Simplex Remote Telemetry Gateway Receiver

High Sensitivity, High Capacity Gateway for Globalstar Satellite Network

SPECTRUM SIGNAL PROCESSING BY VECIMA

Application Note

flexComm

The highly advanced integrated COTS solution for asset tracking and remote monitoring. High sensitivity enables acquisition of signals from low earth orbit satellites; high capacity increases users per gateway by ten times over the current solution.

Your Challenges Do you face any of these challenges?	Spectrum's Solution Spectrum's *flex*Comm™ Simplex Remote Telemetry Gateway Receiver can help you overcome your challenges.
• Increasing your terrestrial coverage at minimal cost	• Innovative detection algorithm at the gateway enables beacon detection at elevations as low as 10 degrees off the horizon
• Conserving battery power in your transmitters	• Innovative detection algorithm at the gateway provides a very high sensitivity receiver, which enables detection of low power transmissions from beacons
• Adding new subscribers in saturated areas	• Innovative differentiation algorithm enables the processing of 960 simultaneous beacon transmissions, enabling a high density of beacons in a given area – 10 times the density of the current legacy system
• Increasing your subscriber base without increasing infrastructure footprint	• High processing power enables high capacity per system – capable of tracking and processing at least 10 million unique beacon messages per day
• Rapidly deploying new service offerings without significantly increasing your operational costs	• Software defined radio (SDR) technology allows a single hardware configuration to support multiple waveform applications, enabling easy repurposing of hardware
• Reducing the system processing burden caused by Doppler effect	• Innovative chip tracking algorithm and Smart Doppler technology compensates for high Doppler rate and high rate of change, enabling tight tracking through signal compression and dilation
• Reducing operational costs by processing message traffic and status from remote sites at a central location	• A back-office software suite that includes secure message distribution, web based status and remote software upgrade capability enables data collection and system management from a central location via the Internet
• Increasing average revenue per unit (ARPU)	• Modular system design and built-in fault detection enables deployment of high-value services by providing high-availability applications
• Reducing subsystem configuration and integration costs	• Spectrum's black-box solution integrates Analog Subsystem, Digital Subsystem and Ancillary Subsystem

Overview

Globalstar, Inc. has an Enterprise data network that provides global coverage through the use of a constellation of satellites and corresponding gateway earth stations. While their increasing subscriber base fuels Globalstar's current growth, their strategic focus is on their simplex data services. These services focus on asset tracking and remote sensor monitoring applications that consist of low bandwidth, infrequent transmissions that are very low power. Globalstar's current technology is reaching the limits of its capability to process these challenging transmissions. In order to position their network for growth a new solution that provided significantly more capability was required. To meet this challenge, Globalstar has acquired Spectrum's *flex*Comm™ Simplex Remote Telemetry Gateway Receiver that provides their earth stations with significantly increased capacity as well as increased sensitivity.

The *flex*Comm Simplex Remote Telemetry Gateway Receiver is a software defined radio-based appliqué to the Globalstar gateway sites. The *flex*Comm Gateway Receiver integrates an Analog Subsystem, Digital Processing Subsystem, and an Ancillary Subsystem to completely process remote telemetry beacon messages from Simplex modems for such applications as asset tracking and remote monitoring. In these applications, the Remote Telemetry Unit (RTU) beacons provide location or status data by sending small, infrequent, low power direct sequence spread spectrum (DSSS) transmissions that are received at a low Earth orbit (LEO) satellite and reflected to a Globalstar gateway. These DSSS beacons are 1.44 second bursts at 100 bits per second BPSK-modulated spread by a 2.5 megachip per second, 255 length code. The transmissions are processed at the gateway and then forwarded over a secure Internet connection to the Globalstar back office.

