SPECTRUM SIGNAL PROCESSING BY VECIMA

MIL-STD-188-181B UHF SATCOM PHY

Physical Layer Implementation Using *flex*Comm™ SDR-4000

Preliminary

Waveform IP

flexComm

Benefits

- Accelerate your radio development program by 8 to 12 months by utilizing an integrated, rugged COTS software defined radio (SDR) platform running the UHF SATCOM waveform.
- Improve utilization of limited Satellite Communications (SATCOM) resources through high spectral efficiency
- Efficiently use power and maximize range of communications through constant envelope modulation technology
- Interoperate with existing MIL-STD-188-181B compliant equipment through use of a standardized waveform
- Future proof waveform architecture through software defined radio technology
- Customize applications through software-based implementation (i.e., vocoders, etc.)
- Reduce development and production costs through simple and economical license models that offer attractive development, demonstration, and production options

Applications

UHF Satellite Communications (SATCOM)

Features

- Software-based physical layer (PHY) implementation of an Ultra High Frequency Satellite Communications MIL-STD-188-181B waveform on the *flex*Comm SDR-4000 3U cPCI transceiver platform.
- Capable of supporting an independent transmit and receive link allowing full-duplex operation
- Operates using narrowband (5 KHz) and/or wideband (25 KHz) channels
- A variety of modulation techniques and coding schemes compliant with MIL-STD-188-181B
- Preamble provides waveform acquisition, automatic data rate detection, and waveform parameter detection
- Includes end-of-message (EOM) detection, carrier slip detection and signal processing for efficient preamble acquisition and detection
- Delivery includes object code and example of environment for operation. The code is designed for portability to multiple target platforms.
- Includes an application programming interface (API) that simplifies the setup and operation of the waveform, including initialization and control functions
- Software Communications Architecture (SCA)-enabled version available as a future option. Please see future options section of this datasheet.

Description

Ultra High Frequency Satellite Communications (UHF SATCOM) provides military users with a long-haul data and voice communications capability. To reduce your technology risk and speed your time to market, Spectrum offers the physical layer (PHY) implementation of the UHF SATCOM MIL-STD-188-181B waveform on its *flex*Comm SDR-4000 rugged small form factor platform.

Table 1 and 2 show data rate capabilities of MIL-STD-188-181B in both its wideband (25 KHz) and narrowband (5 KHz) implementations. Like most waveform standards, the MIL-STD-188-181B specification includes both mandatory functionality and optional functionality. Depending on your program stage, you can select a Development and Demonstration license or Production license, each of which includes both mandatory and optional functionalities for wideband and narrowband modes. Please see Standards documentation for a complete description of operating modes (see reference [1]).

Wideband 25 KHz		
I.D.	Technique	User Data Rate
0	SBPSK / SBPSK Coded r=1/2	9600 bps
1	CPM	9600 bps
2	SBPSK	16000 bps
3	SOQPSK Coded r=1/2	16000 bps
4	FSK*	16000 bps
5	SBPSK	19200 bps
6	SOQPSK Coded r=1/2	19200 bps
7	CPM*	19200 bps
8	CPM / CPM Coded & Interleaved	28800 bps
9	CPM* / CPM Coded & Interleaved	32000 bps
10	CPM* / CPM Coded & Interleaved	38400 bps
11	CPM*	48000 bps
12	CPM	56000 bps

Table 1. Wideband capabilities (*indicate mandatory modes)

Narrowband 5 KHz		
I.D.	Technique	User Data Rate
0	SBPSK / SBPSK Coded r=1/2	75 bps
1	SBPSK / SBPSK Coded r=1/2	300 bps
2	SBPSK / SBPSK Coded r=1/2	600 bps
3	SBPSK* / SBPSK Coded r=1/2	1200 bps
4	SBPSK*	2400 bps
5	SOQPSK Coded r=1/2	2400 bps
6	SOQPSK /SOQPSK Coded r=3/4	4800 bps
7	CPM* /CPM Coded & Interleaved	4800 bps
8	CPM / CPM Coded & Interleaved	6000 bps
9	CPM /CPM Coded	7200 bps
10	CPM / CPM Coded	8000 bps
11	CPM*	9600 bps

