection

Modulation scheme	Bits per symbol	FEC code rate	R-S code rate
BPSK	1	1/2	112/126
QPSK	2	1/2	112/126
8-PSK	3	2/3	201/219
16-QAM	4	3/4	188/204[3]

Table 6. Supported FEC and R-S code rates

[3] In 16-QAM, R-S input takes 187 information bytes and 1 SYNC byte (inserted by modem). The R-S encoder's effective rate is thus 187/204.

Modem data rate = (baud rate)·(bits/symbol)·(FEC code rate)·(R-S code rate)

NOTE:

- 0 – Switch position is down (OFF)
- 1 – Switch position is up (ON)
- FEC code rate is applied when FEC switch **S4** is ON
- RS code rate is applied when R-S switch **S5** is ON
- In 16-QAM, the trellis decoder locks to one of 0° or 180° and 90° or 270°. The residual 180° phase ambiguity is resolved by the R-S decoder when it fails to acquire its unique word within a timeout period. When R-S is OFF, modem enters a debug mode, where in user can use the R-S switch as phase-switch, after start up, to resolve a potential 180° phase ambiguity (indicated when the DTE fails to synchronize).

E_b/N_0 indication

8-bit E_b/N_0 is indicated on a 10-pin header (JP1) in 0.25dB steps over 2.5dB-15dB range. Details of the header are as given below:

Pin	Description
1:8	LSB:MSB in 0.25dB steps
9	DVDD (3.3V)
10	GND

Table 7. JP1 pin description

Example:
0x15 = 5.25dB
Each data pin can sink a current of 1.2mA (sufficient to drive a 1206 LED).

Constellation plot

In BPSK/QPSK/8-PSK/16-QAM modulations, with any of the optional code type chosen, a demodulated constellation (128k baud persistence) of 64x64 pixel resolution may be obtained via the TMS320C6204 DSP's JTAG port.

- Connect Texas Instruments' JTAG (XDS510, XDS510PP-PLUS, etc.) to TMS320C6204 DSP's JTAG (JP2) port and the other end to a PC with Texas Instruments' C6000 Code Composer Studio Software. Switch 'ON' the SATCOM MODEM.
- To observe the constellation, open the Code Composer Studio software and abide by the following instructions:
  - Issue reset command. Debug -> Reset DSP
  - Select View -> Graph -> Image, enter following properties and click OK. Wait for about a minute for the display to appear.