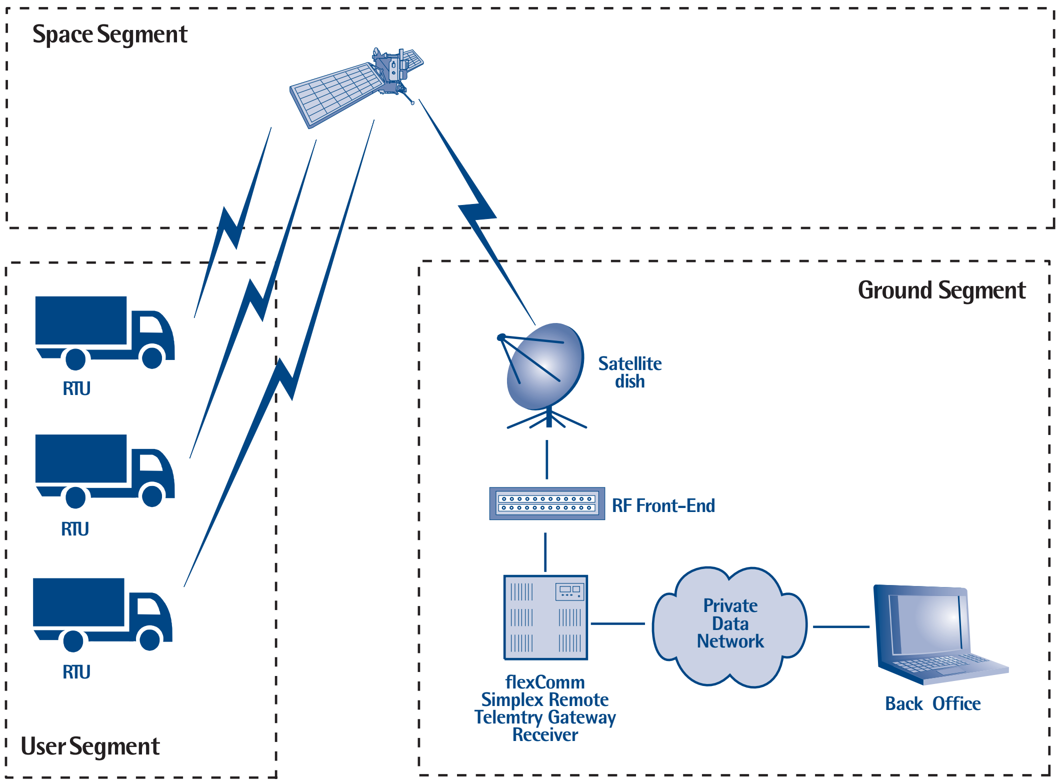

Figure 1: Simplex Remote Telemetry System Overview

Example

To illustrate the features and architecture of the *flex*Comm Simplex Remote Telemetry Gateway Receiver, we will show the process of acquiring and processing a signal from a Remote Telemetry Unit (RTU) beacon mounted upon a multi-modal container of snowboard pants that was shipped from Xiamen Port in China to the Port of Seattle, and has been placed aboard a truck for delivery to a final destination in Aspen Colorado.

[Step 1: Acquiring the Beacon Signal]

The Globalstar network is comprised of 48 low Earth orbit (LEO) satellites. The LEO satellites orbit the earth at a 45 degrees inclination relative to the equator at a height of 1414 km and are visible from horizon to horizon for approximately fifteen minutes. The satellites receive and transmit in a rosette beam pattern the size of North America that is 90 degrees boresight relative to the earth. From the earth, the perimeter that encircles the rosette beam pattern is at 10 degrees elevation from the earth's surface to the satellite. The satellites represented by the Space Segment in Figure 2 are referred to as "bent pipes". The L-Band receivers on the satellite are cross-banded to the C-Band downlink. The bent pipe connection between beacon and gateway is made when both the beacon and the gateway lie geographically with in the rosette beam pattern. In order to take advantage of the full coverage area of a satellite, the appliqué must have the sensitivity to close the communications link when the beacon is at the perimeter of the beam pattern, which is the weakest signal to noise condition in the link budget envelope.

Each satellite footprint (Figure 2) in the Globalstar constellation consists of 16 beams in a rosette pattern, one center beam and 15 petals. The downlink to the Gateway is a C-Band frequency division multiplexed and polarized composite of the 16 beams. The telemetry information from the truck we are tracking is contained in the data from Beam 12.