Table 2. Narrowband capabilities (*indicates mandatory modes)

Architecture

The modulator/demodulator offering data-modes described in MIL-STD-188-181B [2] is implemented as a software application on the SDR-4000. A convenient 5 KHz or 25 KHz channelization carries the spectrally efficient digitally modulated information waveform. A suite of “multi-h” continuous phase modulation (CPM) modulated data-modes complements a variety of linearly modulated modes (PSK, OQPSK, and FSK), offering the user and the application a chance to trade-off power (or alternatively range) and data rate. In the receiver, robust waveform acquisition signal processing establishes timing and phase synchronicity, and maximum likelihood-based estimation techniques are used to ascertain and correct carrier-slips during ongoing phase tracking. CPM data is demodulated using Viterbi techniques, where the memory inherent in the CPM modulation allows excellent detection performance. For added robustness, optional data modes including those with forward error correction (FEC) and interleaving are offered.

The software interfaces are specified, and allow the simple integration of the modem with user applications. The software wrapper for the modem takes care of setting-up the on-air data-format on the transmit side, and makes available the extracted data from the receive waveform on the receive side. Software interfaces allow the application to execute the required commands that instruct the radio to setup the link, define data modes, commence communications, and disable the link.

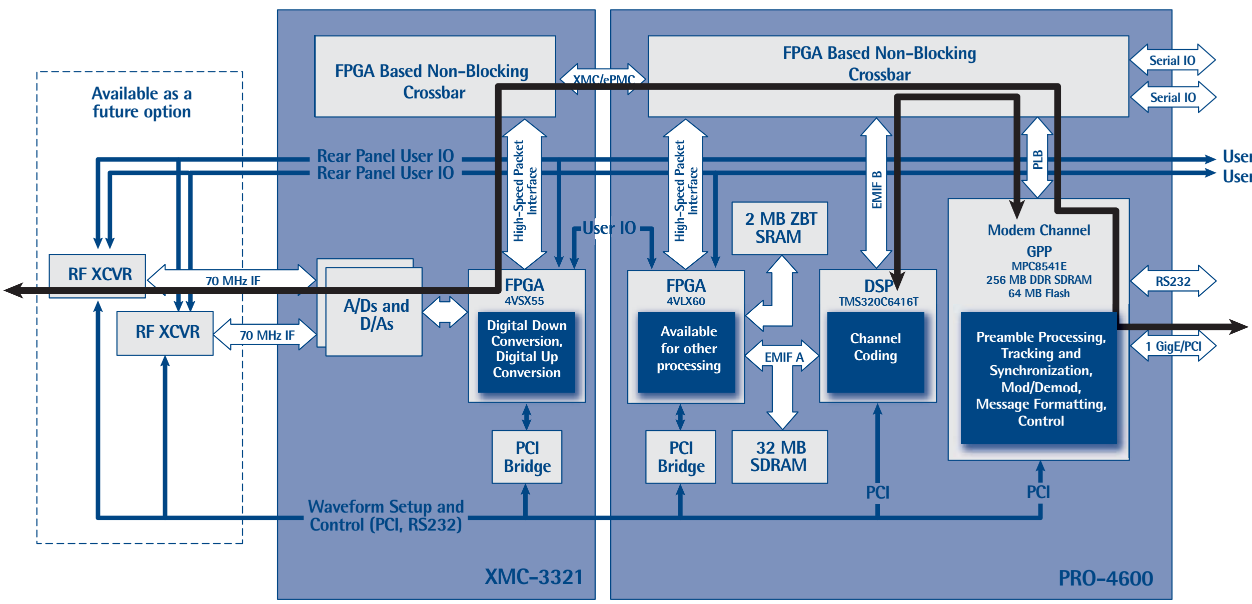

Figure 1. Deployment of the UHF SATCOM Waveform on the SDR-4000 Wireless Modem (WM) Platform