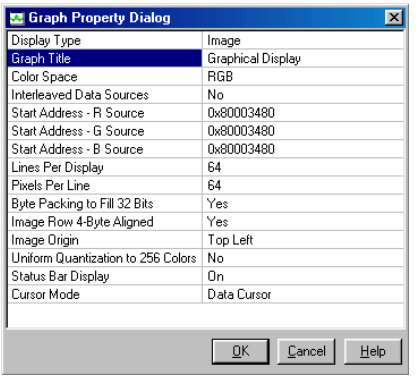


Figure 9. CCS properties to display constellation

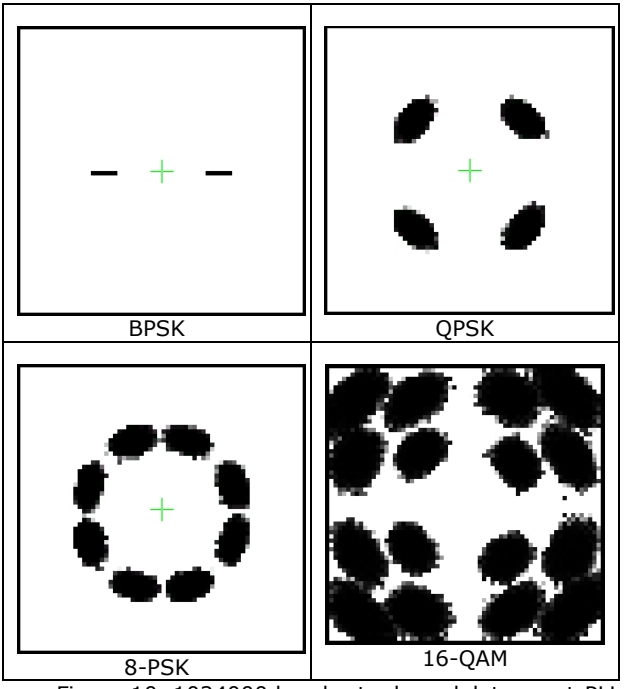


Figure 10. 1024000 baud rate demodulator post-PLL constellations

Specifications

System

Channel symbol rates:	1024000, 512000, 256000, 128000 (in symbols per second)
Modulation:	BPSK, QPSK, 8-PSK and 16-QAM
Optional code types:	BPSK and QPSK (IESS-308), Viterbi rate½, Reed-Solomon (126,112) outer coding, ID = 4 8-PSK/TCM (IESS-310), Reed-Solomon (219,201) outer coding, ID = 8 16-QAM (EN 301 210), Reed-Solomon (204,188) outer coding, ID = 12
Ambiguity encoding:	Binary/ Quaternary/ 8PSK-TCM/ 16QAM-TCM/R-S[4] (see APPENDIX B for details)
Scrambling:	CCITT V.35 as per IESS-308
Data interface:	RS-449
IF frequency:	70MHz (fixed)
Modem performance:	Illustrated in figures 4, 5 and 6
Power supply:	+5V DC, 1.1A

Modulator

Transmit power:	-9dBm (BPSK, QPSK and 8-PSK) -6.7dBm (16-QAM)
Spectral shaping:	BPSK and QPSK: as per Figure 8 of IESS-308 8-PSK: as per Figure 10 of IESS-310; for design details refer http://www.signion.com/bbps.pdf http://www.signion.com/pulse.pdf
Modulator timing:	Internal
Output impedance:	50Ω

[4] Test mode also supports 16QAM-TCM-Manual

Demodulator

Receive level: -15dBm to -5dBm

Acquisition type: Continuous/ Burst

Carrier acquisition range, time (at 1024000 baud rate):

Continuous mode (BPSK):	±80kHz, < 75 ms
Continuous mode (QPSK):	±40kHz, < 150 ms
Continuous mode (8-PSK):	±15kHz, < 1.4 s
Continuous mode (16-QAM):	±5kHz, < 25 s
Burst mode (uncoded QPSK):	±50kHz, < 78.125 μs
Burst mode (coded QPSK):	±16kHz, < 140.625 μs
Burst mode (8-PSK):	± 8kHz, < 140.625 μs
Burst mode (16-QAM):	± 4kHz, < 171.875 μs

Continuous mode tracking (in Hz/s): BPSK: 0.0234% of baud rate
QPSK: 0.0117% of baud rate
8-PSK: 0.0058% of baud rate
16-QAM: 0.0014% of baud rate

Demodulator timing: Recovered clock within ±13% jitter and nominally within 40-60% duty cycle

Input impedance: 50Ω

Mechanical/ Environmental

Dimensions: 163mm x 111mm

Temperature: 0ºC to +60ºC

Features

- E_b/N_0 indicator in 0.25dB steps over 2.5dB-15dB range
- Persistent 64x64 pixel normalized constellation display

Appendix A: Interface details

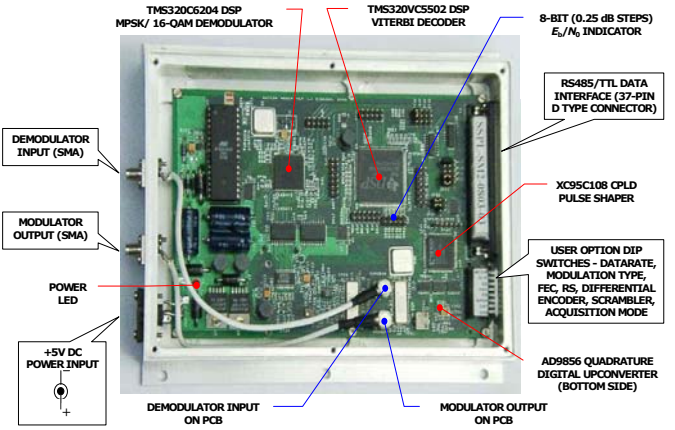


Figure 11. SATCOM MODEM interface

Callouts show SATCOM MODEM chassis connection details
RED lines point to the important components on PCB
BLUE lines show the connector details

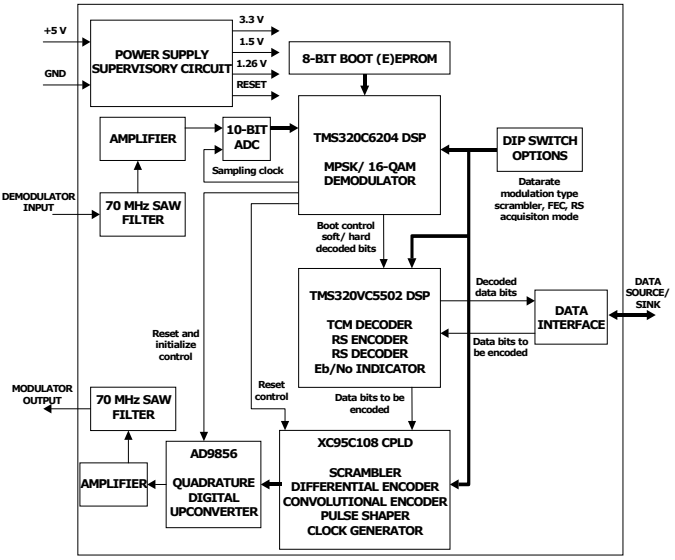


Figure 12. SATCOM MODEM internal block diagram

Appendix B: Ambiguity encoding

Quaternary encoding

The differential equations for the quaternary signals are,

$$I_k = \left[\overline{(A_k \oplus B_k)} \cdot (A_k \oplus I_{k-1}) + (A_k \oplus B_k) \cdot (B_k \oplus Q_{k-1})\right]$$