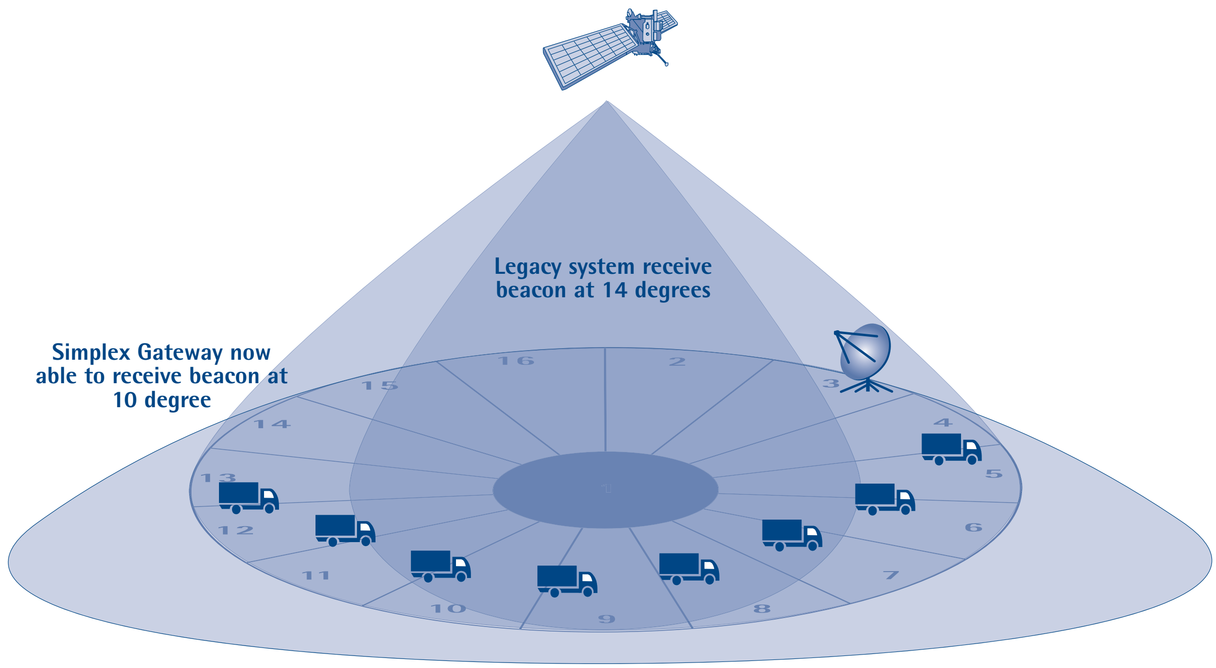

Figure 2: Satellite footprint of the Simplex Remote Telemetry Gateway relative to the legacy system

[Step 2: Processing the Beacon Signal]

The Globalstar gateway has four antennas, three of which are tracking LEO satellites and their associated beams. Each of these antennas provide left and right hand circular polarized C-Band feeds to an RF distribution rack that block downconverts each of the polarizations. Figure 3 represents a single polarization output of the Globalstar RF distribution rack. Each polarization consists of 8 beams; each beam is allocated with a 16.5 MHz band that is composed of four channels; each channel is 2.5 MHz. The beams and channels are frequency division multiplexed.