[Channelization]

Channelization is performed in the first stage of the UHF SATCOM waveform using Spectrum's FPGA-based Multi-Channel Transceiver. On the receive side, the SDR-4000 platform digitizes the 70 MHz IF input, and then passes the digitized IF signal to a Xilinx XC4VSX55 FPGA. The transceiver core operating in this FPGA then extracts a 5 kHz or 25 kHz channel from the digitized IF stream, basebands that channel, and forwards the resulting baseband signal to the MPC8541E General Purpose Processor for receive channel processing. This process is reversed on the transmit side, with a baseband signal received by the transceiver core operating in the FPGA from the transmit channel processing on the MPC8541E, upconverted to a 70 MHz IF, and then output to the digital to analog converter for transmission. The API supplied with the multi-channel transceiver allows tuning of the digital down converter and digital upconverter to any frequency within a 30 MHz span around the nominal 70 MHz IF.

[Transmit Channel Processing]

The waveform implementation provides APIs to control the transmit function. The user application accesses the APIs for the transmitter, and sets up the link by defining the waveform mode (thereby defining data rate, coding scheme, baud rate, any digital filtering). The transmit data is then sent to the transmit block. The transmit block constructs the waveform preamble according to the format defined in MIL-STD-188-181B (see figure 2 and reference [1]). The preamble contains a startup phase, a continuous wave carrier, a repeated bit pattern (different for I and Q), and a start of message (SOM) sequence. The preamble sequences are dependent on the waveform mode chosen. The appropriate modulation parameters for each segment of the preamble are applied to the programmable modulator, and bits in the preamble sequence are modulated, incorporating specified phase relationships between segments.

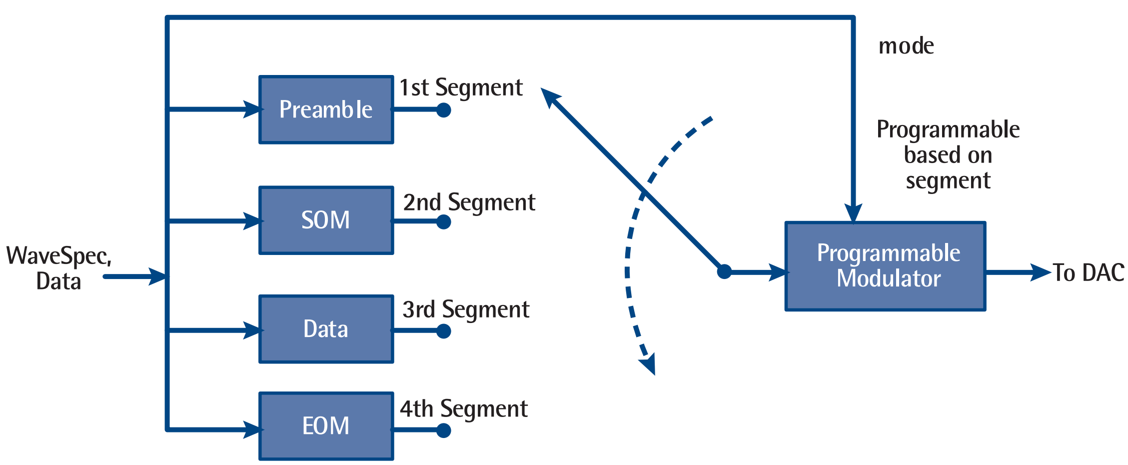

Figure 2. Data flow diagram showing concatenation of major portions of Tx waveform.