$$Q_k = \left[\overline{(A_k \oplus B_k)} \cdot (B_k \oplus Q_{k-1}) + (A_k \oplus B_k) \cdot (A_k \oplus I_{k-1})\right]$$

where A_k and B_k are the input bits and $[I_k \ Q_k]$ are the differentially encoded symbols.

Binary encoding

The differential equation for the binary signal is,

$$I_k = \left[(A_k \oplus I_{k-1})\right]$$

where A_k is the input bit and I_k is the differentially encoded symbol.

8-PSK TCM encoding

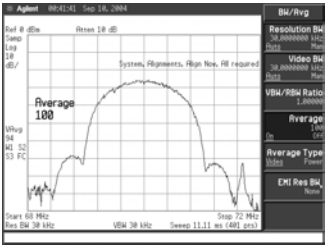
The TCM encoder uses 3 binary differential encoders as shown in Figure 11 of IESS-310.

16-QAM

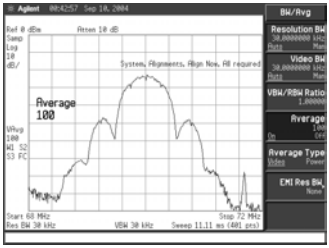
Ambiguity encoder is absent for 16-QAM TCM/R-S, as shown in Figure 11 of EN 301 210. Trellis decoder along with R-S decoder resolves $n \cdot \pi/2$ (n=0, 1, 2 or 3) ambiguity.