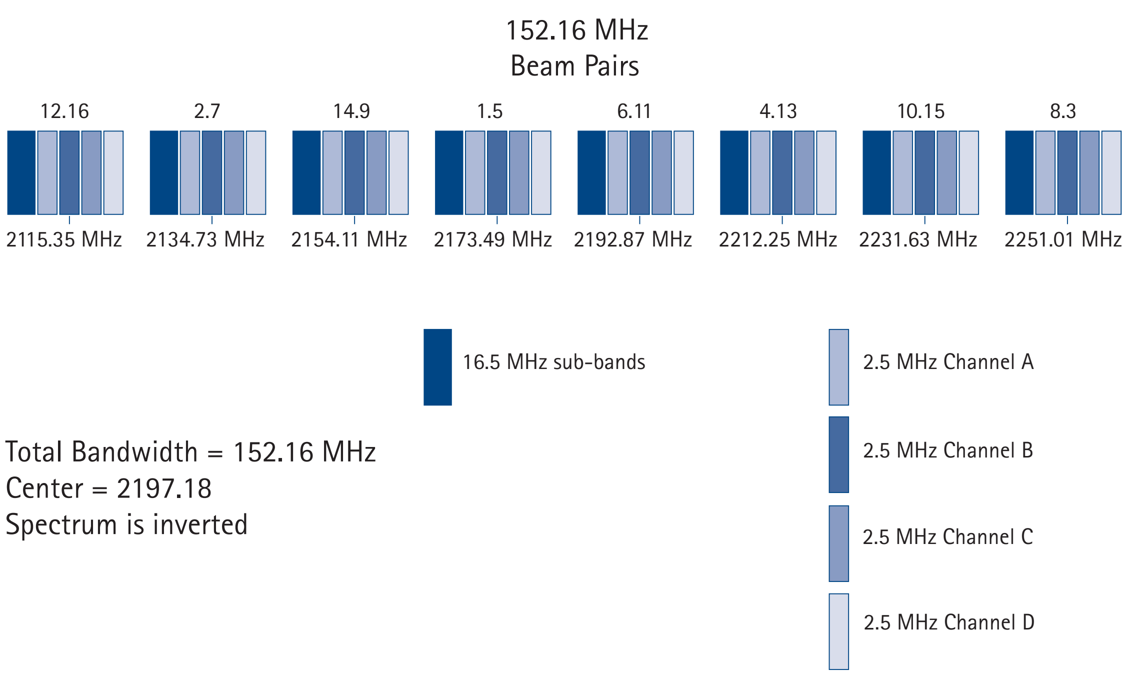

Figure 3: Single polarization output

The Analog Subsystem of the *flex*Comm Simplex Remote Telemetry Gateway Receiver interfaces between the Globalstar gateway's RF distribution rack and the Digital Subsystem to deliver a manageable bandwidth at a matched IF. It consists of an analog switch matrix followed by block downconverters.

The switch matrix accepts each of the eight output feeds from the gateway RF distribution system, and then uses an antenna beam schedule to determine which three of the four antennas are currently active and which is dormant while repositioning to acquire a rising satellite. Based on this schedule, the switch matrix passes three of four pairs of downlink polarizations to an IF band splitter and downconverter. As shown in Figure 4, the band splitter and downconverter converts each of the active 150 MHz polarizations centered at 2.2 GHz site IF to pairs of two 75 MHz IF outputs centered at 140 MHz/160 MHz IF. Each of these outputs is a feed to the Digital Subsystem.