[Receive Channel Processing]

The waveform implementation provides APIs to control the receive function. Figure 3 demonstrates the sequence of signal processing operations involved in the receiver. The first phase involves recognizing the presence of the communications, obtaining information from the preamble that allows the receiver to synchronize, and establish phase and timing references. Information about the mode of data transmission is extracted from the preamble, thereby allowing the demodulation function to obtain estimates of the transmitted data. Optional modes having forward error correction (FEC) and interleaving are conducted on the data estimates from the linear or CPM demodulation blocks. The end of a transmission, signaled by presence of the predefined EOM message, is detected by comparing the sequence of received bits with this unique word.

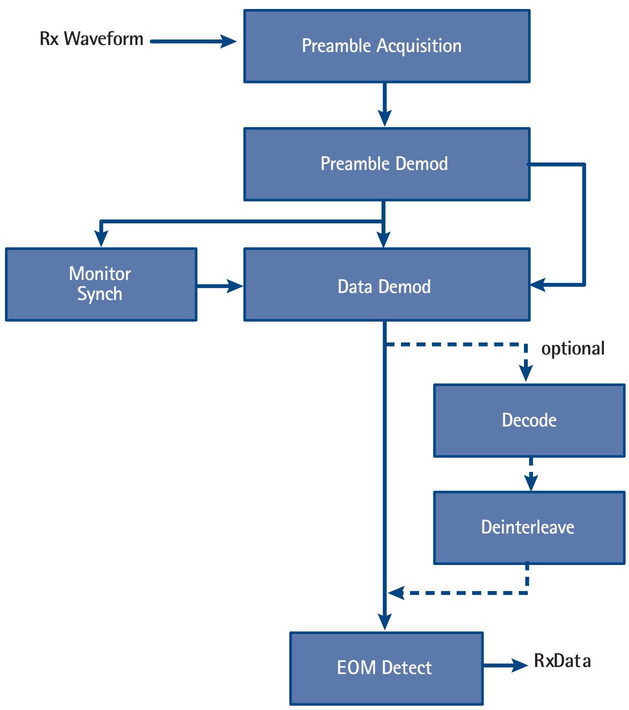

Figure 3: Data flow diagram showing functional blocks conducting receive waveform signal processing.

[Modes and Variants]

The on-air waveform [3] consists of both CPM and linearly modulated data modes that are identified on page 1 as Table 1 (wideband waveform option), and Table 2 (narrowband waveform option). Mandatory modes are identified with an asterisk in these tables. The modes using FEC and interleaving are all optional modes. A brief description of the technology used in each mode is given under the heading 'Technique'. The mode identifiers (under the heading 'I.D.') are used within the APIs to enable the appropriate mode, when that mode is implemented on the SDR-4000.

[Interface Definitions]

The main external interfaces for the waveform are shown in Figure 4.

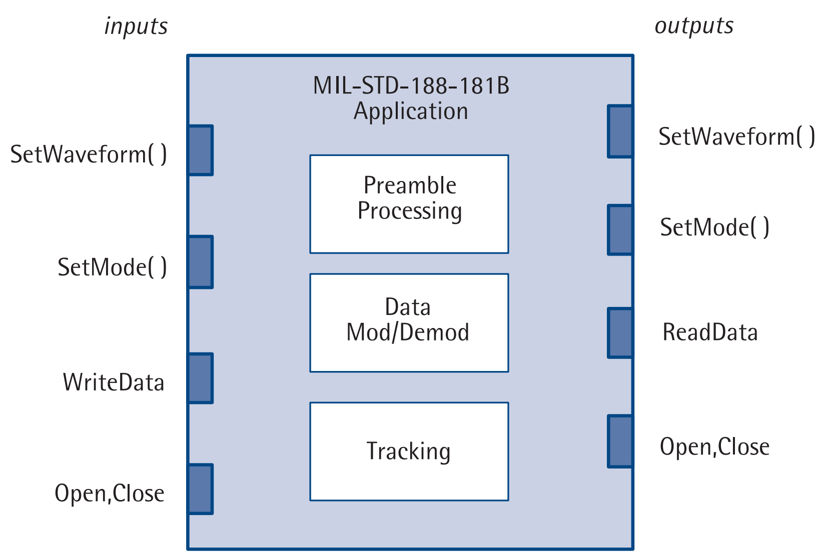

Figure 4. Block diagram for MIL-STD-188-181B PHY layer showing primary software interface function