Appendix C: Modulator spectra

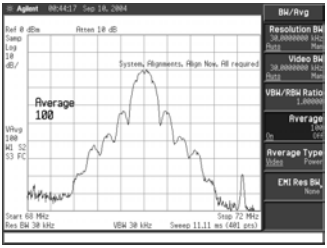
1. BPSK



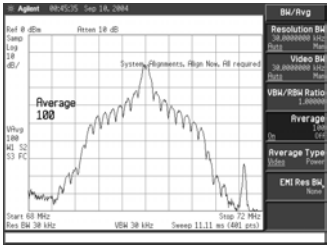
1024000 baud rate



512000 baud rate

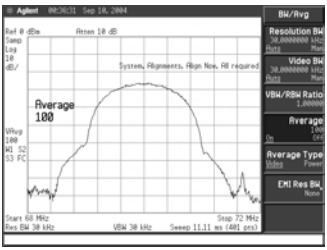


256000 baud rate

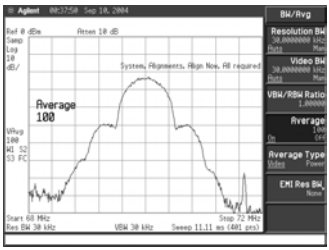


128000 baud rate

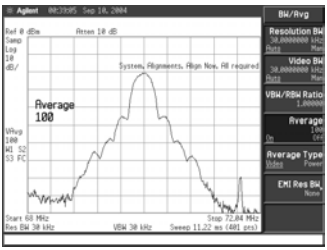
2. QPSK



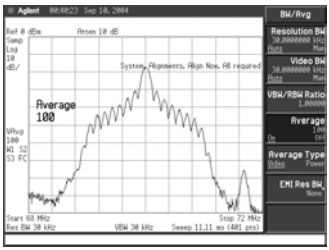
1024000 baud rate



512000 baud rate

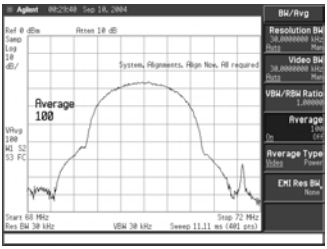


256000 baud rate

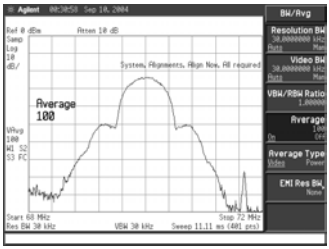


128000 baud rate

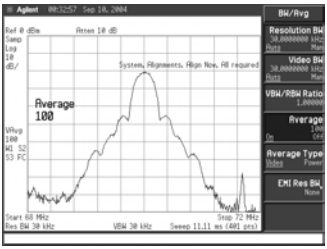
3. 8-PSK



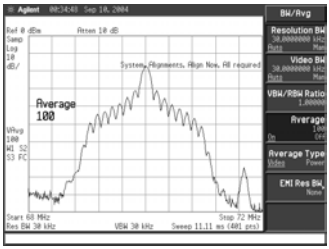
1024000 baud rate



512000 baud rate

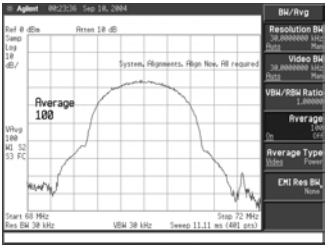


256000 baud rate

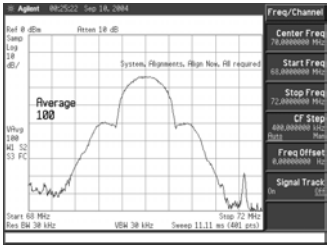


128000 baud rate

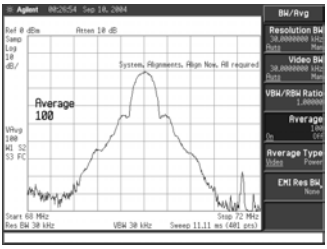
4. 16-QAM



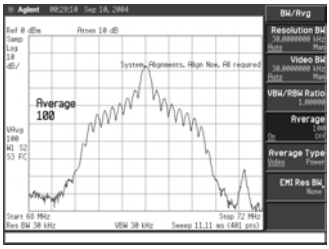
1024000 baud rate



512000 baud rate

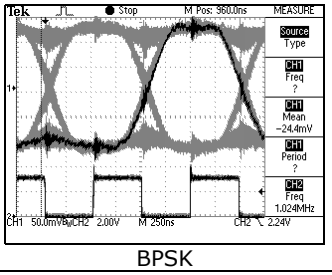


256000 baud rate

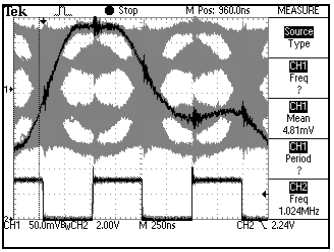


128000 baud rate

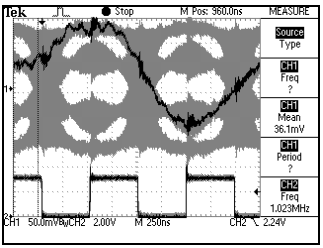
Appendix D: Modulator eye patterns



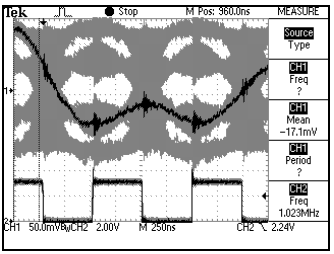
BPSK



QPSK



8-PSK



16-QAM

1024000 baud rate modulator eye patterns ($\phi = \pi/8$)

Appendix E: Troubleshooting

Problem: In the loop back setup without noise, the DTE does not sync up and/or shows errors.

Solution:

- Ensure that the MODEM is connected to the +5V DC **linear** regulated power supply.
- Check the DIP-switch setting; it should be a valid configuration (refer Configuration details).
- Verify the default jumper settings (refer APPENDIX F).
- Ensure that the EPROM is properly inserted in the socket.
- Check the MODEM and DTE interface (refer Loop-back test setup).
- To isolate the problem between modulator and demodulator, give all 1s or 0s as input data to the modulator (with scrambler OFF) and check the modulator output; it should be a pure 70MHz carrier.
- If the modulator output is not a pure carrier, restart the MODEM.

Appendix F: Default jumper settings

The default jumper settings for the SATCOM MODEM board are as follows:

Sr. No.	Jumper	Jumper Selection
1.	JP5	1-2
2.	JP11	1-2
3.	JP12	1-2
4.	JP13	2-3
5.	JP17	1-2
6.	JP20	2-3
7.	JP21	2-3
8.	JP22	2-3
9.	JP24	2-3

JP11	JP5	JP12	JP13
1	**1**	**1**	**1**
2	**2**	**2**	**2**
3	**3**	**3**	**3**

3	**2**	**1**	**JP17**
3	**2**	**1**	**JP18**
3	**2**	**1**	**JP19**
3	**2**	**1**	**JP20**
3	**2**	**1**	**JP21**
3	**2**	**1**	**JP22**
3	**2**	**1**	**JP24**

NOTES