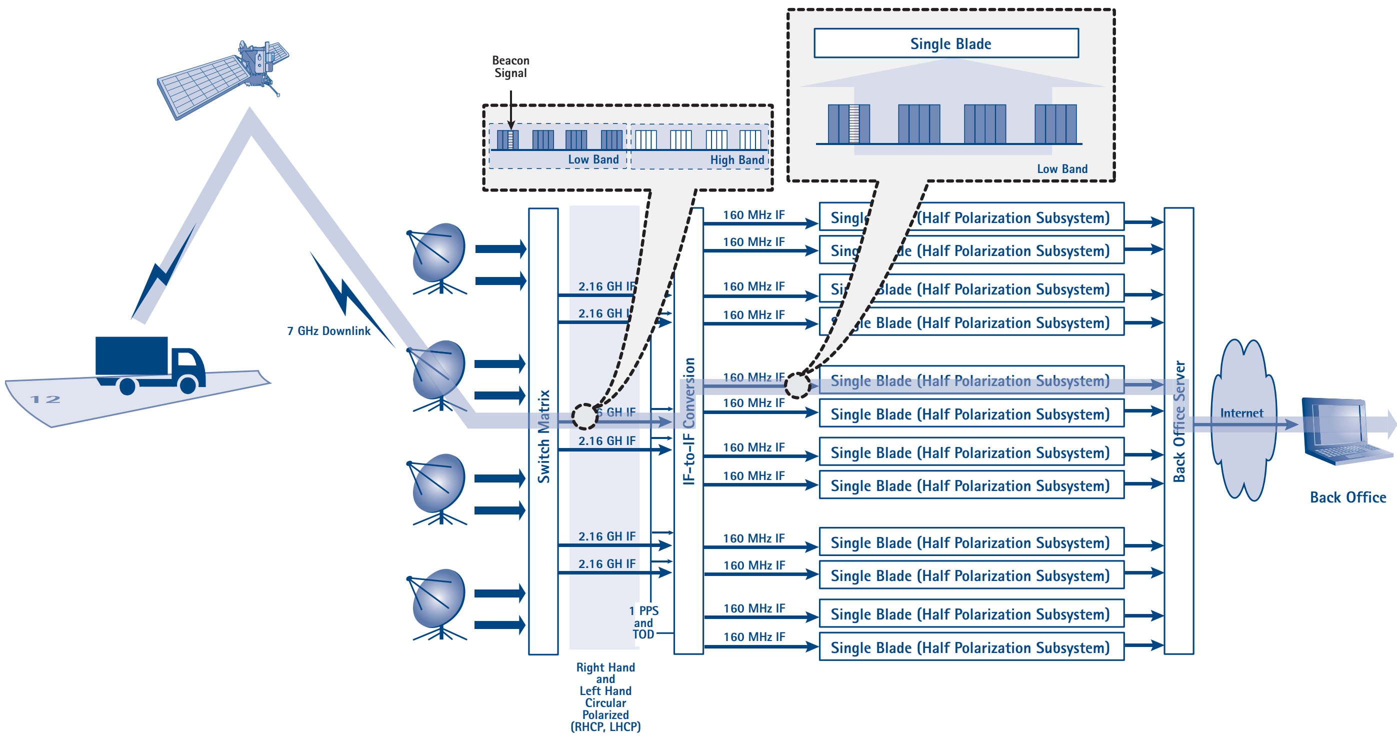

Figure 4: High level block diagram of the Simplex Remote Telemetry Gateway Receiver

The Digital Processing Subsystem is a software defined radio that extracts the bands of interest from each of the IF outputs from the Analog Subsystem and then applies the DSSS physical layer demodulation processing to produce the underlying message data. The input processing chain is illustrated in Figure 5 below.

The input to the Digital Processing Subsystem is one of the pairs of 75 MHz centered at 140 MHz / 160 MHz IF output from the Analog Subsystem. The analog input is sampled at 190 MSPS / 210 MSPS and fed to the input Digital Down Converter (DDC), filtered and truncated to 7 bit samples. Spectrum has empirically determined that 7 bits provides sufficient dynamic range to perform the DSSS processing in the presence of 20 simultaneously transmitting beacons per beam.

The sample rate out of the DDC is 10 MSPS; 4 times oversampled relative to the Nyquist requirement of the 2.5 MHz channel. The segmented correlator receives the samples and applies a PN sequence correlation followed by a partial summation followed by an FFT. The correlations and FFTs are performed on each sample, and the output is placed in an exponentially averaged correlation plane. The correlation surface's axes are the relative chip offset in time and Doppler shift. The surface is analyzed by the constant false alarm rate (CFAR) processing block to determine the appropriate threshold for detection. Integral to the despreader allocation is an algorithm to determine whether the number of threshold crossings over time meet the minimum persistence criteria. If so, a box around the detected bin in the correlation plane is marked and ignored relative to new detections to avoid the subsequent detection of a partial correlation of the current good detection.

The multi-channel tuner, delay line and despread functions manage the reception of up to 20 simultaneous beacons per beam; each of which has varying Doppler frequency shift, Doppler frequency rate of change and temporal chip dilation. The variables need to be tracked over the transmission of each beacon. To improve the efficiency of the detection algorithm, the range of Doppler over which the algorithm must be tolerant is constrained by Spectrum's Smart Doppler technology. Smart Doppler constrains the extent of Doppler by analyzing the satellite's Ephemeris (position in space relative to the Gateway) and instantaneous yaw angle (position of a beam relative to the direction of travel) versus the direction of travel to calculate a net uplink and downlink Doppler range for each beam of the rosette. This approach saves processing and memory resources by limiting the search range of detection, and minimizes the dilation range for the chip tracking algorithm for the despreader. The output of the despread circuit is relatively low rate data samples. Each of the despread channels is 800 samples per second; adequately oversampled to capture the 100 bits per second underlying data rate and facilitate the software BPSK modulation on the MCP 7410 processor.