Table 3 and Table 4 below list some of the modem control functions used to access the UHF SATCOM waveform. The host control program sets the parameters to setup the communications link by defining classes corresponding to transmit and receive modem functionality. As an example, the transmit interface (or API) for C++ has the form

```
class IGenModemTx
    {
      public:
            virtual SetMode(unsigned long modeNumber) = 0;
            virtual unsigned long GetMode(void) = 0;
    };
```

By following a specified programming approach, the modules controlling the modem will be fully interchangeable and readily usable in CORBA, COM, and SCA/SDR. The primary functions for the transmit class are given in Table 3, and primary functions for the receive class are listed in Table 4.

Return value	Function	Arguments/Return	Description
Void	SetWaveform	unsigned long waveIndex	Select a specific waveform referred by index. waveIndex = 0 for narrowband, = 1 for wideband.
Void	SetMode	unsigned long modeIndex	Select a specific mode referred by index.modeIndex takes numerical values according to modem modes listed in Table 1 and Table 2.
unsigned long	InputReady	void	Get the amount of space currently available for writing transmit data bytes.
unsigned long	WriteData	unsigned long count,char* pData	Send <pData> data byte block of size <count> and return the actual number of bytes accepted for transmit.
Void	Open	void	Initiate and start transmit process.
Void	Close	void	Stop and close down transmitter process.

Table 3. IGenModemTx interface functions

Return value	Function	Arguments/Return	Description
void	SetWaveform	unsigned long waveIndex	Select a specific waveform referred by index. waveIndex = 0 for narrowband, = 1 for wideband.
void	SetMode	unsigned long modeIndex	Select a specific mode referred by index.modeIndex takes numerical values according to modem modes listed in Table 1 and Table 2.
unsigned long	OutputReady	void	Get the current amount of received data bytes that are ready to be read out.
unsigned long	ReadData	unsigned long count,char* pData	Read <count> number of received data bytes into <pData> buffer and return the actual number of bytes copied.
void	Open	void	Initiate and start receive process.
void	Close	void	Stop and close down receive process.

Table 4. IGenModemRx interface functions

The “Waveform” is enumerated as either the 5 KHz “0”, or the 25 KHz “1” bandwidth option. Choice of operating “Mode” defines the set of modulation, coding and interleaving options, and values are enumerated in the first column of Table 1 and Table 2 (page 1). See the following code examples for transmit and receive. Customized functionality for specific applications is available. Please contact Spectrum sales for more information.

Example: setting up waveform “0” (5 KHz narrowband option), mode “3” (1200 bps SBPSK mode) and initiating transmission:

```
-    SetWaveform(0)
-    SetMode(3)
-    Open()
-    Buffer = “The quick brown fox jumps over the lazy dog.”
-    Length = strlen(Buffer)
-    If(InputReady() >= Length)
     {    retLength = WriteData(Length, Buffer) }
-    .....
-    Close()
```

Example: setting up waveform “0” (5 KHz narrowband option), mode “3” (1200 bps SBPSK mode) and initiating reception:

```
-    SetWaveform(0)
-    SetMode(3)
-    Open()
-    MaxBlockSize = 100
-    Buffer = Allocate at least 100 bytes.
-    Length = OutputReady
-    If(Length > 100)
     {    Length = 100; }
-    If(Length > 0)
     {    retLength = ReadData(Length, Buffer) }
-    .....
-    Close()
```

[Testing]

Testing of the waveform implementation on the SDR-4000 platform will follow testing procedures indicated in Defense Information Systems Agency (DISA) Standards Report. For custom testing requirements, please contact Spectrum sales.