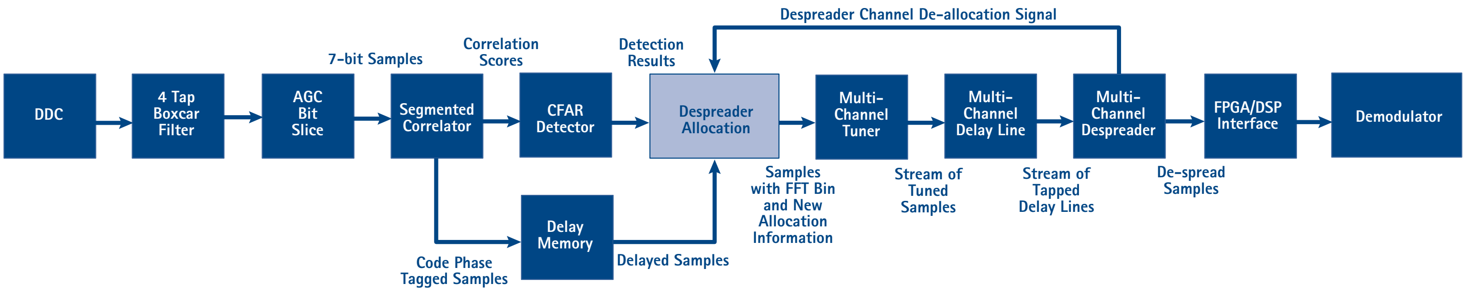

Figure 5: Physical layer application block diagram

After the beacons are demodulated, the resulting messages are transmitted to the Globalstar back office through a private Internet connection. The back office collects the data from all of the 28 gateway sites and distributes the messages to the appropriate subscriber, allowing us to determine that at this moment our shipment is passing through Boise Idaho.

An Ancillary Subsystem provides external receiver services needed to complete the system functionality. These services include timing references, data storage and electric power. In addition, the Ancillary Subsystem provides a common rack storage environment for the Analog and Digital Subsystem equipment. By using a common rack, the system is easier to access for maintenance, upgrades and testing. In addition, this allows for easier storage and transit to installation locations.

System Diagram

A single *flex*Comm Simplex Remote Telemetry Gateway Receiver SDR processing blade is illustrated in Figure 6. A blade consists of a digital section Line Replaceable Unit (LRU) and corresponding analog section block downconverter and provides the basic building block of the Spectrum solution. The digital section LRU is a 6U cPCI carrier card that hosts onboard general purpose processors and mezzanine modules. On the mezzanines are two high-speed ADCs followed by Field Programmable Gate Arrays (FPGA). The FPGAs receive digital samples of a 75 MHz band, extract the beam channel band of interest, detect and despread the waveforms and pass the despread samples to the PowerPC to perform the BPSK demodulation. Two SDR Processing blades make up a single polarization subsystem.

Stable GPS-referenced sample clocks and time reference feed the subsystem components to allow for precise frequency resolution and time stamping of detected signals. A Linux computer provides data storage and back office server functions.

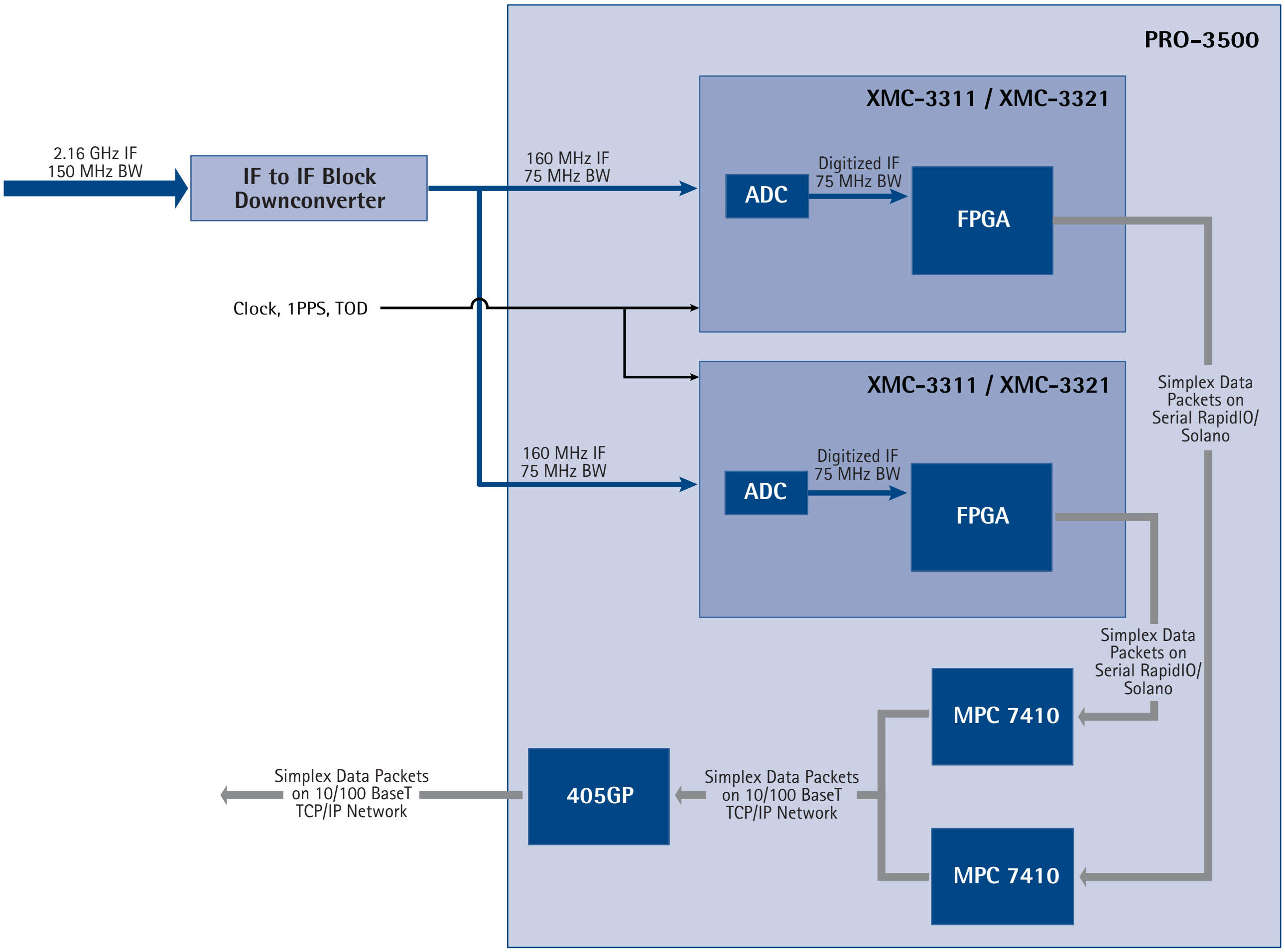

Figure 6: Single Blade (Half Polarization Subsystem) Block Diagram

Performance

Spectrum's solution is unique in its algorithmic and hardware platform approach. The algorithm uses an innovative detection circuit employing a high Doppler tolerant segmented correlator followed by an FFT. The correlations and FFTs are performed on each sample, and the output is placed in an exponentially averaged correlation plane. The correlation surface's axes are the relative chip offset and Doppler shift. The surface is analyzed to determine which peaks meet the minimum threshold energy and persistence selection criteria. Those identified peaks that meet the criteria are passed to the demodulator where they are despread and BPSK demodulated. This approach allows Globalstar to successfully process beacons at a rate of 95% probability at a 10 degree elevation angle of the beacon relative to the satellite.

Figure 7 shows the performance of the system relative to the signal to noise ratio (SNR). The minimum SNR (-29dB) corresponds to 10 degrees elevation between the satellite and the beacon; and maximum SNR (-15dB) corresponds to 90 degrees elevation (directly overhead).