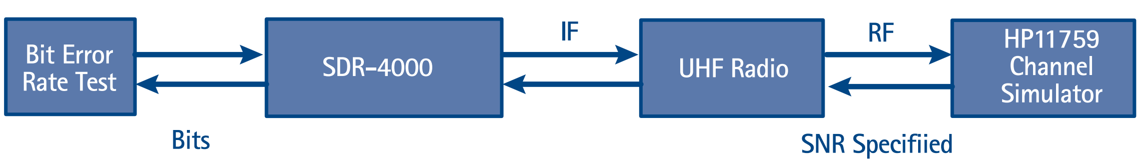

Figure 5. Typical test scenario for bit error rate testing for UHF SATCOM waveform

[About the Platform SDR-4000 Rugged 3U CompactPCI]

The SDR-4000 is a commercial-off-the-shelf (COTS) black-side wireless modem solution for Tactical Military Communications (MILCOM) and satellite communications (SATCOM) systems. The standard SDR-4000 product line is 3U in size and follows the CompactPCI specification. In order to address tactical military needs for harsh environments, SDR-4000 cards are designed to support conduction-cooling, extended temperature range, and increased shock and vibration immunity.

The initial hardware offering within the SDR-4000 series of products comprises two major component level products: the PRO-4600 SDR modem processing engine and the XMC-3321 dual transceiver I/O mezzanine card. Together, these products provide a wireless modem that supports up to two channels per slot. The PRO-4600 and XMC-3321 have been engineered to meet the requirements of a wide range of Tactical MILCOM applications and support Spectrum's *quic*Spin design methodology that enables rapid optimization of size, weight, power consumption, cost and ruggedization based on specific program requirements.

For more information, please see the SDR-4000 family datasheet.

As a future option, Spectrum can integrate the SDR-4000 platform with an RF transceiver*, providing an integrated "RF to Ethernet" solution covering the frequency band utilized by the UHF SATCOM waveform, as well as other frequency bands as appropriate. For more details, please contact Spectrum Sales.

Licensing Terms and Ordering Information

[UHF SATCOM PHY IP Packages]

Based on your program, you may choose one of the following license models for the UHF SATCOM PHY implementation:

- System Development and Demonstration License
- Production License

To order or for more information, please contact Spectrum Sales.

The UHF SATCOM MIL-STD-188-181B waveform implementation is subject to the export control laws of Canada. It is NOT subject to the United States International Traffic in Arms Regulations (ITAR).

[Hardware]

650-00555	Commercial Air-Cooled SDR-4000 Board Bundle (PRO-4600 and XMC-3321) - VXWORKS
650-00562	Commercial Air-Cooled SDR-4000 Board Bundle (PRO-4600 and XMC-3321) – INTEGRITY

See SDR-4000 datasheet for ordering information for other equipment that may be required.

[Future Options]

Future options may be implemented at the discretion of Spectrum Signal Processing based on market demand.**

- SCA-enabled version of the UHF SATCOM MIL-STD-188-181B implementation
- Extending waveform functionality to the DSP
- Second channel
- Integration of a UHF MHz RF transceiver

[References]

[1] M.K. Nezami and B. Peterson, "Performance of efficient tactical UHF-SATCOM waveforms: Occupied bandwidth, coding gain, spectral efficiency, bit error rate, and adjacent channel interference," in Proc. IEEE MILCOM 2002.

[2] US Department of Defense, "Interoperability Standards for Single-Access 5 KHz and 25 KHz UHF Satellite Communications Channels," MIL-STD-188-181B, 20 March 1999.

[3] Defense Information Systems Agency (DISA) "MIL-STD-188-181/ MIL-STD-188-181A/ MIL-STD-188-181B Conformance test procedure," Joint Interoperability Test Command, Fort Huachuca AZ, May 2001.

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