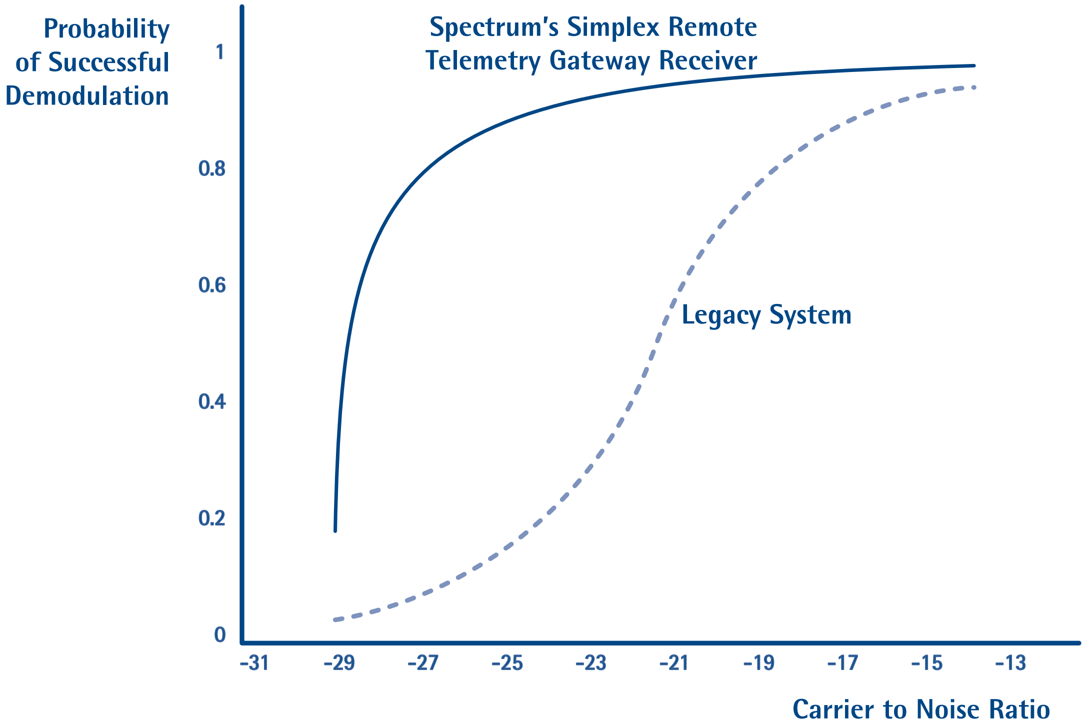

Figure 7: Improvement in Receiver Operating Characteristic Curve

[Current Traffic Density]

The density of beacon traffic is defined as the number of simultaneous beacons that are received at any instant in time. Since the beacons are not synchronized, they will transmit at random, which creates the possibility of collision since the code sequences could be in alignment. In other words, since there is only one code, orthogonality of signals is achieved by time and frequency offset, so if the transmitters are geographically proximate (no frequency offset) and transmit at precisely the same time then their code sequences would be in alignment causing interference that will make the underlying messages unrecoverable.

An additional benefit of Spectrum's approach is that with the high resolution available with increased sensitivity, beacons that are transmitting simultaneously are separable in time and frequency, and can be captured discretely when only 3 chips apart in time (1.2 microseconds). Twenty transmitters per beam are guaranteed with the current system design, a ten-fold increase over the current of two per beam.

[Upgrades and Maintenance]

Spectrum's architecture provides another significant benefit. The implementation of software defined radio technology in the Simplex Remote Telemetry Gateway Receiver allows system upgrades through software uploads that can be performed remotely reducing cost of ownership. The waveform's physical layer can be improved or modified, and multiple waveforms can be supported without expensive hardware upgrades.

The hardware platform consists of a set of identical processing resources that simplifies maintenance and sparing. The resources are modular, so as new technology becomes available, the system can be easily upgraded. The waveform software has been written in a scalable and portable fashion to facilitate sensitivity improvement and technology upgrades.

About the System Configuration

For more information about the system, please visit www.spectrumsignal.com/products

[processing subsystem]	SDR Processing Blade	12 x PRO-3500 6U CompactPCI Processing blades 24 x XMC-3311 High Speed Transceiver and Processing Module For detailed specifications, please see Spectrum's PRO-3500 and XMC-3311 datasheets at www.spectrumsignal.com/products/sdr/
	Back Office Server	Linux Server
[analog I/O]	Switch Matrix	8 input by 6 output non-blocking any-to-any
	Receiver Block Downconversion	2.16 GHz IF, 150 MHz BW, split into 2 x 75 MHz and translated to 160 MHz IF
	Receiver IF Sample Rate	210 MSPS
[external interfaces]	Analog In	8 Channels, N-Type Connectors, 50 Ohm
	GPS Antenna In	BNC Type
	Network Interface	RJ-45
[performance]	Beacon SNR min	-31 dB = 58% successful demodulation -29 dB = 95% successful demodulation -24 dB = 99% successful demodulation > -25 dB = 100% successful demodulation
	Processing Capacity	20 simultaneous beacons per beam x 16 beams per antenna x 3 active antennas = 960 simultaneous beacons per system
[software]		Please see Spectrum's Back Office Server Software Package Application Note for more information.
[electrical]	Supply Voltage (AC)	110 VAC
	Current Consumption	18.2A @ 110 VAC
[mechanical]	Size	1911.35 mm (43U) high x 600 mm wide x 800 mm deep (enclosure internal dimensions)
[environmental]	Temperature	Operating temperature range of 13 to 27 degrees C
	RoHS	Please see component level datasheets for RoHS compliance or contact Spectrum Sales.

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Rev 07.04.13_RB.SM.TD.MB_09.02.25